WCTR 2013 RIO

SELECTED PROCEEDINGS

INVESTMENT IN GREENER SHIPPING A REAL OPTIONS APPROACH

MICHELE ACCIARO, DNV RESEARCH AND INNOVATION, DET NORSKE VERITAS, MICHELE.ACCIARO@DNV.COM

This is an abridged version of the paper presented at the conference. The full version is being submitted elsewhere. Details on the full paper can be obtained from the author.

ISBN: 978-85-285-0232-9

13th World Conference on Transport Research

www.wctr2013rio.com

15-18 JULY 2013
Rio de Janeiro, Brazil

INVESTMENT IN GREENER SHIPPING
A REAL OPTIONS APPROACH

Michele ACCIARO

DNV Research and Innovation
Det Norske Veritas

Veritasveien 1
1363 Høvik, Norway

Michele.Acciaro@dnv.com

http://www.dnv.com

Abstract

An array of technical and operational solutions is available to shipowners for compliance with existing and upcoming environmental regulation. In order to survive in the complex shipping business owners have to carefully assess various investment opportunities vis-à-vis operational strategies and market conditions. Environmental compliance can be an opportunity to improve the company bottom line, since investment in new technologies can generate competitive advantage. But new technologies inherently carry substantial risk and an infelicitous investment decision may have irreversible consequences that could potentially jeopardise the future of the shipping company.

Accurate and flexible decision support models are then of great value for shipowners in order to assess the risks and benefits of specific environmental compliance options. Most existing decision models though are based on Discounted Cash Flow (DCF) techniques and do not account for important strategic issues such as investment flexibility or the owner ability to change investment strategy. Real Option Analysis (ROA) has been proposed as a complement to DCF for its ability to account for more complex strategic settings where investment decisions are being made. ROA however has rarely been applied to environmental investment decisions in shipping.

The present paper proposes a decision support model that makes use of ROA to look at Liquefied Natural Gas (LNG) retrofit options for shipowners have in order to comply with environmental regulation. The paper presents an analysis of various investment options and makes specific account of the value of an investment deferral strategy versus the advantages obtainable from the immediate exploitation of fuel price differentials. The model shows that there is a trade-off between low fuel prices and capital expenses for investment in the new technology. While in most cases it would not be recommended to invest in the new technology as early as today, ROA shows that investment can make economic sense already in 2017. The development in the new technologies is critically dependent on the reduction in capital costs and ship retrofitting costs. In this respect, policy makers can play a crucial role in providing support to technologies that have not yet achieved a degree of full maturity and in avoiding ambiguity on regulation.

Key-words

Green shipping; environmental compliance; LNG; emissions to air; ECA; real options.

INVESTMENT IN GREENER SHIPPING
A REAL OPTIONS APPROACH

1. INTRODUCTION

In the last decades the attention of the media and of the public has increasingly focused on the environmental profile of the shipping industry. National and regional governmental bodies and the International Maritime Organisation (IMO) have concerned themselves with regulation aiming at reducing the negative environmental impacts of shipping. The development of more stringent environmental regulation is likely to affect extensively maritime transport, requiring ship owners and operators to implement new, more energy efficient technologies and encouraging the use of greener fuels.

The regulator efforts in the last decades have been affecting various aspects of shipping, but increasing focus is been set on emissions to air, such as sulphur and nitrogen oxides, on greenhouse gas emissions, and on ballast water management. The main issue of concern for ballast water management is related to the proliferation and development of nonindigenous maritime species transported in ship ballast water tanks (Endresen *et al.* 2004; Pimentel *et al.* 2005). The recently adopted (but not yet ratified) IMO ballast water convention will require vessels to implement a ballast water management plan (Gollasch *et al.* 2007; Endresen *et al.* 2004) and has stimulated in the last decade the development of various operational alternatives.

Emissions to air are another area where regulation is rapidly being implemented. The IMO, the USA and the EU have been particularly active on the development of policies (e.g. IMO Resolution MEPC.176(58) and EU Directive 2005/33/EC) aiming at the reduction of sulphur and nitrogen oxide emissions from ships (Miola *et al.* 2010, Acciaro 2011*b*), given their well-documented noxious effects on the environment, human health and climate[1] (Eyring *et al.* 2010; Endresen *et al.* 2008; Buhaug *et al.* 2009). These effects are linked to the type of fuel burned and the type of engine used and can be reduced if the engines are adapted to use alternative fuels (LNG, biofuels) or higher quality fuels (distillates), or if exhaust gas cleaning systems are implemented. Since distillates are considerably more expensive than the heavy fuel oil traditionally burned in ships (Notteboom 2011), and the other alternatives require rather costly engine modifications, most analyses have focused on the cost impacts of regulation (Wang *et al.* 2007*a*; 2007*b*; Notteboom 2011; CEDelft *et al.* 2006; Psaraftis and Kontovas 2009; 2010; Kontovas and Psaraftis 2009; Bosch *et al.* 2009; NERA Economic Consulting 2005).

Finally, another area where regulation is likely to develop rapidly in shipping is related to greenhouse gas emissions. In addition to the recently adopted Energy Efficiency Design Index (EEDI) (see Longva *et al.* 2010 on the EEDI economic effects), a heightened debate has been ongoing on a set of possible market based measures (Faber *et al.* 2010; Heitmann and Khalilian 2011; Miola *et al.* 2010). Several studies have shown that substantial reductions in carbon dioxide emissions can be obtained through technical and operational measures (Eide *et al.* 2011; Eide *et al.* 2009), or by using alternative fuels (Acciaro *et al.* 2012*a*). The implementation of these measures though comes at a cost and

[1] Although climate effects are complex and their description beyond the scope of this paper, it should be noted that there is evidence that sulphur emissions have had a net cooling effect on the atmosphere (Fuglestvedt *et al.* 2009).

until clear indications will be provided by the policy maker, it is unlikely that the industry will take decisive action.

