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ARTICLE

Barriers to energy efficiency in shipping

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Abstract The shipping industry shows potential for improvements in energy efficiency. Nonetheless, shipping companies appear reluctant to adopt these seemingly cost-efficient technical and operational measures aiming at reducing energy costs. Such phenomenon is not specific to the shipping industry and is commonly referred to as the *energy efficiency gap*. Decades of research in other sectors have contributed to the development of taxonomy of economic, organizational and psychological barriers that determine energy efficiency gaps through the use of a variety of research frameworks. This article aims to apply this research in the shipping context through interviews and review of existing literature and applications from other industries, with the objective of providing useful insight for shipping managers. The article discusses examples of barriers that are typical to shipping and that are related to information asymmetries and power structures within organizations. Managers of shipping firms are encouraged to look through their organizations in search of principal agent problems and power structures among the possible causes for energy efficiency gaps in their companies' operations and possibly strive towards organizational change.

Keywords Energy efficiency gap · Energy management · Energy policy · Shipping Economics

1 Introduction

The challenge of abating the climate impact of the shipping sector can partly be met through the adoption of technical and operational measures that increase energy efficiency[1]. The *Second IMO Report* demonstrated in 2009 that between 25

[1] Energy efficiency is defined in this paper as decreasing energy use (as opposed to energy cost) while maintaining (or increasing) the level of service provided. "Efficiency" is thus contrasted with "conservation", which implies only a reduction in energy use. In shipping specifically, energy efficiency is often defined as the ratio between energy and transportation work (e.g. the product of tones cargo and nautical miles).

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and 75 % of CO_2 emissions could be reduced almost exclusively due to energy efficiency measures (Buhaug et al. 2009), a statement which has later been verified by, for example, Eide et al. (2011). In other words, a large potential for energy efficiency improvement with significant economic impact is not realized. This paradoxical phenomenon has been observed across various sectors and is generally referred to as an *energy efficiency gap* (Jaffe and Stavins 1994).

Energy efficiency is increasingly becoming important, as global anthropogenic emissions of CO_2 need to be substantially reduced and as fossil fuels remain the primary source of energy in many industrial processes (IPCC 2007). Furthermore, rising energy prices are bound to increase pressure on companies' bottom lines, and energy efficiency is likely to remain on top of the agenda of many executives. As for the shipping sector, its contribution to total global CO_2 emissions is estimated at 3.3 %, and as the world economy becomes larger, emissions are expected to grow further (Buhaug et al. 2009). It has even been shown that the implementation of all available cost-efficient technologies aiming at reducing fuel consumption or at curbing emissions will not be sufficient in the case of shipping to counteract the effects of the growth of the sector (Faber et al. 2011; Eide et al. 2011).

From the perspective of the legislator or policy maker, this calls for more effective policy intervention in order to correct potential failures in markets and to ensure that reductions are achieved. Within the International Maritime Organization (IMO), discussions are ongoing on the possible implementation of sector specific market-based measures (MBM), and recently, the adoption of a set of indexes aiming at improving the performance and design of vessels have been recommended[2]. It was recently demonstrated that emissions from shipping will continue to rise despite the policy measures introduced through the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) and that further measures are needed if the shipping industry is to contribute to the efforts of counteracting climate change (Bazari and Longva 2011).

From the perspective of a shipping company, it is more relevant to focus on what prevents energy efficiency improvements within the organization and what can be done to overcome existing barriers. If not for meeting the present and upcoming regulation, shipping companies should try to overcome such energy efficiency gaps, since direct fuel costs are likely to rise in the future. Other costs are likely to increase as well, as other environmental externalities start being accounted for and as emission control areas (ECAs) are being introduced. The role of energy efficiency as a critical success factor for shipping companies is thus likely to be increasingly strengthened. The question of how to achieve greater energy efficiency from the perspective of the management of a shipping company has not yet been covered to any large extent in shipping.

[2] These indexes are the following: the Energy Efficiency Operational Index (EEOI), aiming at improving the shipping operations; the Energy Efficiency Design Index (EEDI), targeting the energy consumption profile of new designs; and the Ship Energy Efficiency Management Plan (SEEMP). In July 2011, the Parties to MARPOL Annex VI accepted the amendments proposed in the Maritime and Environmental Committee of IMO (MEPC 62) with resolution MEPC.203(62) and added a new chapter 4 to Annex VI of MARPOL. This chapter addresses regulations on energy efficiency for ships and makes mandatory the EEDI for new ships and the SEEMP for all ships.

