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Barriers to energy efficiency in shipping: A triangulated approach to investigate the principal agent problem

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HIGHLIGHTS

- We provide the first analysis of the principal agent problem in shipping.
- We develop a framework that incorporates methodological triangulation.
- Our results show the extent to which this barrier is observed and perceived.
- The presence of the barrier has implications on the policy most suited to shipping.

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ABSTRACT

Energy efficiency is a key policy strategy to meet some of the challenges being faced today and to plan for a sustainable future. Numerous empirical studies in various sectors suggest that there are cost-effective measures that are available but not always implemented due to existence of barriers to energy efficiency. Several cost-effective energy efficient options (technologies for new and existing ships and operations) have also been identified for improving energy efficiency of ships. This paper is one of the first to empirically investigate barriers to energy efficiency in the shipping industry using a novel framework and multidisciplinary methods to gauge implementation of cost-effective measures, perception on barriers and observations of barriers. It draws on findings of a survey conducted of shipping companies, content analysis of shipping contracts and analysis of energy efficiency data. Initial results from these methods suggest the existence of the principal agent problem and other market failures and barriers that have also been suggested in other sectors and industries. Given this finding, policies to improve implementation of energy efficiency in shipping need to be carefully considered to improve their efficacy and avoid unintended consequences.

1. Introduction

1.1. Background

Shipping is a derived demand, i.e. it exists in response to demand for the transport of freight. Transportation, and particularly shipping, thus plays a critical role in the global economy and as such is one of the key enablers of globalisation. The shipping industry supplies a safe, reliable and cheap form of transport connecting the world's consumers with the world's raw materials and skilled, low-cost labour markets. Given the high correlation between the historic relationship of global Gross Domestic Product (GDP) and shipping activity (measured in tonne miles, i.e. payload by distance) as shown in Fig. 1, the global GDP can be used to some extent estimate the demand for future shipping activity, although currently this relationship is showing signs of decoupling. At an annual GDP growth rate of around three to four per cent, it is estimated that shipping's activity will increase by around 200–300% by 2050 (Buhaug et al., 2009; Smith et al., 2014).

This continued growth rate brings with it several challenges which may question the sustainability of the shipping industry; one of them being climate change. Energy efficiency (i.e. increasing productivity using the same amount of energy) is one of the strategies to address the issues of climate change (UNEP, 2011) and other strategies include using renewable energy sources (e.g. solar, wind), using fuels with lower carbon content (e.g. liquid natural gas and biofuels) and using emission reduction technologies (e.g. through chemical conversion, capture and storage). Currently, the global transport sector emissions represent around 13% of global CO_2 emissions, of which total shipping CO_2 emissions (from international and domestic shipping) accounted for over 3% (around

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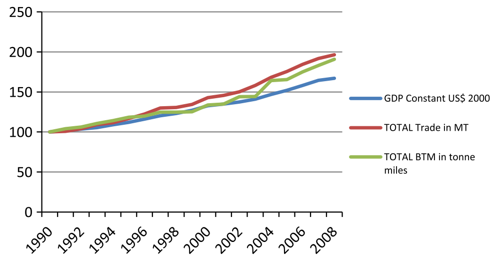

Fig. 1. Historic relationship between shipping activity and GDP Data from UNCTAD (1997–2008) and Clarksons (2010).

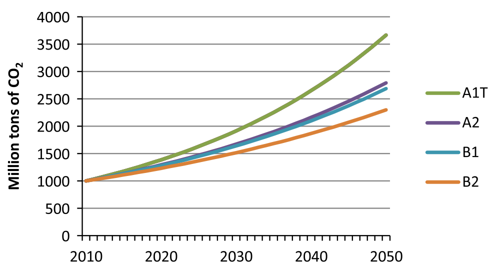

Fig. 2. International shipping emissions based on IPCC SRES Scenarios. *Source*: Buhaug et al. (2009).

1 Gt) of global CO_2 emissions in 2007. This contribution to emissions in comparison to the cargo transported, makes shipping the most energy efficient form of transport compared to air, road and rail (Buhaug et al., 2009). However, given the aforementioned growth rate, it is estimated that shipping's CO_2 emissions will grow by one and half to three times under the business-as-usual scenario (compared to emissions in 2007) by 2050 as shown in Fig. 2. Hence there is an even greater need for improving energy efficiency of the ships. The industry has adopted 'first of its kind' international regulation in its efforts to mitigate CO_2 emissions, the energy efficiency design index (EEDI), a command and control, design based standard that is tightened every five years from 2015 to 2030, but its impact is estimated to be only around 25% reduction in CO_2 emissions on business as usual by 2050 (Bazari and Longva, 2011).

Currently, fuel costs in shipping generally account for between 50% and70% of a ship's operating costs, which is set to increase as Heavy Fuel Oil (HFO)[1] costs increase, creating further incentives towards energy efficiency in shipping. More than fifty measures (Eide et al., 2009; Buhaug et al., 2009; Wang et al., 2010) have been identified that could result in efficiency gains and they are generally grouped as technical measures (some applicable to new and some to existing ships) and operational measures. These measures along with their abatement potentials have also been presented in several shipping specific marginal abatement cost curves[2] (MACC's) (Buhaug et al., 2009; Faber et al., 2011; Eide et al., 2009; Wang et al., 2010) that commonly feature measures, especially operational measures, that are cost-effective. A cost-effective measure is one that is economically efficient (yields a positive Net Present Value) and energy efficient (Sweeney, 1993; Golove and Eto, 1996). Yet, the implementation of these cost-effective measures has not been empirically examined in shipping and this paper attempts to gauge this with a view to understanding the barriers that may be inhibiting the uptake of such measures.

[1] A type of residual fuel oil that is the predominant type of fuel used in ships.
[2] A common method to calculating the techno-economic potential of CO_2 reducing measures and the order in which they may be adopted.

1.2. Barriers to energy efficiency

The barriers to energy efficiency debate has gained momentum since the 1980's with the first bibliographical account of barriers to energy efficiency by followed by empirical research by Blumstein et al. (1980), which is then followed by a host of literature, see for example Fisher and Rothkopf (1989), Hirst and Brown (1990), Howarth and Andersson (1993), Sanstad and Howarth (1994), Jaffe and Stavins (1994), Howarth and Andersson (1993) Howarth et al. (2000), Thollander and Palm (2013). Several studies across a wide range of sectors and regions have empirically shown that cost-effective energy efficiency measures are not always implemented despite the substantial abatement potential, see for example Velthuijsen (1993), Gillissen and Opschoor (1994), Harris et al. (2000) Sorrel et al. (2004), Zilahy (2004), Rohdin et al. (2007), Shi et al. (2008), Sardianou (2008), Thollander and Ottosson (2008), Schleich (2009), Hasanbeigi et al. (2009), Trianni et al. (2012). A common conclusion of these studies, mainly based on respondent perceptions (measured through surveys), has been the identification of a range of barriers that result in a sub-optimal level of uptake. They define barriers as postulated mechanisms that inhibit investment in technologies which are both energy efficient and economically efficient (Sorrel et al., 2004). The difference between the actual or observed lower levels of implementation of cost-effective measures and the higher level that would appear to be cost-effective from the consumers or firms point of view based on techno-economic analysis (Brown, 2001; Golove and Eto, 1996) is referred to as the 'energy efficiency gap' (Jaffe and Stavins, 1994). Some of the energy efficiency gap can be explained by rational behaviour to market barriers that may not be captured by the techno-economic analysis. If these can be accurately modelled, then the remaining energy efficiency gap can be explained by market failures, behavioural and organisational barriers as shown in Fig. 3. The magnitude of the energy efficiency gap will also be dependent on the extent to which models address take-up of measures and the way implementation is measured.