It should be recognised however, that in the various transportation industries, companies have opted for an environmentally proactive attitude towards emission reduction, not only to comply with regulation, but also in the attempt to avail themselves of the cost reduction benefits deriving from a more efficient fleet and of the positive effects of green marketing (Huang and Rust 2011; Peattie and Crane 2005). In shipping, even more than in logistics, financial considerations are still the most important criterion to justify large investments (Acciaro 2011*a*; Young et al. 2010; Flatters and Willmott, 2009; Pickett-Backer and Ozaki, 2008), although there is increasing recognition that sustainability can be a main driver for innovation (Acciaro 2011*a*; Nidumolu *et al.* 2009).

In addition, even when environmentally proactive strategies are energy efficient and can in principle benefit the company bottom-line, they tend not to be implemented easily if reliant on new technologies. Ship owners and managers are reluctant to implement technical innovation, and uptakes are slow also for relatively well established energy efficiency and fuel saving technologies (Acciaro *et al.* 2012*b*; Johnson and Andersson 2011; Johnson *et al.* 2012).

These considerations often call for increased investment flexibility and for the exploration of various compliance alternatives. Existing decision support tools, however, are often based on Discounted Cash Flow (DCF) techniques and are not always able to account for important strategic issues such as the ability to change or defer an investment following altered framework conditions internal or external to the company. DCF methods cannot account, for example, for the costs associated with being locked in a (yet unproven) technology.

An alternative is offered by *Real Option Analysis* (ROA), extensive accounts of which are given in Brach (2003) and Trigeorgis (2002). ROA techniques have been employed successfully also to model a number of strategic optionalities in the shipping industry. Alizadeh and Nomikos (2009) provide various examples of the application of real options to shipping specific problems. The first formalisation has been proposed by Dixit (as cited in Alizadeh and Nomikos 2009) where decisions to lay up vessels are modelled through a ROA. The same technique was used then to evaluate the decision to enter and exit the market (Dixit 1989). Various studies made use of ROA to model other strategic decision problems related to shipping investment and operations, such as the option to extend a time charter agreement (Bjerksund and Ekern 1995); the option to invest in a new service (Bendall and Stent 2001); the option to switch between dry and wet markets for a combined carrier (Sødal *et al.* 2008) or for a shipping investor (Sødal *et al.* 2009); investment in new vessels or portfolio of vessels (Hopp and Tsolakis 2004; Bendall and Stent 2003; 2005; 2007; Dikos 2008); the option to change the flag of a vessel (Kavussanos and Tsekrekos 2011).

The use of the option to defer has been mentioned in the shipping literature (Alizadeh and Nomikos 2009: pg. 462; Hopp and Tsolakis, 2004). In their book Alizadeh and Nomikos briefly present the option of deferring the fixing of the ship in case of momentary supply-demand imbalances. Hopp and Tsolakis (2004) present and advanced case involving investment in a bulk vessel. No reference is made in the shipping literature to the use of ROA for investment decision support in the case of environmental compliance. Smaller investments, such as equipment or retrofitting, allow for a simplification of the analysis and use of 'vanilla' call options, since the capital costs can be estimated with more precision than in the case of the purchase of a vessel.

This paper aims at showing that in the case of compliance with environmental regulation in shipping, the uncertainty relative to the availability and price of alternative fuels (specifically LNG) and the high CapEx of some of the solutions, may significantly delay investment decision, therefore contributing to the slow uptake of fuel saving technologies today. Since some of this uncertainty might be resolved in the future, the paper models the problem of investment in LNG retrofit as an option to defer.

The paper is structured in the following way. In addition to this introduction that describes the problems associated with greener shipping and outlines the emerging literature on the application of ROA in shipping, the next section describes a general ROA model that can be used for greener shipping applications. Section three presents an application of the model and discusses the main results of the ROA. Section four provides some concluding policy recommendation and directions for further research.

2. REAL OPTION ANALYSIS

2.1. Real option analysis and discounted cash flows

ROA is the application of financial options, decision science, corporate finance and statistics to evaluating real or physical assets as opposed to financial ones. Real option analysis makes use of option theory to provide a better insight into the consequences of managerial decisions. One of the main differences of real option analysis with respect to discounted cash flow is a better account of flexibility in managerial decisions. The capital budgeting method looks at single projects by determining the future cash flows the project will generate and discounting them at project specific discount rates. Risk is measures indirectly since the discount rate is the opportunity cost of capital. Project appraisal techniques based on the capital budgeting method assume that the firm embarks on a rigid and inflexible investment path and ignores that the risk pattern of the project will change over time as the project progresses.

ROA is ideal for the shipping industry since many investment decisions in shipping are characterised by large CapEx and uncertain revenue stream or costs. In discounted cash flow analysis, decisions are made now and the cash flow streams are fixed for the future. Projects are not considered in their relations in the firm and once launched they are passively managed. These characteristics do not fit well with the real investment practices in the shipping industry, where uncertainty and variability in future outcome often require delays in taking decisions. Furthermore sometimes maritime related projects cannot be evaluated as stand-alone (network, synergies, regulation etc.) and are usually actively managed through the life cycle of the investment, by modifying the fleet profile by Sale and Purchase (S&P), or scrapping some of the vessels, or delaying or cancelling delivery of new vessels.

In the present analysis we identify as project the investment related to the capital investment necessary to comply with upcoming environmental regulation in shipping. As outlined before, shipowners have several alternatives at their disposal all characterised by specific CapEx, OpEx and fuel savings. The decision to invest can be formalised as an option to defer, since the decision on which alternative to invest can be postponed until more information, specifically on regulation and on fuel prices is available. The option to defer derives its value form reducing uncertainty by delaying an investment decision until more information has arrived.

2.2. The option to defer

Options to defer are similar to the Parisian Barrier Option. In Parisian barrier options the pay-off to the option depends not only on the value of the underlying asset at maturity date but also on whether the asset has reached during the lifetime of the option a certain, predetermined threshold (the barrier).

In this case we model the ship-owners decision in the following way. A ship owner today has the option to invest in LNG or keep on running on a combination of heavy fuel oil and distillates. If he invests in LNG he will not have to worry about compliance with upcoming emission regulation. The benefits of investing today is that he can directly ripe the savings of running on LNG and have a longer time to offset investment, although he is not obliged to invest today.