In this paper, previously developed frameworks, methods and results for research on energy efficiency will be compared with data drawn from a literature on shipping as well as interviews with different experts and business people in shipping. It will focus on barriers to energy efficiency from the perspective of these actors. It will also indicate what implications eliminating such barriers would have for the management of shipping companies. The objective of the paper is to understand to what extent research done on other sectors is applicable also to shipping, and to provide suggestions for further research. The paper will argue that the role of managerial strategic decision making in shipping cannot be understated when it comes to energy efficiency.

The paper is structured in the following way: A section detailing method (semi-structured interviews) and scope of the paper will be followed by a discussion on what is known on the potential for increasing energy efficiency in shipping from a technical and economical point of view. Previous research on energy efficiency, especially related to the energy efficiency gap, will be overviewed, after which, data from the interviews will be presented in the context of this research. Finally, implications for management of shipping companies will be discussed as well as directions for further research.

2 Method and scope

The two main research questions guiding this article are the following: Given that a large technical and economic potential exists, why do shipping organizations not act on these seemingly cost-efficient opportunities? What insights can be gained from applying the frameworks developed from research on other sectors on the shipping sectors?

In order to explore these questions, 19 interviews were conducted between the spring of 2009 and the autumn of 2010. Interviewees were selected from companies in the Nordic shipping sector using a snow-balling method (Biernacki and Waldorf 1981). The intention was to locate people in companies that had a reputation of being ambitious in terms of energy efficiency as well as in companies that appeared more conservative in the implementation of new technologies. Also, interviewees were sought in different parts of the organizations, with the criteria being that they were likely to make decisions in their role that affected energy use. This means not only technical managers in the case of a shipping company but also operational managers. In addition to shipping companies, also classification societies, consultancies, suppliers of measures and services to increase energy efficiency etc. were targeted.

The interviews were carried out using a semi-structured approach, i.e. through open-ended questions that have been developed on the basis of existing theoretical framework. Focus was put on shortcomings and barriers in energy management practices. Cases from the interviews were compared to findings in other sectors and to energy efficiency research in general.

3 The potential for increased energy efficiency in shipping

The shipping industry is an energy intense industry in the sense that energy costs constitute a large portion of total operating costs. For a typical tanker, 50 % of total operating costs are energy related. Compared to other sectors, this is a very large ratio. Thollander and Ottosson (2010), for example, in their paper on energy management practices in Sweden, define energy intense production industries as those industries with energy costs above 5 % and mostly between 5 and 20 %.

Compared to other transportation modes, shipping is in general considered to be characterized by a relatively high energy efficiency levels (Buhaug et al. 2009). In some sectors, however, such as short-sea shipping, the efficiency of shipping as opposed to land-based transportation has been questioned, in particular with respect to SOx and NOx emissions per transportation work and also when it comes to energy efficiency (Hjelle 2010).

The potential for further improvement in energy efficiency has been demonstrated to be substantial. Table 1 shows the breakdown of estimates made by Buhaug et al. (2009). The measures are not only related to technical changes of existing ships and new builds. Also operational measures are of high importance. Thus, from the viewpoint of a shipping company, measures are found within different parts of the organization. Each measure potentially improves energy efficiency by a fraction of a percentage point up to few percentage points. Also, efficiency measures may be operational (planning and executing a voyage efficiently), tactical (planning overhauls) or may involve the organization at a more strategic level (new buildings). It will later be argued that these characteristics of the set of measures impose certain demands on a shipping organization in terms of how work with energy efficiency is effectively managed.

The estimates have later been discussed and confirmed by other researchers. Lindstad et al. (2011) demonstrated that 28 % reduction in CO_2 emissions could be achieved by reduction of speed alone, at zero abatement cost[3]. Eide et al. (2011) assessed cost and reduction potential of various abatement measures in a model which includes fleet growth projections, and conclude that a 33 % CO_2 emission decrease with respect to the baseline, could be achieved by 2030 at a zero marginal cost per ton reduced.