According to Brown (2001) market barriers are obstacles that are not based on market failures but nonetheless contribute to the slow diffusion and adoption of energy efficient measures. They can

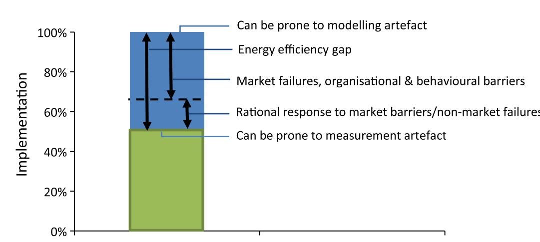

Fig. 3. Explaining the energy efficiency gap.

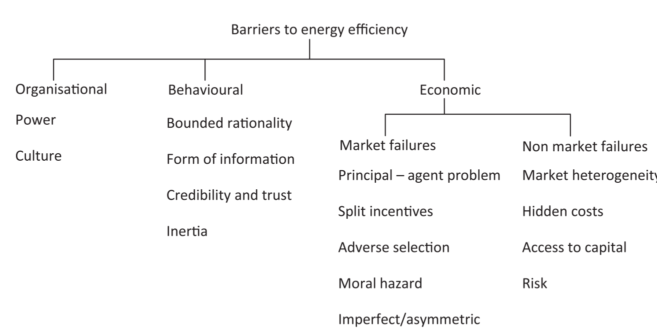

Fig. 4. Classification of barriers.

Table 1
Cost allocations in shipping.

Cost element	Voyage charter $/tonne	Time charter $/day
Cargo Handling	Charterer	
Voyage Expenses		
Operating expense		
Capital costs	Owner	

Table 2
Principal agent problems in shipping contracts.

	Principal selects technology	Principal cannot select technology
Principal pays energy bill (direct energy payment)	No principal agent problem. Case 1 Cargo owner operated ships	Efficiency problem. Case 2 Time chartered ships
Principal does not pay energy bill (indirect energy payment)	Usage and efficiency problem. Case 3 N.A	Usage problem. Case 4 Voyage chartered ships

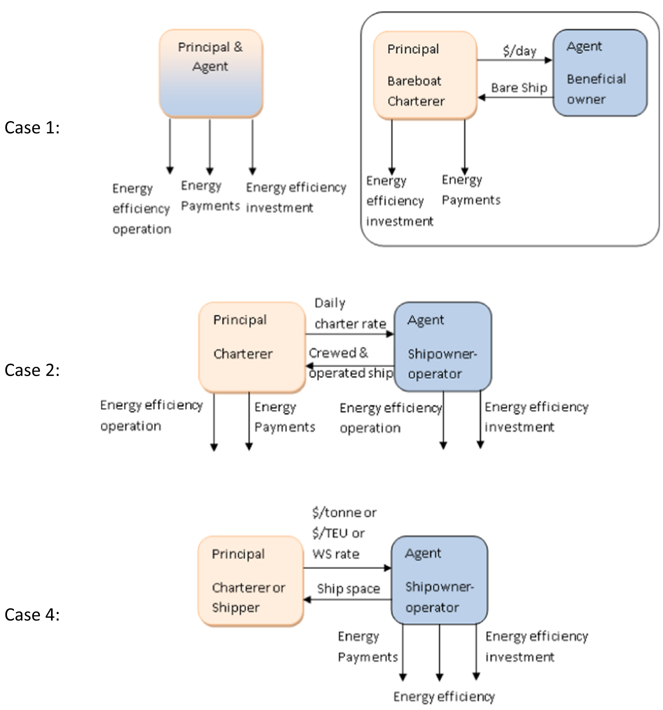

Fig. 5. Depiction of principal agent problems in shipping contracts.

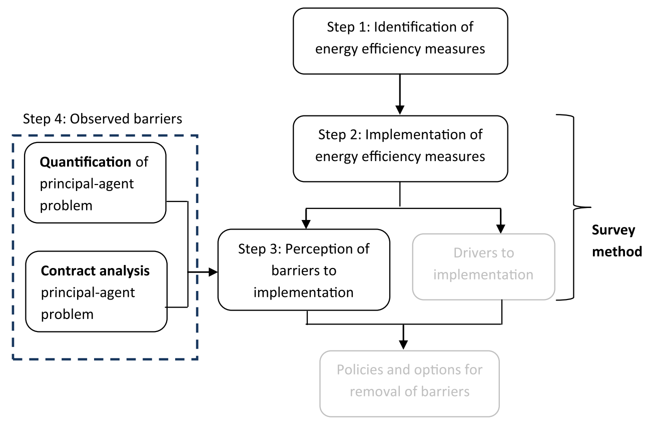

Fig. 6. Framework to investigate barriers to energy efficiency in shipping.

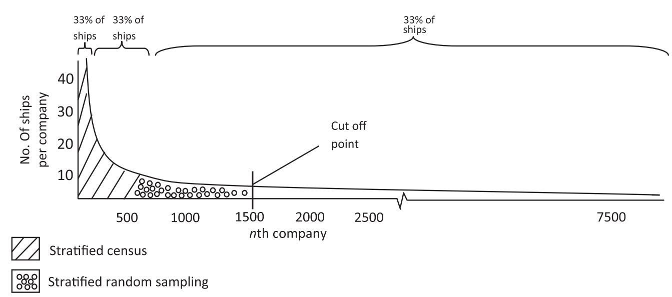

Fig. 7. Sampling method and sampling frame.

therefore be called non-market failures, which are defined as "where the organisation is behaving rationally given the risk adjusted rate of return on an investment in the existing context of energy, capital and unavoidable 'hidden' costs" (Sorrell et al., 2004, p33). These are real features of the decision making environment, albeit ones which are difficult to incorporate in engineering-economic modelling (Sorrell et al., 2000). A market failure on the other hand occurs when the requirements for efficient or optimal allocation of resources through well-functioning markets are violated, which leads to incomplete markets, imperfect competition, imperfect and asymmetric information, i.e. they result in a flaw in the way a market operates (Brown, 2001). The important distinction between market barriers and market failures is to do with the legitimacy of policy intervention to rectify market failures (Sorrell et al., 2004; Thollander and Palm, 2013).

According to Weber (1997) barriers are intangible and it is "empirically impossible" (Weber, 1997, p. 834) to find the true reason for lack of action and Blumstein et al. (1980) suggests that the causes of barriers are often interlinked and follow a causal chain. Nonetheless, Sorrell et al. (2000 and 2004) provide a useful framework for investigating barriers to energy efficiency by categorising them as shown in Fig. 4, although other ways of categorising barriers have also been presented (UNEP, 2006; Shi et al., 2008; etc.). For a full description of these barriers refer to Sorrel et al. (2004) and Thollander and Palm (2013) and in context of shipping refer to Rehmatulla and Smith (2012).

It has been noted that barriers to energy efficiency differ depending on industry sector and region (Rohdin et al., 2007), which

Table 3
Population divided according to major geographic regions for large and medium firms*.

	EU	West	Asia SC	Far East	Total
Wetbulk Large	9 (2%)	6 (1%)	2 (0%)	10 (2%)	27 (5%)
Wetbulk Medium	88 (15%)	6 (1%)	14 (2%)	33 (6%)	141 (24%)
Drybulk Large	4 (1%)	3 (1%)	1 (0%)	10 (2%)	18 (3%)
Drybulk Medium	75 (13%)	11 (2%)	6 (1%)	49 (8%)	141 (24%)
Container Large	13 (2%)	0 (0%)	0 (0%)	11 (2%)	24 (4%)
Container Medium	37 (6%)	4 (1%)	2 (0%)	14 (2%)	57 (10%)
Mixed Large	23 (4%)	1 (0%)	4 (1%)	21 (4%)	49 (8%)
Mixed Medium	80 (13%)	1 (0%)	8 (1%)	54 (9%)	143 (24%)
	329 (55%)	32 (5%)	37 (6%)	202 (34%)	600 (100%)

* Companies were only included in the sampling frame if they belonged to one or more of the sectors of interest i.e. companies that actively traded in the wetbulk, drybulk and container sector. Actively traded in sector is defined when more than 90% of the company's fleet is engaged in the any one of the sectors. Companies actively engaged in all the above sectors were categorised as operating in mixed sectors.

implies the need for research on barriers to energy efficiency that is both industry and region specific. From the foregoing review, it can be seen that previous empirical studies mainly focussed at firms in non-transport sectors (specifically industrial) e.g. Velthuijsen (1993), Sardinaou (2008), Sorrell et al. (2000), thus have ignored the transportation and shipping sectors and that they predominantly focussed on the perception of industry stakeholders. There is very scarce literature, mainly in the form of industry reports that look at the subject of barriers to energy efficiency in shipping e.g. Faber et al. (2011), Maddox Consulting (2012) and most of these do not base their analysis on any established barriers framework or theories as well as being methodologically weak in their methods e.g. sampling (Rehmatulla, 2014). Having recognised this gap, this paper attempts to empirically investigate the energy efficiency gap in shipping with particular focus on the principal agent problem that could be affecting implementation of cost-effective measures in shipping.