Every year, the shipowner has the option still of investing in LNG, or keep on running on heavy fuel oil and distillates, until 2015 and 2017, where more stringent regulation will require running on distillates only[2]. With the requirements of MARPOL becoming more stringent, shipowners will have to either switch fuels or make new investments. In 2017, the shipowner will have more information on the way the markets are developing specifically on what the energy prices will look like and can still decide to invest in LNG or run on MDO. It should be stressed that LNG is one of the various alternatives available to shipowners, other viable alternatives being biofuels, exhaust gas cleaning devices and a large array of energy efficiency measures (Acciaro 2012*a*; Eide *et al.* 2009).

LNG has become a more popular fuel for maritime use in the last few years. This development has gone hand in hand with the creation of a distribution network and in general of the transport and availability of gas in LNG form. LNG availability is very different from country to country and although the number of ships using LNG has been increasing, LNG engines are far from being as common as diesel engines[3]. Furthermore the use of LNG requires a set of modifications for the vessel including tanks and specific type of engines that comes with substantial CapEx.

Among the benefits of natural gas is the fact that it does not require any cleaning of emissions to comply with SO_x regulation and has very low emission of NO_x and particles[4]. As far as CO_2 is concerned, LNG is a fossil fuel and as such its impact on CO_2 emissions is limited[5]. One of the main advantages of LNG is its lower price with respect to oil based distillates, although large differences can be observed among countries since a global LNG market does not exist and distribution costs can still be substantial. LNG prices are likely to benefit from the availability of cheap natural gas resulting from the exploitation of unconventional gas resources. The influence of such resources on the LNG market is, however, largely unknown, because on the uncertainty connected on the one side to the market response to their exploitation and on the other side to the environmental impacts of the extraction and distribution processes (Howarth *et al.* 2011).

---

[2] This is a rather strong assumption since in reality fuel requirements can be met in some cases by low sulphur heavy fuel oil depending on the sailing profile of the vessel and the engine type.

[3] 27 ships and approximately a hundred LNG carriers sailing with LNG engines today, compared to some 80-100.000 diesel fuelled ships.

[4] NO_x emissions are reduced by 85–90%, SO_x and particles by close to 100%.

[5] CO_2 equivalent emission reduction is estimated between 15–25% (Pitt *et al.* 2010; Æsøy *et al.* 2011) depending on the incidence of methane accidental releases. Emission reductions are even lower if life cycle assessment and fugitive emissions of methane and volatile organic compounds during distribution are considered (Brett 2006; Bengtsson *et al.* 2011; Bengtsson 2011). A realistic estimation of well-to-propeller life cycle emissions is in the range of 10% lower than diesel fuel chains (Verbeek *et al.* 2011). Bio LNG produced from bio-methane also exists but it is not widely used (Ecofys 2012).

Investment in LNG retrofitting appears therefore characterised by a large set of uncertainties mostly related to the costs, the availability and the technical reliability of the alternative fuel. It is likely that some of these uncertainties will be resolved over time, as a global market for LNG for maritime use is created, as the technology reaches maturity, and as a larger number of ships will eventually run on this type of fuel. Conceptually the deferral option allows for accounting for the strategic decision to wait and observe how the market and the technology develop before committing to it. This analysis could be extended to include a growth options, that is often used for unproven technologies (Leiblein and Ziedonis 2007).

2.3. Model description

The objective of the model, a description of which is provided in more detail in Brach (2003: pp. 68 *et seq.*), is that of providing the price of the option as well as the value of the deferral option. The first step in determining the value of the option is the calculation of the value of investing now. In our case this is the present value of the savings made possible by the investment in a new piece of equipment that would favour environmental compliance as a result of the utilisation of a cheaper fuel. The present value of this amount, which is obtained by simple difference between the various investment strategies and the base line case, is calculated for the various fuel scenarios.

For each fuel price then the option price is calculated as:

$$C = \max\left(0; \frac{p \cdot V_{max} + (1-p) \cdot V_{min}}{(1+r)^t} - K \cdot (1 + r_c)^t\right)$$

where K is the investment cost today, r is the risk free rate, r_c is the opportunity cost of capital, t is the time period at which the option can be exercised, V_{max} is the value to be obtained in the best case scenario, V_{min}, the value achieved in the worst case scenario and p is the risk free probability, defined as:

$$p = \frac{(1+r) \cdot V_e - V_{min}}{V_{max} - V_{min}}$$

where V_e is the expected asset value. By comparing the option prices we can rank the various options so that management can have an additional decision support tool.

If management defers the investment for t years, it will have a much better understanding of the fuel market and therefore be able to make a better informed decision on whether LNG is a substantially lower alternative to comply with regulation. If indeed high energy prices have materialised, making any fuel saving reduction more important, then management will be better able to quantify the benefits of LNG. In case of those strategies that allow for investment deferral, we have the possibility of calculating the revenues in the worst and the best case scenarios, and the savings that can be gained or foregone in the various scenarios. For each scenario, we will determine the highest pay-off between investing and not investing, including the opportunity cost of capital. The pay-offs for all scenarios will then be used to calculate the risk free probability p and the option price as:

$$C = \frac{p \cdot V_{max} + (1-p) \cdot V_{min}}{(1+r)^t}$$

It should be noted that the pay-off values include in this case also the value of capital and the opportunity cost of capital. If we call C_q the option price of investing in year q, where C_0 denotes the option price of investing today, and calculate the revenue foregone by delaying the investment decision (*RF*), i.e. the savings that could have been made if the investment was performed today, we have:

$$C_0 = C_q - RF_q$$

When the equality holds, the value of deferring is clearly zero. But this is not necessarily the case, so that we can define the price of the deferral option (for q years) as D_q:

$$D_q = C_q - RF_q - C_0$$

2.4. Multi-period analysis

Let us assume that the investment horizon for the shipowner is n years. Today (year 0), the shipowner has the possibility of investing in a new technology, and pay capital expenses K or defer the investment decision. In case he invests now, his pay-off will be given by the expected value of the savings obtainable by using the new fuel. If on the contrary he decides to defer, in year 1, the shipowner will have two options, either invest in year 1 and pay K at time 1 or defer the decision. If the shipowner invests in year 1, he will receive the present value of the savings made in $n-1$ years. If he does not invest (he defers the decision) in year two the ship owner will have the possibility of investing and paying K in time 2, and so on. In year n, the shipowner will not have the possibility of investing and his pay-off will be given by the expected value of the non-investment strategy, i.e. no savings. The option to defer comes at a cost, i.e. the revenue foregone (RF). The revenue forgone increases every year the decision is postponed, so that $RF_{q-1} \leq RF_q$.