2. Method

2.1. Characterising principal agent problems in shipping

Within the context of barriers to energy efficiency, agency theory has been utilised to explain some of the market failures, such as the split incentives and asymmetric information (Levinson and Neimann, 2003; Murtishaw and Sathaye, 2006; Prindle et al., 2006; IEA, 2007; Graus and Worrel, 2008; Vernon and Meier, 2012). The theory aims to create the most efficient contracts for the ubiquitous agency relationship, in which one party (the principal) delegates work to another (the agent), who performs that work (Ross, 1973; Eisenhardt, 1989) or when one individual depends on the action of another (Pratt and Zeckhauser, 1985) and delegates some decision making authority (Jensen and Meckling, 1976). From the perspective of the key stakeholders involved in shipping, the shipowner and the charterer can be seen as being involved in an agency relationship, where the principal i.e. the charterer hires the shipowner as an agent to provide service of carrying goods from A to B, this classification follows Murtishaw and Sathaye (2006), IEA (2007), Vernon and Meier (2012) and Veenstra and Dalen (2011). The theory aims to resolve two agency problems that occur as a result of this relationship:

- Problem 1: The desires or the goals of the principal and agent conflict (split incentives problem)
- Problem 2: It is difficult or expensive to verify agent's actions (informational problem)

To date, the principal agent problem (i.e. split incentives component of the agency theory in context of energy efficiency) has been investigated generally through applying a set methodology (Prindle et al., 2006; IEA, 2007; Vernon and Meier, 2012) to estimate the effect of principal agent problem on energy efficiency. The first step is to identify situations where principal agent problem may occur. In shipping there are two basic forms of contracts (charterparties) for carriage of goods with which the shipowner-

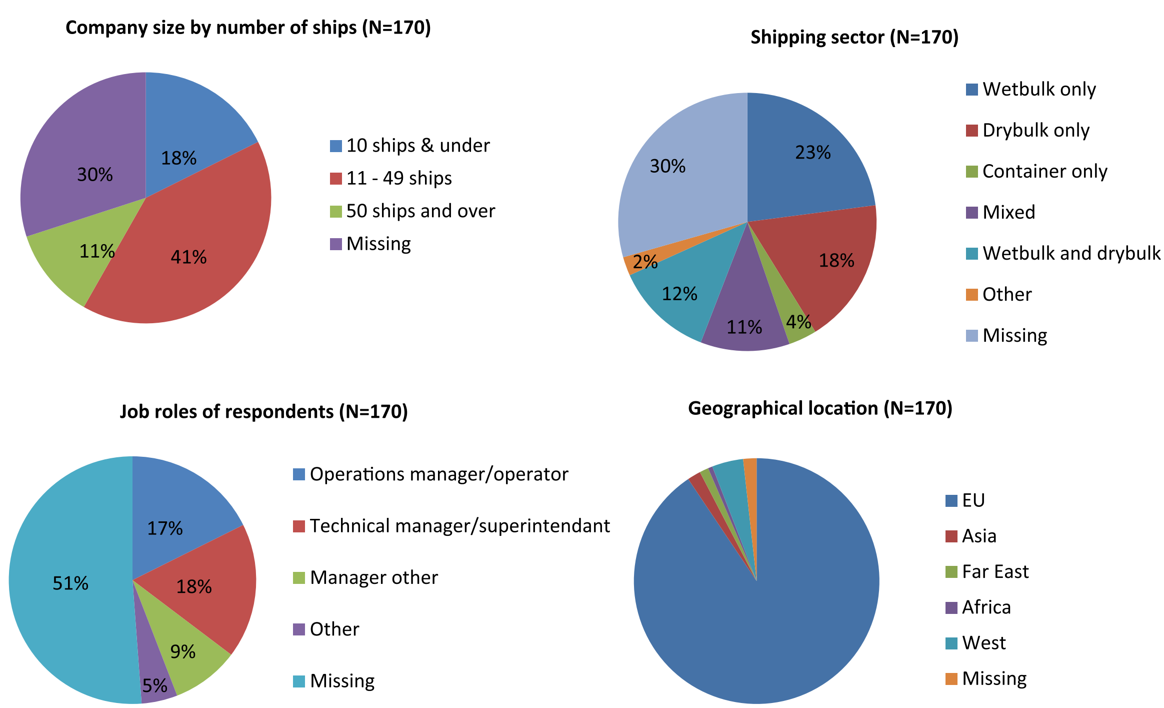

Fig. 8. Survey respondent demographics.

Table 4
Required sample sizes and actual responses achieved*.

Sector	Size	Population	± 15% error (90% CL)	± 20% error (90% CL)	± 15% error (95% CL)	± 20% error (95% CL)	Actual results achieved
Wetbulk	Large	27	15	11	17	13	9
	Medium	141	25	16	33	21	17
Drybulk	Large	18	12	9	13	11	3
	Medium	141	25	16	33	21	17
Container	Large	24	14	11	16	13	1
	Medium	57	20	14	25	18	4
Mixed	Large	49	19	13	24	17	6
	Medium	143	25	16	34	21	27
All	Small	≈ 1000	30	17	41	24	20

* The actual results may be higher than what is shown for each stratum because not all respondents completed demographic questions and due to partial responses.

Table 5
Grouping the chartering ratio and survey respondents.

Group	Description	Survey indicator	*N*
1 – Case 4	Majority of the fleet is owned and majority of the fleet is chartered out on voyage charter.	> 50% owned and > 50% chartered out on voyage	21
2 – Case 2	Majority of the fleet is owned and majority of the fleet is chartered out on time charter.	> 50% owned and > 50% chartered out on time	21
3 – Case 4	Management company with majority of its managed fleet out on voyage charter.	> 50% chartered out on voyage	9
4 – Case 2	Management company with majority of its managed fleet out on time charter.	> 50% chartered out on time	20

Table 6
Regrouping into two groups.

Group	Description	Grouping rule	*N*
1 – Case 4	Majority of the fleet is chartered out on voyage charter.	> 50% chartered out on voyage	30
2 – Case 2	Majority of the fleet is chartered out on time charter.	> 50% chartered out on time	41

operators and charterers contract, namely the voyage charter and time charter. There are other types of contracts but these are not contracts for carriage of goods, for example the bareboat charter is a lease of the vessel to the charterer. Other hybrid forms of charters also exist but these can be reclassified as either voyage or time charter due to the similarities in the cost allocation, examples of these are trip charters which fall into time charter category despite the contract being for a single voyage and Contracts of Affreightment (COA) which fall into the voyage charter category despite the time element (Wilson, 2010; Stopford, 2008). The voyage and time charters allocate or divide the responsibility for capital and running costs (including fuel costs) between a shipowner-operator and charterer as shown in Table 1. The result of this divided responsibility for costs is that both parties could have diverging or conflicting interests to minimise their share of costs at different points in time (e.g. design, operation, sale etc.) Table 2 and Fig. 5 identify where principal agent problems may exist in shipping.

The above suggests that the specific structure of the shipping markets could be susceptible to market barriers and failures, but to date there has been little work to quantify the consequence of any failures and to test rigorously for their existence. In this paper, the focus is mainly on Case 2 (as shown in Table 2 and Fig. 5), which represents the principal agent efficiency problem that occurs in time chartered ships. In the time charter, the shipowner-operator (classed as an agent providing the service), determines the level of technological energy efficiency, while the time charterer (classed as a principal demanding the service) bears the costs associated with that level of energy efficiency (Agnolucci et al., 2014). The extent of this problem is therefore directly related to how well the charter rate reflects the ships energy efficiency, in other words, to what extent are shipowner-operators rewarded (for an energy efficient ship) through higher time charter rates, as a result of cost savings made by the time charterer. Agnolucci et al. (2014) explore this for the drybulk panamax ships and find that 40% of the fuel savings are recouped by the shipowner-operators through higher charter rates for the period 2008–2012. This has important implications for effectiveness of policies being considered at global and regional levels.

2.2. Framework for methodological for triangulation

From the foregoing review, one can conclude that it is important not only to measure the perception of barriers to energy efficiency, but to also seek other means of corroborating the perceptions i.e. validating them in order to investigate the multi-faceted nature of barriers to energy efficiency. This paper attempts this by investigating perceptions and observations of barriers to energy efficiency, using the mixed methods (Greene et al., 1989; Tashakkori and Teddlie, 2003) approach to triangulate (Denzin, 1970) the research findings, as shown in Fig. 6. In doing so, the research questions that the work informing this paper aims to consider include;

1. What are indications from the industry on the implementation of different energy efficiency measures?
2. What are the industry's perceptions of barriers to energy efficiency?
3. What barriers can be observed in shipping contracts and from actual energy efficiency data?
4. What can the combination of methods tell us about shipping's energy efficiency gap?

In answering these research questions, it is beyond the scope of this paper to discuss all of the aforementioned barriers to energy efficiency for shipping in sufficient detail. For a discussion of the above mentioned barriers in context of shipping refer to Rehmatulla and Smith (2012), Rehmatulla (2012), Rehmatulla et al. (2013), Faber et al. (2011) and Maddox Consulting (2012). This

Table 7
Categorising response choice to specific barriers to energy efficiency.

Survey response choices	Barrier	Type
a) Savings cannot be fully recouped b) Lack of direct control over operations c) Difficult to implement under some types of charter d) (Divided responsibility for fuel costs)	Split incentives	Market failures
a) Lack of reliable information on cost and savings b) (Lack of information sharing on savings among parties)	Informational problems	
a) Uncertain/long payback b) Immature technology c) Sailing off design conditions	Risk	Market barriers (non-market failures)
a) Lack of access to capital	Capital	
a) Additional costs e.g. transactional b) Opportunity costs	Hidden costs	Modelling artefacts
a) Unsuitable to trade/route of operation b) Incompatible with other measures	Heterogeneity	
a) Not allowed due to charterparty clauses b) Standard charterparty clauses c) Inadequate port infrastructure	General/other specific to shipping	

Table 8
Charterparties analysed.

Sector	*Voyage charterparties*	*Time charterparties*
Wetbulk	BIMCHEMVOY INTERTANKVOY ASBATANKVOY BEEPEEVOY 4 SHELLVOY 6	INTERTANKTIME BIMCHEMTIME BPTIME 3 SHELLTIME
Drybulk	COALOREVOY OREVOY NIPPONORE POLCOLVOY SYNACOMEX BHPBVOY03 NIPPONCOAL NUBALTWOOD RIO DOCE ORE AMWELSH GRAINCON	BHPBTIME03 BALTIME GENTIME NYPE 46 NYPE 93 ASBATIME BOXTIME
General	GENCON *SCANCON* *NUVOY*	

paper focuses on the principal agent problem as explained in Section 2.1.

2.3. Survey description

A thorough evaluation of the research strategies, research designs, research methods and research modes was conducted to find the best approach to investigating barriers to energy efficiency and answering the research questions aforementioned (Rehmatulla, 2014). In conclusion an online survey following the tailored design method (TDM) (Dillman, 2007) was administered to assess the actual uptake of energy efficient operational interventions that were perceived to be cost-effective for shipping and to obtain views on barriers to their implementation. The survey attempted to measure three different types of variables (de Vaus, 1995):

- Measures of the dependent variable (what the research is trying to explain), in this case implementation of measures and perception of barriers to energy efficiency.
- Measures of the independent variable (causal variables), in this case chartering ratio or group.
- Measures of test variables (clarifying the link between independent and dependent variable similar to the background measures such as age, sex, religion, etc.), in this case sector of operation, company type and company size.

The online survey makes use of a list based sampling method, similar method to traditional sampling (Fricker, 2008) and the initial list for the sampling frame was derived from the Clarksons Shipping Information Network (SIN). There are many other sampling frames (or online databases) that represent to a good degree the population of interest, such as the IHS Fairplay Sea-web, World Shipping Register and Infomarine. Clarksons SIN has the most up to date information and it is believed that this is the most comprehensive list of the target population. Upon comparison with other online databases such as World Shipping Register slight under-coverage of companies was noted, suggesting a non-coverage error/frame coverage bias, for which every effort was made to merge the frames to cover as accurately as possible the target population. Thus a completely new frame had to be constructed for the purposes of this research.

Fig. 7 shows that the census tracts approach was used to contact the large and medium sized companies and these were stratified according to the sector of operation and location (by headquarters) as shown in Table 3. For small sized firms a simplified random sample was used.

The sampling frame represented well the different variables (sector, size and region) which other similar studies in shipping have lacked, although over-representing respondents from the European region (Fig. 8). Further details on the design and implementation of the survey can be found in Rehmatulla (2014). In order to be representative and to make generalisations i.e. reach statistically significant results with a confidence level of 90% or 95% and margin of error interval of $\pm 15\%$ or $\pm 20\%$ each stratum required a certain number of responses as shown in Table 4. The total number of respondents was 170, which consisted of 120 almost complete (90% item response) responses and 50 partially completed responses.

Other than ensuring the correct sampling methods and strategies (in order to reduce sampling error), the survey also uses different techniques to improve response rates and reduce non-sampling errors (coverage, measurement, non-response error) (Groves et al., 2004);

- Use of Tailored Design Method (Dillman, 2007) – personalisation, pre-notification, deadlines, reminders, mixed mode follow ups.
- Design of questionnaire – visual appearance, content, type of questions, and length of survey (determined through pilot research and pre-testing and well evaluated web survey software as well as guidelines from Dillman (2007)).
- Use of incentives – non monetary, survey results report.

The principal agent problem in other sectors (e.g. buildings residential and commercial) has been represented by assessing the proportion of properties that are owner-occupied and those that

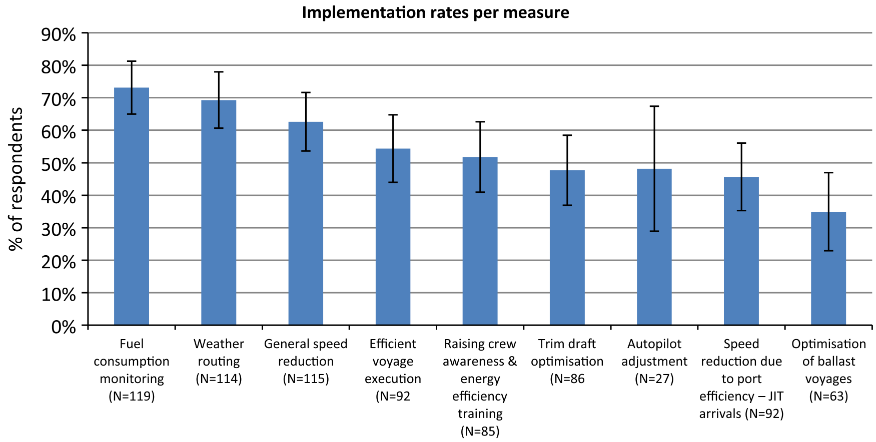

Fig. 9. Average implementation rate of cost-effective operational measures.

are rented (Murtishaw and Sathaye, 2006; IEA, 2007). The principal agent problem in shipping could be represented using the chartering ratio or chartering level of a shipping company as shown in Table 5 and this was used as an indicator of principal agent problem in the survey. This indicator can also be regrouped in to two chartering groups, one representing respondents with majority of their fleet chartered out voyage (i.e. combining group one and three) and another group representing respondents with majority of the fleet chartered out time (i.e. combining group two and four) (Table 6). These groups can be said to be reflecting the cases presented in Table 2 and Fig. 5.