Every year the savings that the shipowner can make are a function of the differential between the new fuel and the old fuel. If the new fuel is cheaper, and the shipowner had invested in the new fuel he will obtain some gains. Since the shipowner does not know how the fuel differential will behave, he is obliged to consider various alternatives. If we were to map all these alternatives over time we would observe that as the value of the call option decreases the value of the deferral option increases as the decision is postponed to the future. The revenue foregone though will also increase as the investment decision is postponed.

3. MODEL RESULTS

3.1. Data description

The model has been tested using a Handysize vessel, similarly to the one used in Acciaro (2012*a*). The specifications of the vessel are given in the table below. In the analysis we focus on two cases. One in which the remaining economic life of the vessel is 8 years and one in which the economic life of the vessel is 18 years. We consider a price differential between LNG and distillate fuels of 30% (different price differentials have been analysed in other studies. We also consider that following the enforcement of stricter sulphur emission reduction regulation in 2015, the ship will only be allowed to sail on distillate fuels or on LNG, since the alternative of installing exhaust gas emission reduction devices, such as scrubbers, is out of the scope of this paper.

Table 1. Ship parameters.

Ship	***Unit***	***Ship 1***
Size		Handysize
DWT	tons	35 000
GT	tons	25 000
Engine		MAN 6S50ME-B9 127 rpm
Power	kw	8 000
Fuel Consumption	tonnes	6 162
Cost of LNG retrofit	US$	18 million
Days at sea	days	240
Engine load	%	80 %

Source: Author.

The standard deviation of the distillate fuel price is 378 US$, and the average is 1034 US$ per tonne. For LNG the standard deviation is 301 US$, while average is 823 US$ per tonne. The fuel price distributions are elaborations on the International Energy Agency and the Energy Information Administration and are the same as those used in Acciaro (2012*a*; 2012*b*) and fuel consumption is corrected for the different calorific values of the different type of fuels. The distributions of the fuel prices are independent, i.e. a high gas fuel price scenario can be associated with a low oil price scenario or a high oil price scenario with equal probabilities. Risk free interest rate is 6% while the internal firm discount rate is 15%. The investment option is retrofitting a vessel to LNG every year between 2014 and 2019.

This gives, together with the option of not doing any modifications on the vessel, eight different cases. The total CapEx, total OpEx and the expected savings for each of the eight options and for the two different economic life profiles for the vessels are reported in Table 2.

Table 2. CapEx, OpEx and savings for the various investment alternatives.

		2020		*2030*	
Alternative	CapEx	Total OPEX	Savings	Total OPEX	Savings
0) Base line	$0	$24 180 510	$0	$35 913 178	$0
1) LNG in 2019	$25 533 344	$22 503 832	$1 676 678	$30 076 841	$5 836 337
2) LNG in 2018	$24 088 060	$21 498 067	$2 682 443	$29 071 077	$6 842 102
3) LNG in 2017	$22 724 585	$20 363 609	$3 816 901	$27 936 618	$7 976 560
4) LNG in 2016	$21 438 288	$19 366 461	$4 814 049	$26 939 471	$8 973 708
5) LNG in 2015	$20 224 800	$18 244 980	$5 935 531	$25 817 989	$10 095 190
6) LNG in 2014	$19 080 000	$18 232 587	$5 947 923	$25 805 597	$10 107 582
7) LNG now	$18 000 000	$18 218 667	$5 961 843	$25 791 676	$10 121 502

Source: Author.

3.2. ROA results

The results of the option model are presented in Table 3. As it was to be expected the call option price increases as the investment time horizon moves further in the future. This is the result of the increasing information that the shipowner would possess by the time of the investment decision. The deferral option exercise prices, i.e. the revenue foregone, also increase as the investment horizon increase in the future.

Table 3. Call option prices, deferral option prices and option exercise prices.

Alternative	Call price		Deferral option price		Exercise Price Revenue foregone
	2020	*2030*	*2020*	*2030*	
0) Base line	NA	NA	NA	NA	$5 175 309
1) LNG in 2019	$17 827 088	$14 718 749	$13 541 924	$10 433 585	$4 285 165
2) LNG in 2018	$16 955 254	$13 660 415	$13 675 854	$10 381 015	$3 279 400
3) LNG in 2017	$15 875 256	$12 382 726	$13 730 315	$10 237 785	$2 144 942
4) LNG in 2016	$14 795 514	$11 093 432	$13 647 720	$9 945 638	$1 147 794
5) LNG in 2015	$13 480 443	$9 556 236	$13 454 131	$9 529 924	$26 312
6) LNG in 2014	$13 132 077	$8 972 418	$13 118 157	$8 958 498	$13 920
7) LNG now	$0	$0	NA	NA	$0

Source: Author.

The analysis indicates that for LNG retrofitting CapEx of $ 18 million, the option of investing today is not in the money. This is confirmed if a DCF analysis was to be performed on our data. For the call option to be in the money for the ship shortest remaining economic life (2020 horizon), the CapEx would have to be as low as $ 5 million, while in a 2030 horizon in the range of $ 8 million.

As shown in the Figure 1, we observe that for high CapEx, the call option value decreases as the investment horizon is reduced. For lower values of the CapEx, the option value decreases less sharply or even increases as the time horizon of the investment is reduced. This seems to indicate that for the current CapEx level ($ 18 million), investment in LNG retrofitting does not make sense today on the basis of the savings resulting from LNG and fuel oil price differentials. It may make sense in the next few years though if the CapEx could be reduced in the range of half the current costs. This could be achieved either by providing support for those shipowners that are willing to invest in LNG today, or by increasing the costs of not reducing emissions (for example through a sulphur or a carbon tax).