Most studies (e.g. Murtishaw and Sathaye, 2006; IEA, 2007; Vernon and Meier, 2012; Bird and Hernandez, 2012; Pelenur and Cruickshank, 2012) focus on technical energy efficiency and show that the principal agent efficiency problem exists, since the technical efficiency levels of different principal agent cases differ significantly. However, to date only a handful of studies have empirically investigated how implementation of operational measures is affected by the principal agent problem (Levinson and Neimann, 2003; Young and Maruejols, 2010; Gillingham et al., 2011; Maruejols and Young, 2011). Maruejols and Young (2011) suggest that split incentives impact some aspects of occupant behaviour, such as households that do not pay directly for their energy opting for increased thermal comfort and being less sensitive to whether or not somebody is at home and the severity of the climate when deciding on temperature settings, thus being operationally inefficient compared to households that pay for their energy. Most of the studies for example hypothesise that households on rental market (with no energy included) will have lower implementation of technical measures, and this has been confirmed by several studies (e.g. Graus and Worrel, 2008; IEA, 2007; Berchling and Smith, 1994; Bird and Hernandez, 2012; Pelenur and Cruickshank, 2012). It is important to extend this original hypothesis to investigate that the same rental households (with no energy included rents) may have better operational efficiency, based on the principal agent incentives. Conversely, households on rental markets (with energy included in rents) will have higher implementation of technical measures but may suffer from lower implementation of operational measures. The key here is the end user's or tenant's (principal's) incentives to conserve energy. Whilst operational efficiency in households or other sectors may not be as important, it certainly is in the case of shipping. Smith et al. (2013) show that there is a wide range of operational efficiencies for different ship types, suggesting a greater potential for energy efficiency or CO_2 reduction through these measures

The second purpose of the survey was to gauge the perception of barriers to operational energy efficiency measures. This was measured in two ways; the first method is brief and uses general barriers classification in a single grid for the measures that were believed not to have a high fuel saving potential. The second method is through asking respondents tailored follow-up questions on the measures they had selected had high potential but had not yet implemented (e.g. Trialling, plan to implement, etc.). The response choices that were presented to the respondents were then grouped according to the barriers categories they fall into (Table 7). This approach of providing more specific choices and then recoding them as general barriers is adapted from previous research by Sorrell et al. (2000) and Thollander and Ottosson (2008).

2.4. Charterparty content analysis

Qualitative content analysis of charterparties is used as a method to observe the level of principal agent problem in shipping. The use of qualitative inductive content analysis is recommended when there are no previous studies dealing with the phenomenon or when knowledge is fragmented (Elo and Kyngas, 2008). In order to limit the research to a manageable body of texts and to collect data by means of sampling that minimises bias, a relevance sampling strategy is used. This sampling method is typical of qualitative research as it helps to enhance the understanding of the information-rich case (Sandelowski, 2000; Patton, 1990; Bryman, 2008). In order to identify the most important standard form charterparties an email was sent to twenty survey respondents who were selected based on the primary sector of their company. The survey contained a detailed list of standard form charterparties for each sector and the respondents were asked to select and comment on the most commonly used charterparties. This brief investigation confirmed that there are about fifteen to twenty most often used standard form voyage and time charterparties. The standard form charterparties are usually modified in two ways, by use of rider clauses agreed between the parties and generally be appended to the standard clauses and amending the actual clauses. The result of these modifications is that sometimes the final agreement bears little resemblance to the original standard form (Wilson, 2010). Acknowledging this possibility, the focus of this analysis is nonetheless focussed on the standard form charterparties for ease of comparison. Based on this brief research, literature on most often used charterparties from UNCTAD (1990) and from Baltic and International Maritime Council's (BIMCO) charterparty editor (IDEA), the most relevant charterparties to analyse were selected and are presented in Table 8.

Table 9
Perception of barriers for measures not implemented.

	Weather routing	Autopilot adjustment	General speed reduction	Fuel consumption monitoring	Trim/draft optimisation	Speed reduction JIT arrivals	Raising crew awareness and training	Efficient voyage execution	Optimisation of ballast voyages
Lack of reliable information on cost and savings	24%	27%	6%	15%	26%	7%	22%	16%	15%
Savings cannot be fully recouped from the investment	4%	12%	9%	11%	7%	5%	13%	6%	8%
Difficult to implement under some types of charter	16%	7%	29%	5%	21%	26%	6%	24%	24%
Lack of access to capital	4%	6%	2%	4%	3%	4%	4%	1%	5%
Additional costs e.g. transactional, contractual	9%	8%	10%	13%	7%	6%	7%	4%	7%
Uncertain/long payback	11%	14%	3%	22%	12%	6%	20%	5%	8%
Not allowed due to charterparty clauses	5%	4%	28%	4%	4%	26%	3%	17%	15%
Lack of direct control over operations	17%	13%	10%	15%	10%	17%	13%	20%	15%
Other (Please specify)	9%	9%	2%	13%	8%	2%	13%	8%	3%
Total responses	75	197	87	55	121	121	112	107	164

2.5. *Fixtures analysis*

Step four of the framework also attempts to observe the level of the principal agent problem in shipping and compare this with results from the survey and contract content analysis. Murtishaw and Sathaye (2006), Prindle et al. (2006) and IEA (2007) suggest estimating the population of end users that are affected by the principal agent problem followed by the estimation of the energy consumption affected by the principal agent problem. A separate study by Smith et al. (2013) assessed the technical and operational efficiency of ships using satellite automatic identification system (S-AIS). In order to investigate whether energy consumption varies by the principal agent cases, data on technical and operational efficiency is split in the two main forms of charter using additional fixtures data from Clarksons Shipping Information Network (SIN). Data is filtered for ships that occur only in one type of fixture for the period of analysis (2011), thus removes subletting of ships and ships interchanging from one type of charter to another. The filtering results in a very small count of ships on time charter and therefore statistical significance could not be achieved in this analysis.

3. Results

3.1. *Survey results*

Fig. 9 shows to what extent the highest fuel saving potential measures selected by the respondents have been implemented. This approach of gauging implementation is similar to other empirical studies (Velthuijsen, 1993; Gillisen and Opschoor, 1994; Harris et al., 2000; Sorrel et al., 2004). The implementation in the survey was originally based on five choices; 'considering or trialling', 'considered and decided against', 'plan to implement', 'already implemented' and 'did not consider'. These have been later recoded as implemented (already implemented) and not implemented (which includes the remainder categories) as this allows for crosstabulation and elaboration analysis for relationships between size, sector and chartering group. From Fig. 9 it can be seen that even the top three cost-effective operational measures that were deemed to be of highest potential have actual implementation rate of around 60–70% ($\pm$9% for 95% confidence level). The average implementation across all the measures drops to around 50%, ranging from 35% to 70%.

Analysis of the responses to the perception questions shows that there are specific barriers pertaining to each of the measures, as shown in Table 9. Lack of reliable information on cost and savings are mainly related to the more technical operational measures such as weather routing, autopilot adjustment, trim/draft optimisation although these have been shown to be mature technologies (Maddox Consulting, 2012) for which information is readily and reliably available (Lockley et al., 2011). On the other hand, for measures mainly related to speed (general speed reduction and Just In Time arrivals) or those that had an element of speed (efficient voyage execution and optimisation of ballast voyages) the respondents mainly cited that these were difficult to implement under different types of charter and that charterparties did not allow for implementation, which are indicators of split incentives component of the principal agent problem.

Under the time charter, the charterer who has operational control of the ship is mainly responsible for the speed of the ships and under voyage charter where the shipowner has operational control of the ship the speed is set through use of charterparty. Therefore, in general only in the ballast leg is a shipowner operator allowed to decide the speed of the vessel. The speed at which a ship travels varies according to many factors such as the sector it

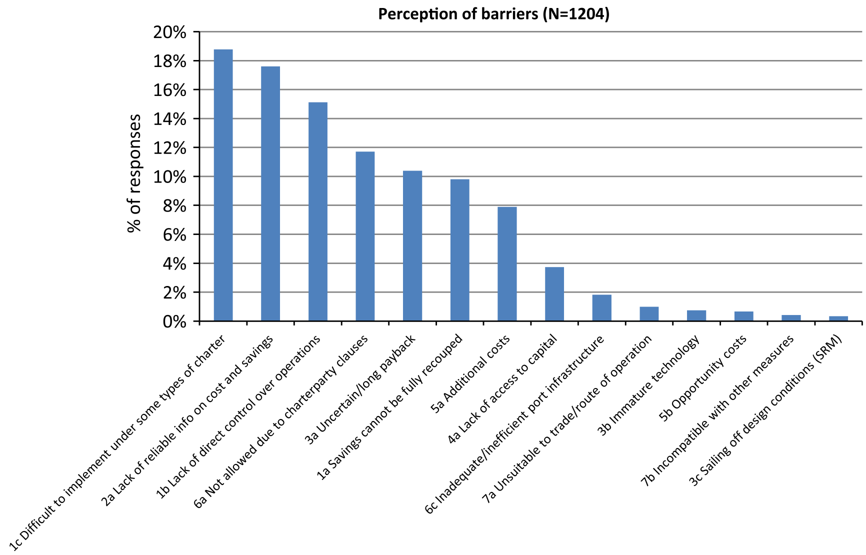

Fig. 10. Perception of barriers to energy efficiency.

operates in, the publisher of charterparties, the power of agents involved etc., which will be further investigated in through content analysis of charterparties. As shown in Fig. 10, the respondents perceived the split incentives barrier as the most important barrier to implementation of operational energy efficiency measures. These combined with informational problems as market failures outweighed the non-market failures (market barriers) such as risk, costs etc. This finding goes further than those of Faber et al. (2011) and Maddox Consulting (2012) that suggest that all types of barriers including split incentives affect the uptake of cost-effective measures.

3.2. Content analysis of contracts

From the modelling, survey results and literature, the speed reduction measure is considered as the most important measure that could affect the energy efficiency of ships. Following Creswell (2009) sequential explanatory design, the charterparty content analysis therefore focussed on the identification of barriers to speed reduction. A detailed content analysis of the voyage and time standard form charterparties highlighted interesting corroborative findings to the survey results e.g. respondents citing standard charterparty clauses as the most important barrier to speed reduction. Close reading of the charterparties revealed that there were different express obligations of utmost despatch (the obligation to proceed at full speed once the cargo is loaded) which are consequently coded into four categories under the goal conflict proposition of the agency theory (Eisenhardt, 1989) as shown in Table 10. Table 11 summarises the results of the charterparty content analysis of nineteen voyage charterparties. The results suggest that the focus of the contracts is around resolving the goal conflict problem within the agency relationship and this consequently affects the implementation of cost-effective measures specifically the speed reduction measure.

3.3. Fixtures analysis

Fig. 11 shows the technical efficiency, speed reduction implementation (design vs. operational ratio) and the operational efficiency comparisons for the wetbulk and drybulk sector and how the observations differ for the two principal agent cases; case two being the time charter and case four being the voyage charter. These parameters are an attempt to reflect the real or practical differences between the principal agent cases.

4. Discussion

The average implementation rate obtained across all the operational measures (50%) is slightly lower compared to that obtained by Faber et al. (2011) survey of five shipowners, who report implementation for operational measures of around 60%. Similarly, Maddox Consulting (2012) based on expert judgement report implementation of six operational measures to be around 65%. The answers to this question clearly show that despite the easiness of implementation and short payback of most cost-effective operational measures (Wang et al., 2009; Lockley et al., 2011) some measures still do not see high implementation rates. The average implementation rate is to some extent comparable to that observed in non-shipping sectors. Harris et al. (2000) show an implementation rate of energy efficient measures implemented by industrial firms to be around 80% (based on an audit recommendation of six measures, selected out of a thirteen specific measures, therefore suggesting a net implementation around 45%). For households or residential sectors Kema-Xenergy et al. (2004) show an implementation rate for energy efficient appliances to be around 50% and IEA (2007) shows an implementation rate for space heating measures of around 50%. Thollander and Palm (2013) cite three government initiatives (based on energy audits and recommendations that aimed to promote implementation of energy efficiency in organisations) had implementation rates between 40% and 80%. Therefore, the implementation rate of operational measures for shipping can be said in the same range as the aforementioned sectors, where the energy efficiency gap has been established. The aforementioned sources also confirmed the implementation of energy efficiency measures differed significantly between owned (owner-occupied) and rented properties, confirming the efficiency principal agent problem i.e. case two. The extent to which the implementation of cost-effective measures in shipping differs according to the principal agent cases is shown in Fig. 12.

Fig. 13 shows the zero order relationships (uncontrolled) between the implementation of the top three operational measures and chartering group (denoting the two principal agent cases under investigation). It can be seen that there exists to some extent a relationship between the chartering group and three operational measures. For example, for the speed reduction measure, it can be seen that group one and three (fleet mainly chartered out voyage) had lower implementation compared group two and four