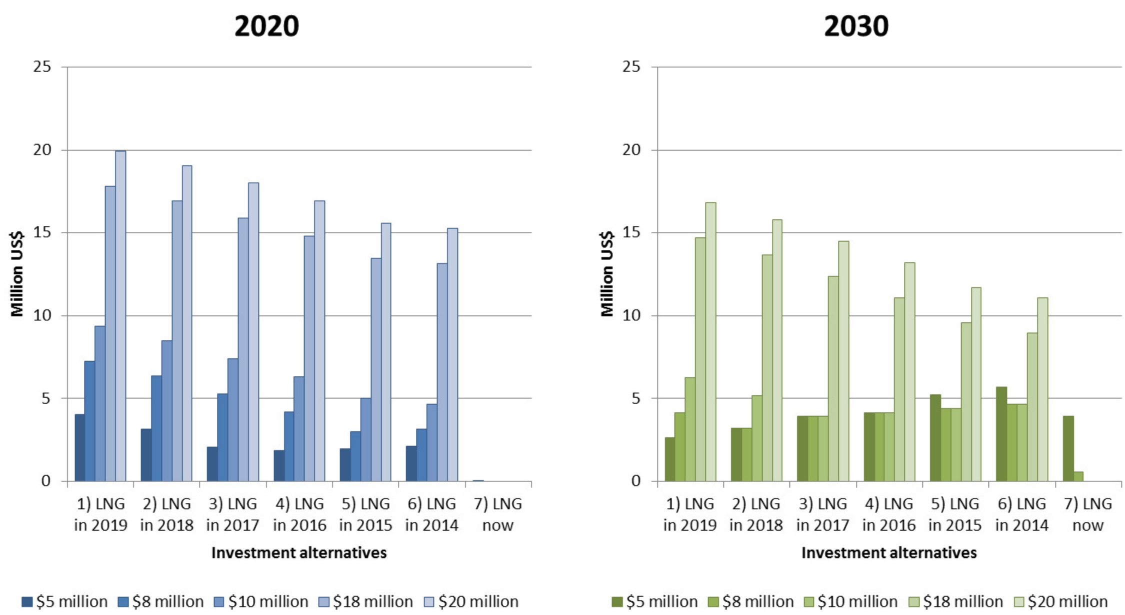

Figure 1. Call option prices for various CapEx values.

Source: Author.

3.3. Deferral option price analysis

The analysis of the deferral option price though indicates that for the 2020 time horizon the most valuable deferral option is investing in LNG in 2017, as also shown in Figure 2. This also appears to be the strategy that currently most shipowners are choosing. The deferral period can be used to reduce some of the variability related to the price of the alternative fuel, or clear some of the technological and policy uncertainties connected with the use of the new technology.

Deferring the investment appears to be more valuable in general as a strategy if the economic life of the vessel is shorter. This may appear counterintuitive but is related to the fact that the investment deferral matters more when the deferral option affects substantially the savings foregone as a portion of the total savings obtainable.

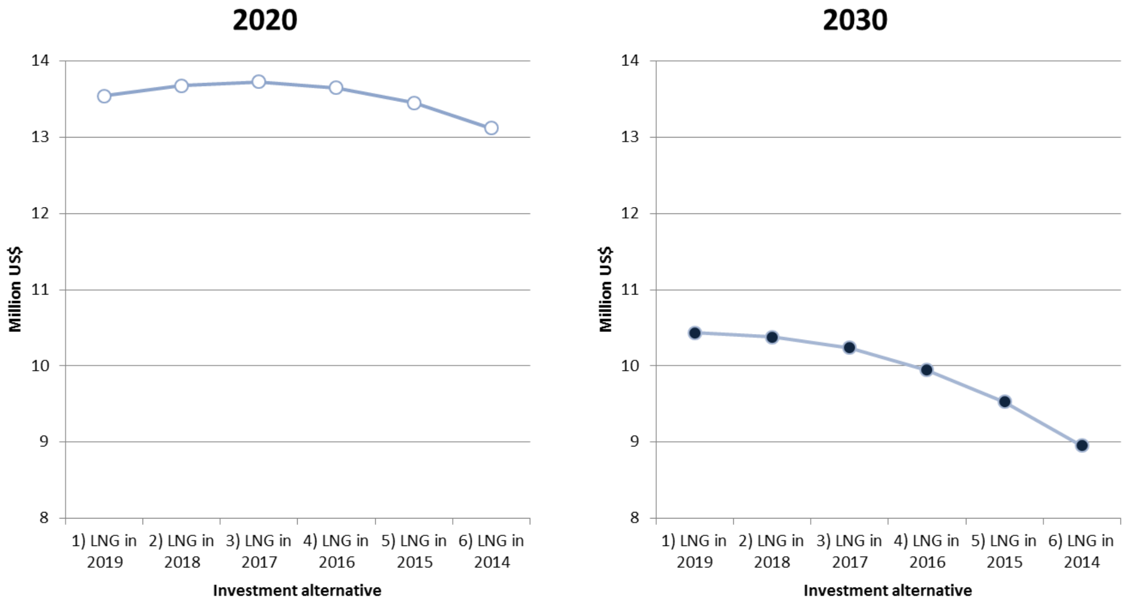

Figure 2. Deferral option values.

Source: Author.

Figure 3, below shows how the value of the deferral option behaves as the CapEx change. The deferral option value decreases as CapEx decrease, and in general it is lower for a ship with the longer remaining economic life (2030 horizon, right panel in Fig. 3). For lower CapEx, the deferral option is not in the money for longer deferrals.