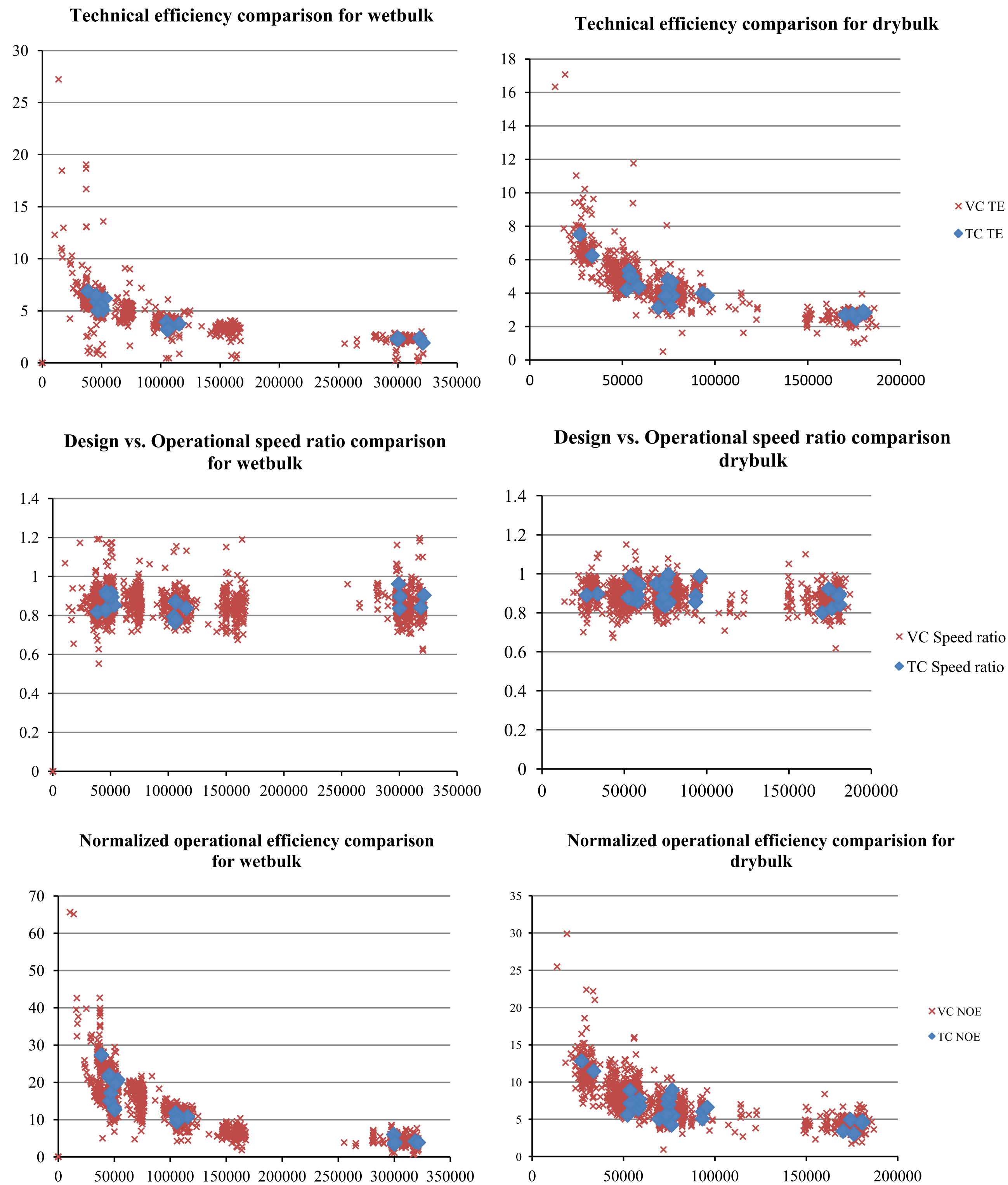

Fig. 11. Comparing efficiency parameters for voyage (case 4) and time charters (case 2).

(fleet mainly chartered out on time). The same could be said for weather routing measure and to some extent for fuel consumption monitoring measure. This suggests that operational measures may not be susceptible to the principal agent problem and this is because the charterer has operational control as well as the incentive to save fuel which is under their account, switching the time charter (from case two) to case one of Table 2 for operational measures. Controlling the above relationships for sector strengthens the relationship further and statistically significantly for the drybulk sector for the three measures.

The different categories of goal conflict discussed in Table 10 belonged to specific sectors, for example the lack of express mention of reasonable despatch was only found in general form charterparties (used for trades for which no specifically approved form is in force) e.g. Gencon makes no mention utmost despatch for the loading or discharging leg. The difference between the bulk

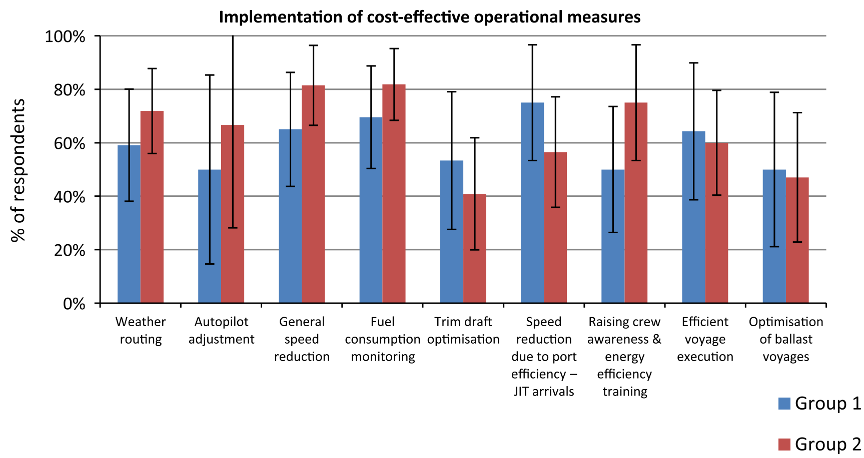

Fig. 12. Implementation of cost-effective operational measures by chartering group or cases.

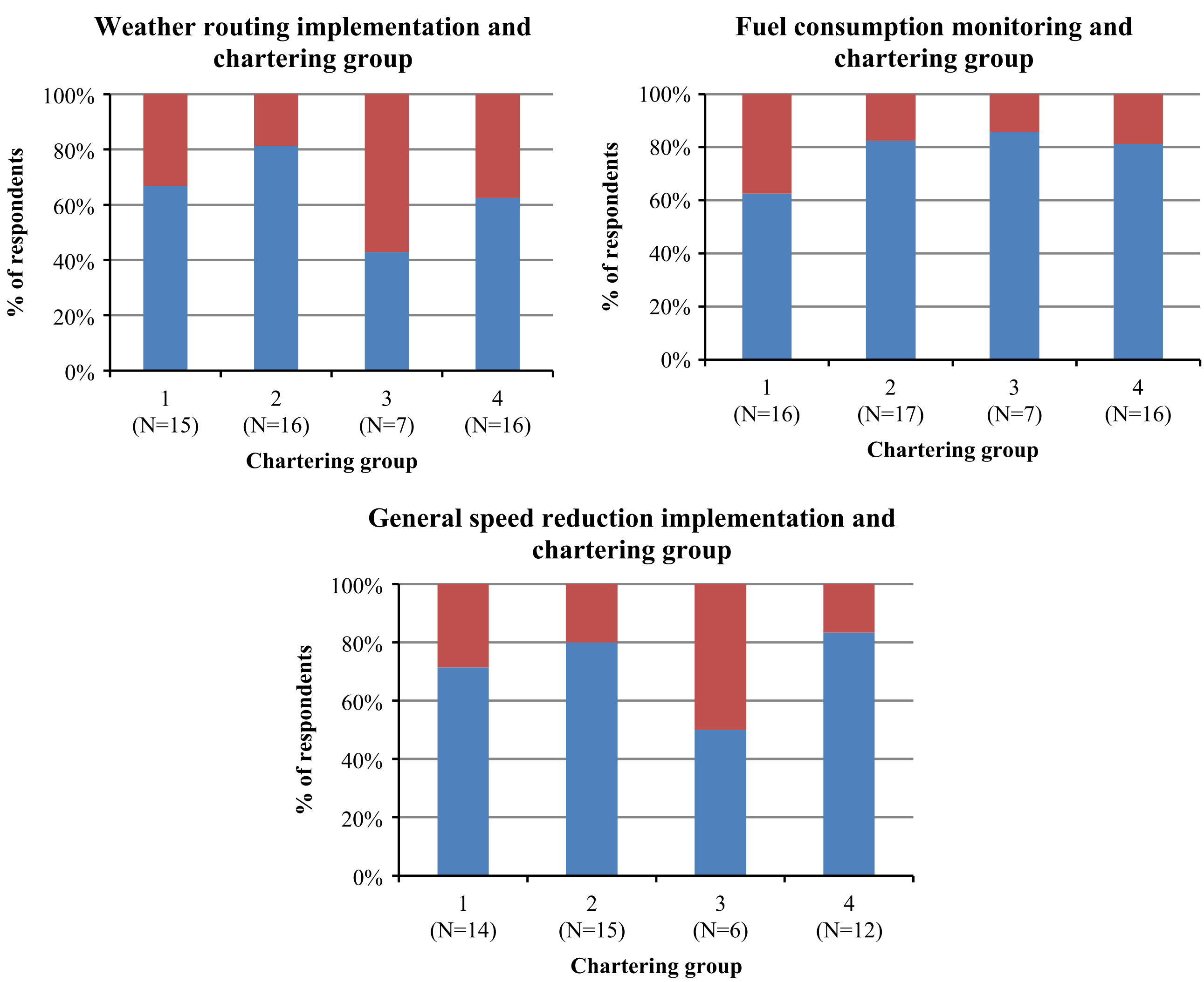

Fig. 13. Implementation of operational measures by chartering group.

and container sector can be explained by the use of bill of ladings, where liner bill of ladings e.g. Conlinebill, permit the owner/operator to slow steam. These results are consistent with the survey findings, which reflect the perception of respondents in those sectors, where almost 80% of drybulk and wetbulk sector perceived standard utmost dispatch clauses as a significant barrier to speed reduction compared to around 60% of respondents in the container sector. One of the ways operational energy efficiency has been realised is through revisiting the utmost despatch clause, for example the'Virtual Arrival' clause (OCIMF and INTERTANKO, 2010) which allows a vessel's speed to be reduced in order to meet a revised arrival time (e.g. due to lack of cargo storage at port), thus enabling the vessel to arrive at a port at the right time (Just in Time – JIT). Virtual arrival therefore shifts the port waiting time