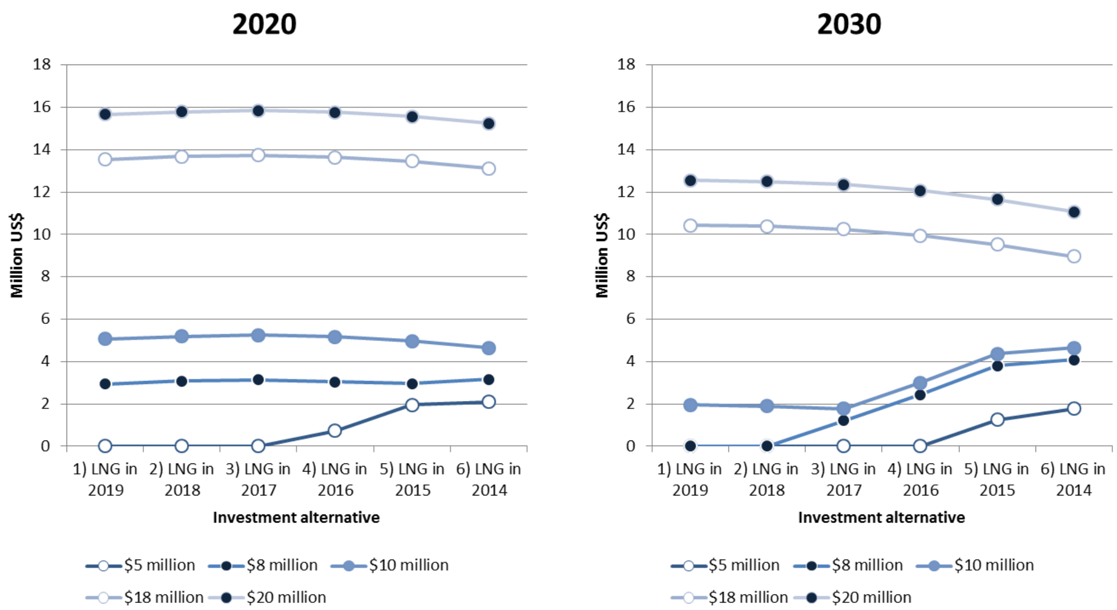

Figure 3. deferral option values for different CapEx.

Source: Author.

4. CONCLUDING REMARKS

The development of environmental regulation is likely to increase the complexity of the investment decisions that ship owners have to make. If on the one side many of the measures that can be adopted for environmental compliance have the potential of improving the ship energy efficiency profile, on the other side various uncertainties persist with respect to the availability, reliability and costs associated with new technologies. The increasing stringency of environmental regulation and the uncertainty associated with some of the technical alternatives calls for the development of investment assessment tool that can take into account the flexibility and the diversity of strategic optionalities available to ship owners.

A suitable set of techniques is provided by ROA. ROA has been applied in shipping but very few applications have focused on environmental compliance. This article is one of the first applications of ROA in the area of greener shipping and makes use of a simple model in order to account for the possibility of deferring an investment decision in an emerging new technology in order to gain better insights on the technological and market developments associated with the technology.

The model has been applied with reference to retrofitting a handysize vessel with LNG. The costs of retrofitting the vessel can be partially compensated by the benefits obtainable by reducing the shipowner fuel bill as a result of cheaper LNG prices. Given though the uncertainty on LNG prices and the high capital costs associated with a LNG retrofit, the investment would in general be rejected if traditional DCF models were to be used. The real option approach shows that, although investment in LNG does not make economic sense as of today, a valid strategic option is that of deferring the investment decision and gain better insight in the fuel market development. Depending on the remaining economic life of the vessel, investment in LNG might be an attractive proposition already in 2017.

The model also assessed the option price results for various CapEx levels. The reduction in CapEx appears to make investment deferrals less attractive. This entails that when

CapEx are high, deferrals are necessary to reduce the risks associated with the investment decision. High CapEx, in other words, increase the urgency of clarifying some of the uncertainties related to the implementation of the new technology, by investing, for example, in new market research or in overcoming the technical limitations of LNG today. CapEx are likely to be reduced in the future as the technology matures and an increasing number of maritime operators make use of alternative fuels. Nonetheless a policy maker could favour the development of the new technology by providing financial incentives to research or technology adoption, or by implementing emission reduction market based measure such as emission trading schemes or emission quotas.

The use of ROA in this area of shipping appears very promising since these models are able to account, in their more advanced applications, for the uncertainties associate with the shipping operating environment and allow for the inclusion of complex optionalities. This paper has focused on LNG but a similar approach could also be used for energy efficiency measures, or with some modifications for ballast water management systems. In the specific case discussed in the paper it would be interesting to combining the option to defer with the option to grow as outlined for example in Leiblein and Ziedonis (2007).

AKNOWLEDGMENTS

The author would like to acknowledge the contribution of Martin C. Wold, Peter N. Hoffmann, Øyvind Endresen and Magnus Eide who provided valuable inputs to this paper. Some of the ideas presented in this paper have been presented at the SIG2 Conference in May 2012. Some of the ideas developed in this paper are the result of discussions conducted during the author involvement in the *Low Carbon Shipping* and the *EmiSol* projects under the auspices of the Research Council of Norway, and in the DNV Research and Innovation Internal Project *Regulatory Outlook*. The usual disclaimers apply.

REFERENCES

Acciaro, M. (2011*a*). 'Pricing in sustainable global container transport', *Int. J. Decision Sciences, Risk and Management*, vol. 3, nos. 3/4, pp. 293-310.

Acciaro, M. (2011*b*). 'Regulating Air Emissions from Ships', presentation at the *Reducing the impact of emissions from shipping and aviation* conference, 9th September 2011, Edinburg, UK.

Acciaro, M. (2012*a*). 'A real option approach to investment in low sulphur maritime transport', WCTRS SIG2 Conference, Key Developments in the Port and Maritime Sector, 21-22 May, 2012; Antwerp, Belgium.

Acciaro, M. (2012*b*). Maritime Fuel price projections to 2035. DNV report no. 2011-1663.

Acciaro, M., Chryssakis, C., Eide, M.S. and Endresen, Ø. (2012*a*). 'Potential CO_2 reductions from energy mix changes in the world fleet', the International Association of Maritime Economists (IAME) Annual Conference, 6-8 September, 2012; Taipei, Taiwan.

Acciaro, M., Hoffmann, P.N. and Eide, M.S. (2012*b*). 'The Energy Efficiency Gap in Maritime Transport', in Francesc Xavier Martínez de Osés and Marcel·la Castells i Sanabra (eds.) *Proceedings of the 5th Maritime Transport Conference, Technological Innovation and Research, 27-29 June, Barcelona, Spain*, pp. 960-981, Univesitat Politècnica de Catalunya, BarcelonaTech; Barcelona, Spain.