Table 10
Charterparty clauses affecting implementation of speed reduction in voyage charters

Coding category and questions	Definition	Example	Coding rule
Goal conflict	Conflicting interests between the charterer (principal) and shipowner (agent), which means use of:-Utmost despatch clauses in both voyage legs	"The said vessel being suitable for mechanical loading and grab discharge, shall with all convenient speed sail and proceed to the loading port. ...Being so loaded the vessel shall therewith proceed with all convenient speed to the discharging ports"	VSG1 = utmost despatch in ballast leg (load port) AND laden leg (discharge port)
Q: How does the outcome based contract address the principal agent speed goal conflict?	Conflicting interests between the charterer (principal) and shipowner (agent), which means use of:-Utmost despatch clauses only in laden leg	"The vessel shall proceed with due despatch to a safe port, berth, dock.... For loading the cargo, as ordered by charterers... And being so loaded proceed as ordered on signing of Bill of Lading ... As ordered by charterers"	VSG2 = utmost despatch in only laden leg
Q: How does the goal conflict affect speed reduction measure implementation?	Conflicting interests between the charterer (principal) and shipowner (agent), but no use of utmost despatch clauses.	"The said vessel shall proceed to the loading port....and being so loaded the vessel shall proceed to the discharging ports..."	VSG3 = No utmost despatch clause
	Conflicting interests between the charterer (principal) and shipowner (agent), which means use of: -Slow steaming clause	"…However, unless 'no' is inserted in box 17 Part A, the owners may order the vessel to proceed at reduced speed solely to conserve fuel"	VSG4 = Slow steaming clause is present

Table 11
Coding categories for the goal conflict arising in speed reduction measure.

Voyage charterparty	Utmost despatch to load port	Utmost despatch to discharge ports	ETA/ERL	Specific NOR times	Specific NOR place
BIMCHEMVOY	✓	✓ through B/L	✓	✗	✗
INTERTANKVOY	✓	✓ through B/L	✓	✗	✗
ASBATANKVOY	✓	✓ through B/L	✓	✗	✗
BEEPEEVOY 4	Stated speed	Stated speed	✓	✗	✗
SHELLVOY 6	✓ + stated speed	Stated speed	✓	✗	✗
COALOREVOY	✗	✓	✓	✗	✓
OREVOY	✗	✓ or reduced speed	✓	✗	✓
NIPPONORE	✓	✓	✓	User	✓
POLCOLVOY	✗	✓	✓	✓	✗
SYNACOMEX	✓	✓	✓	✓	✓
BHPBVOY03	✓	✓	✓	User	✓
NIPPONCOAL	✓	✓	✓	User	✓
NUBALTWOOD	✓	✓ through B/L	✓	✓	✗
RIO DOCE ORE	✓	✓	✓		
AMWELSH	✓	✓	✓	✓	✓
GRAINCON	✓	✓	✓	✓	✓
GENCON	✗	✗	✓	✓	✓
SCANCON	✗	✗	✓	✓	✓
NUVOY	✗	✓ or reduced speed	✓	User	User

into extra sailing time, resulting in fuel cost savings from speed reduction, generally shared 50-50 between the shipowner and charterer, without affecting demurrage income that would have been gained had laytime been exceeded (Laytime refers to the loading/discharging window and when this is exceeded the shipowner is entitled to liquidated damages called demurrage). This clause is also in the process of being drafted into commonly used industry charterparties by BIMCO. Table 11 shows that there is clear difference in the voyage charterparties of the different sectors for other clauses that could be affecting implementation of speed reduction measures, such as place of tendering, Notice of Readiness (NOR) and timing of NOR (i.e. when a ship is ready load or discharge). Wetbulk charterparties generally were found to be port charters whereas most drybulk charterparties were observed to be berth charterparties. Similarly, for NOR times, there were clear sectoral differences in the charterparties. Wetbulk charterparties had no specific times in which NOR has to be tendered whereas in contrast majority of the drybulk and general charterparties had specific times in which shipowners had to tender NOR. Therefore, the utmost dispatch clauses, place of NOR and timing of NOR affect the implementation of speed reduction measure in the voyage charter.

The survey results showed that operational measures had higher implementation in case two i.e. in time charters compared to case four i.e. voyage charters. The finding for the observed level of energy efficiency (both technical and operational) from analysis of fixtures for the year 2011 shows that there is not a significant difference between the operational efficiency of ships on the different types of charter. Comparing means using independent sample *t*-tests (95% confidence level, two tailed tests) for each ship type also suggested that the null hypothesis (no difference in means) could not be rejected for the average operational efficiency and ratio of operational speed to design speed. Because of the low number of cases (in the time charter) the results cannot be corroborated with the survey findings on the level of implementation of operational measures by the different chartering groups. This problem is also acknowledged in literature (e.g. IEA, 2007) that finding the real energy efficiency or energy consumption for different cases in principal agent matrix is rarely straightforward.

5. Conclusions and policy implications

The survey results showed that the implementation rate of the top three energy efficiency measures do not correspond to their high energy saving potential and cost-effectiveness. The implementation rate of these measures is similar to the aforementioned shipping industry studies that have investigated the barriers to energy efficiency and that of other sectors, showing implementation rate range of around 50–75%. Case two of the principal agent matrix (Table 2) i.e. the efficiency problem, proposes that the technical efficiency of the ship will be lower due to shipowner being responsible for capital costs and time charterer responsible for voyage (including fuel costs), unless the shipowner-operator can recoup the investment in energy efficiency through higher charter rates for the savings in energy made by the charterer. For operational measures it was suggested that case two of the principal agent problem i.e. 'efficiency problem' would be lower because the time charterer has operational control as well as the incentive to save fuel which is under their account, thus switching the time charter (from case two) to case one of Table 2 for operational measures. This is reflected in the implementation of operational measures, which consistently showed that ships on time charter had higher implementation of operational measures. This seems to suggest that implementation of operational measures may not be affected by the principal agent problem to the same extent as technical measures. Perhaps the reason for this is that the principal i.e. the charterer would rather implement operational measures in a time charter, one of the reasons for this being energy efficiency information is difficult to observe (similar to credence goods) and to monetize during the contracting process.

The speed reduction measure is commonly suggested to have the highest fuel saving potential and under the current market conditions it would be envisaged that it would be implemented to the highest levels but the survey results show otherwise. On average it was implemented by around 65–70% of the respondents and breaking this down by chartering group shows that general speed reduction implementation is higher in ships under time charter than ships under voyage charter. Satellite AIS data also confirms this finding, as not all ships were operating at lower speeds compared to the design speed (Smith et al., 2013). Possible explanations to the lack of uptake can be obtained from the results of the modelling (Smith, 2012; Rehmatulla and Smith, 2012) and charterparty content analysis, which suggest that with reduction in EEDI, operating speed increases due to a lightening of the cost burden of 'speeding-up' of technologically more efficient ships, increased capital costs, and the use of speed for a competitive advantage.

The presence of these barriers creates complexity for policy makers. On the one hand, the presence of market failures implies that a market-based measure would not be a cost-effective means to drive change. This then incentivises the use of command and control regulation such as minimum energy efficiency requirements for a ship's technical specification (e.g. EEDI as defined in MARPOL Annex VI), or for a ship's operation (e.g. some type of speed limit or target for EEOI). As this work identifies significant market barriers, shipping is unlikely to respond efficiently to market stimuli such as a carbon price. However, there can also be problems with command and control measures, as it is possible to foresee scenarios where the outcome of their implementation could be perverse (for example mandatory technical efficiency standards being compensated through changes in operational efficiency).

The data (survey results, charterparty content analysis and fixtures analysis) that has been used to date to draw inferences is, believed to be some of the best available data. However, uncertainty remains and given the significance of the issues that are being addressed and the risk of creating unnecessary burden on the shipping industry with ineffective regulation, further work would appear to be required. The advent of an IMO (ideally) or EU Monitoring Reporting and Verification (MRV) regulation would go some way to improving the quality of the data available for assessing the system dynamics and barriers to energy efficiency in the shipping industry.

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