Æsøy, V., Einang, P.M., Stenersen, D., Hennie, E. and Valberg, I. (2011). 'LNG-Fuelled Engines and Fuel Systems for Medium-Speed Engines in Maritime Applications', Proceedings of the International Conference on Fuels and Lubricants, SAE, 28 August-2 September, Kyoto, Japan.

Alizadeh, A. H. and Nomikos, N.K. (2009). *Shipping Derivatives and Risk Management*, Palgrave MacMillan; Basingstoke, UK.

Bendall, H. and A.F. Stent (2003). 'Investment strategies in market uncertainty', *Maritime Policy & Management*, vol. 30, no. 4, pp. 293-303

Bendall, H. and A.F. Stent (2005). 'Ship Investment under Uncertainty: Valuing a Real Option on the maximum of Several Strategies', *Maritime Economics and Logistics*, vol. 7, no. 1, pp. 19-35.

Bendall, H. and A.F. Stent (2007). 'Maritime investment strategies with a portfolio of real options', *Maritime Policy & Management*, vol. 34, no. 5, pp. 441-452

Bendall, H. B. and A. F. Stent (2001). 'A Scheduling Model for High Speed Container Service: A Hub and Spoke Short Sea Application', *International Journal of Maritime Economics*, vol. 1, no. 3, pp. 262–77.

Bengtsson, S. (2011). Life Cycle Assessment of Present and Future Marine Fuels, MSc Thesis, Chalmers Institute of Technology; Gothenburg, Sweden.

Bengtsson, S., Andersson, K. & Fridell, E. (2011). 'A comparative life cycle assessment of marine fuels; liquefied natural gas and three other fossil fuels'. *Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment*, vol. 225, no. 2, pp. 97-110.

Bjerksund, P. and S. Ekern (1995) 'Contingent Claims Evaluation of Mean Reverting Cash Flows in Shipping', in L. Trigeorgis (ed.) *Real Options in Capital Investment*, pp. 207-21, Praeger; London, UK.

Bosch, P., Coenen, P., Fridell, E., Åström, S., Palmer, T., and Holland, M. (2009). Cost Benefit Analysis to Support the Impact Assessment accompanying the revision of Directive 1999/32/EC on the Sulphur Content of certain Liquid Fuels. Final AEA Report, 2009. Available at: http://ec.europa.eu/environment/air/transport/pdf/CBA_of_S.pdf

Brach, M. (2003). *Real Options in practice*, John Wiley & Sons; Hoboken, USA.

Brett, B.C. (2008). Potential market for LNG-Fuelled Marine Vessels in the United States, Master thesis, Massachusetts Institute of Technology; Cambridge, USA.

Buhaug, Ø., Corbett, J.J., Endresen, Ø., Eyring, V., Faber, J., Hanayama, S., Lee, D.S., Lee, D., Lindstad, H., Markowska, A.Z., Mjelde, A., Nelissen, D., Nilsen, J., Pålsson, C., Winebrake, J.J., Wu, W.–Q., Yoshida, K. (2009). *Second IMO GHG study 2009*; MEPC 59/INF.10. International Maritime Organization (IMO); London, UK.

Dikos, G. (2008). 'Real option econometrics for aggregate tanker investment decisions', *International Journal of Ocean Systems Management*, vol. 1, no. 1, pp. 31-33.

Dixit, A. K. (1989) 'Entry and Exit Decisions under Uncertainty', *Journal of Political Economy*, vol. 97, no. 3, pp. 620-38.

Ecofys 2012. *Potential of Biofuels for Shipping*, report prepared for the European Maritime Safety Agency (EMSA), project no. BIONL11332.

Eide, M S., Endresen, Ø, Skjong, R, Longva, T and Alvik, S. (2009). Cost-effectiveness assessment of CO_2 reducing measures in shipping, *Maritime Policy & Management*, vol. 36, no. 4, pp. 367-384.

Eide, M.S., Longva, T., Hoffmann, P., Endresen, Ø., Dalsøren, S.B. (2011). 'Future cost scenarios for reduction of ship CO_2 emissions', *Maritime Policy and Management* vol. 38, no. 1, pp. 11-37.

Endresen, Ø., Lee Behrens, H., Brynestad, S., Bjørn Andersen, A., and Skjong, R. (2004). 'Challenges in global ballast water management', *Marine Pollution Bulletin*, vol. 48, no. 7, pp. 615-623.

Endresen, Ø., Dalsøren, S., Eide, M., Isaksen, I.S., Sørgård, E., (2008). 'The environmental impacts of increased international maritime shipping, past trends and future perspectives', Proceedings of the OECD/ITF Global Forum on Transport and Environment in a Globalising World, 10-12 November, Guadalajara, Mexico.

Eyring, V., Isaksen, I., Berntsen, T., Collins, W., Corbett, J., Endresen, Ø., Grainger, R., Moldanova, J., Schlager, H., Stevenson, D. (2010). 'Transport impacts on atmosphere and climate: Shipping', *Atmospheric Environment*, vol. 44, no. 37, pp. 4735-4771.

Faber, J., Markowska, A., Eyring,V., Cionni, I., Selstad, E. 2010. *A Global Maritime Emissions Trading System Design and Impacts on the Shipping Sector, Countries and Regions*, Delft, CE Delft.

Flatters, P. and Willmott, M. (2009). 'Understanding the Post-Recession Consumer', *Harvard Business Review*, vol. 87, no7-8, pp. 106-112.

Fuglestvedt, J., Berntsen, T., Eyring, V., Isaksen, I., Lee, D.S. and Sausen, R. (2009). 'Shipping Emissions: From Cooling to Warming of Climate—and Reducing Impacts on Health', *Environmental Science & Technology*, vol. 43, no. 24, pp. 9057-9062.

Gallasch, S., David, M., Voigt, M., Dragsund, E., Hewitt, C., and Fukuyo, Y. (2007). 'Critical review of the IMO international convention on the management of ships' ballast water and sediments', *Harmful Algae*, vol. 6, no. 4, pp. 585-600.

Heitmann, N., and Khalilian, S. 2011. 'Accounting for carbon dioxide emissions from international shipping: Burden sharing under different UNFCCC allocation options and regime scenarios'. *Marine Policy*, vol. 35, no. 5, pp. 682-691.

Hopp C., and Tsolakis, S.D. (2004). 'Investment Applications in the Shipping Industry', Proceedings of the 8th Annual International Conference on Real Options, Montréal, Canada, 17-19 June.

Howarth, R.W., Santoro, R. and Ingraffea, A. (2011). 'Methane and the greenhouse-gas footprint of natural gas from shale formations, A Letter', *Climatic Change*, vol. 106, no. 4, pp. 679-690.

Huang, M. and Rust, R. (2011). 'Sustainability and consumption', *Journal of the Academy of Marketing Science*, vol. 39, no. 1, pp. 40-54.

Johnson, H. and Andersson, K (2011). 'The Energy Efficiency gap in Shipping: Barriers to improvement', International Association of Maritime Economists Annual Conference, 25- 28 October, Santiago de Chile, Chile.

Johnson, H., Johansson, M., and Andersson, K (2012). 'Barriers to energy efficiency in short sea shipping: a case study', Short Sea Shipping 2012 Conference, 2-3 April, Lisbon, Portugal.

Kavussanons, M.G. and Tsekrekos, A.E. (2011). ‘The option to change the flag of a vessel’, in Cullinane, K. (ed). *International Handbook of Maritime Economics*, pp. 47-62, Edward Elgar; Cheltenham, UK.

Kontovas, C.A. and Psaraftis, H.N. (2009). ‘An Online Ship Emissions Calculator as a Decision-Making Aid and Policy Evaluation Tool’, 13th Congress of Intl. Maritime Assoc. of Mediterranean IMAM 2009, 12-15 October, Istanbul, Turkey.

Leiblein, M.J., and Ziedonis. A.A. (2007). ‘Deferral and growth options under sequential innovation’. *Advances in Strategic Management*, vol. 24, no. 3, pp. 225-245.

Longva, T, Eide, M.S., Skjong, R. (2010). ‘Determining a required energy efficiency design index level for new ships based on a cost-effectiveness criterion’, *Maritime Policy and Management*, vol. 37, no. 2, pp. 129-143.

NERA Economic Consulting (2005). Economic Instruments for Reducing Ship Emissions in the European Union, report prepared for the European Commission, Directorate-General Environment, Contract No. 070501/2004/383959/MAR/C1.

Nidumolu R., Prahalad C.K., Rangaswami M.R. (2009). ‘Why Sustainability Is Now The Key Driver Of Innovation. *Harvard Business Review*, vol. 87, no. 9, 56-64.

Notteboom, T. (2011). ‘The impact of low sulphur fuel requirements in shipping on the competitiveness of roro shipping in Northern Europe’, *WMU Journal of Maritime Affairs,* vol. 10, no. 1, pp. 63–95.

Miola, A., Ciuffo, B., Giovine, E., and Marra, M. 2010. Regulating Air Emissions from Ships The State of the Art on Methodologies, Technologies and Policy Options. JRC Reference Reports, November 2010.

Peattie, K. and Crane, A. (2005). ‘Green marketing: legend, myth, farce or prophesy?’, *Qualitative Market Research: An International Journal*, vol. , no. 4, pp.357-370.

Pickett-Baker, J. and Ozaki, R (2008). ‘Pro-environmental products: marketing influence on consumer purchase decision’, *Journal of Consumer Marketing*, vol. 25, no.5, pp.281-293.

Pimentel, D., Zuniga, R., and Morrison, D. (2005). ‘Update on the environmental and economic costs associated with alien-invasive species in the United States’, *Ecological Economics*, vol. 52, no. 3, pp. 273-288.

Pitt, M., Eide, M.S, Brathagen, S. and Dimopoulos, G. (2010). Natural Gas versus Diesel Power for Ships - A Technical Review, also Considering Economic Aspects. DNV Report No. 2010-0605 (revision 4).

Psaraftis, H., and Kontovas, C. (2010). ‘Balancing the economic and environmental performance of maritime transportation’, *Transport and Environment, Transportation Research Part D*, vol. 15, no. 8, pp. 458-462

Psaraftis, H.N., C.A. Kontovas, (2009). ‘Ship Emissions: Logistics and Other Tradeoffs’, in Erikstad, S.O. (ed.) *International Marine Design Conference (IMDC 09), Trondheim, Norway, May 2009*, Tapir Akademisk Forlag; Trondheim, Norway.

Sødal, S., S. Koekebakker and R. Adland (2008) ‘Market Switching in Shipping – a Real Option Model Applied to the Valuation of Combination Carriers’, *Review of Financial Economics*, vol. 17, no.3, pp. 183-203.

Sødal, S., S. Koekebakker and R. Adland (2009) ‘Value Based Trading of Real Assets in Shipping under Stochastic Freight Rates’, *Applied Economics*, vol. 41, no. 22, pp.2793-2807.

Trigeoegis, L. (2002). *Real Options,* the MIT Press; Cambridge, USA.

Verbeek, R., Kadijk, G., van Mensch, P., Wulfferts, C., van den Beemt, B., and Fraga, F. (2011). Environmental and economic aspects of using LNG as a fuel for shipping in The Netherlands, TNO Report, TNO-RPT-2011-00166.

Wang, C., Corbett, J.J., Winebrake, J.J. (2007*a*). ‘The costs and benefits of reducing SO_2 emissions from ships in the US West Coastal waters’, *Transportation Research Part D: Transport and Environment*, vol. 12, no. 8, pp. 577-588.

Wang, C., Corbett, J.J., Winebrake, J.J. (2007*b*). ‘Cost-Effectiveness of Reducing Sulphur Emission from Ships’, *Environmental Science & Technology*, vol. 41, no. 24, pp. 8233-8239.

Young, W., Hwang, K., McDonald, S. and Oates, C. J. (2010). ‘Sustainable consumption: green consumer behaviour when purchasing products’. *Sustainable Development*, vol. 18, no. 1, pp. 20-31.