Even though these potentials may appear large, they will not be enough to reduce the *total* emissions from the shipping sector. For example, it is unlikely that the shipping sector will be able to contribute to emission reductions in the magnitude required for example by the European Commission, i.e. 40–50 % by 2050 (EC 2011). Faber et al. (2009) as well as Eide et al. (2011) demonstrated that the gains in efficiency will be more than compensated through increased transportation work as the world economy grows. Bazari and Longva (2011) showed that policy measures introduced by the IMO, so far, will not be enough to stop total shipping emissions from rising.

The problem is thus twofold: our current capacity to reduce emissions is insufficient, as is the ability of shipping companies to implement apparently cost-efficient measures. As Shove (1998) argued: “technical potential which cannot be realized for a range of perfectly explicable sociotechnical reasons is not really technical potential, or at least it is not technical potential which is of any relevance in the race to reduce CO_2 emissions.” (p. 1110). This paper deals with this problem and its implication for the management of shipping companies.

[3] In this context, costs are taken to be fuel, time charter and cargo costs.

4 Frameworks and results in previous energy efficiency research

The existence of an energy efficiency gap has been of interest to researchers, managers and policy makers since the oil crises of the 70s: if the potential is great, why so little action? The building sector has been particularly well researched. For example, some performance indicators in the Swedish building sector have actually stagnated: the average specific energy use for heating new buildings was shown to be twice as high as the best performing buildings 20 years earlier (Nässén et al. 2008). Nässén and Holmberg (2005) identified, among other reasons, weak rules and regulations, strong building companies and weak contractors and incentives for changing user behaviour for this development. Ryghaug and Sørensen (2009) argue in the case of Norway that this is due to a conservative building industry, deficiencies in public policy as well as limited governmental efforts. Pinkse and Dommisse (2009) showed that companies that were more actively seeking information as well as building internal technical capacities were more likely to adopt cost-efficient measures.

This gap has been quantified and explained in further sectors, such as the Swedish foundry industry (Rohdin et al. 2007), the Swedish paper and pulp industry (Thollander and Ottosson 2008), the German commercial and services sector (Schleich 2009), the Indian household sector (Reddy 2003), the Greek industrial sector (Sardianou 2008), the American department of defence (Umstattd 2009), etc. but has not yet been discussed to the same extent in the context of shipping. The topic has been treated outside of peer-reviewed literature: Buhaug et al. (2009) discuss contractual arrangements as affecting the realization of operational measures. Faber et al. (2011) argued for the existence of technical, institutional and financial barriers. Missing from these reports is the theoretical context given below, the relationship to findings in other sectors as well as barriers related more to organization and behaviour. Moreover, they are focused on implications for policy rather than management.

Before the shipping sector is treated specifically, a general overview of energy efficiency research will be given. In the next section, this material will be used to

Table 1 Measures for CO_2 reductions, adapted from Buhaug et al. (2009)

	Saving (%) of CO_2 per tonne-mile	Combined	Total
Design (new ships)			
Concept, speed and capability	2–50	10–50 %	25–75 %
Hull and superstructure	2–20		
Power and propulsion systems	5–15		
Low-carbon fuels[a]	5–15		
Renewable energy[a]	1–10		
Exhaust gas CO2 reduction[a]	0		
Operations (all ships)			
Fleet management, logistics and incentives	5–50	10–50 %	
Voyage optimization	1–10		
Energy management	1–10		

[a] These are measures that reduce CO_2 emissions without necessarily increasing energy efficiency

discuss data gathered on shipping. Energy efficiency is a multidisciplinary research topic. Researchers have found it useful to discuss data through different frameworks in order to find adequate explanations for what determines energy efficiency gaps and barriers in the various sectors. A multidisciplinary approach is also needed as focus is moved from markets to organizations to the behaviour of individuals within a single firm. Collingridge and Reeve (1986) argued that this is typical for problems related to policy: they do not arrange themselves nicely within one discipline.

Part of the explanation could be that new superior technologies typically diffuse gradually, requiring communicational channels and a supporting social system (Rogers 1962). Technical change is path dependent, due to positive feedback processes and increasing returns to adoption (Arthur 1994). It could still be worthwhile to investigate whether the present level of diffusion is optimal from a societal perspective—some barriers to diffusion could be cost efficient to remove. This may apply especially for the introduction of more advanced technologies in meeting long-term climate targets (Sandén and Azar 2005).

A common approach has been to explain this gap in terms of *barriers*, here defined as an obstacle to an actor in reaching a certain goal in terms of energy efficiency (Weber

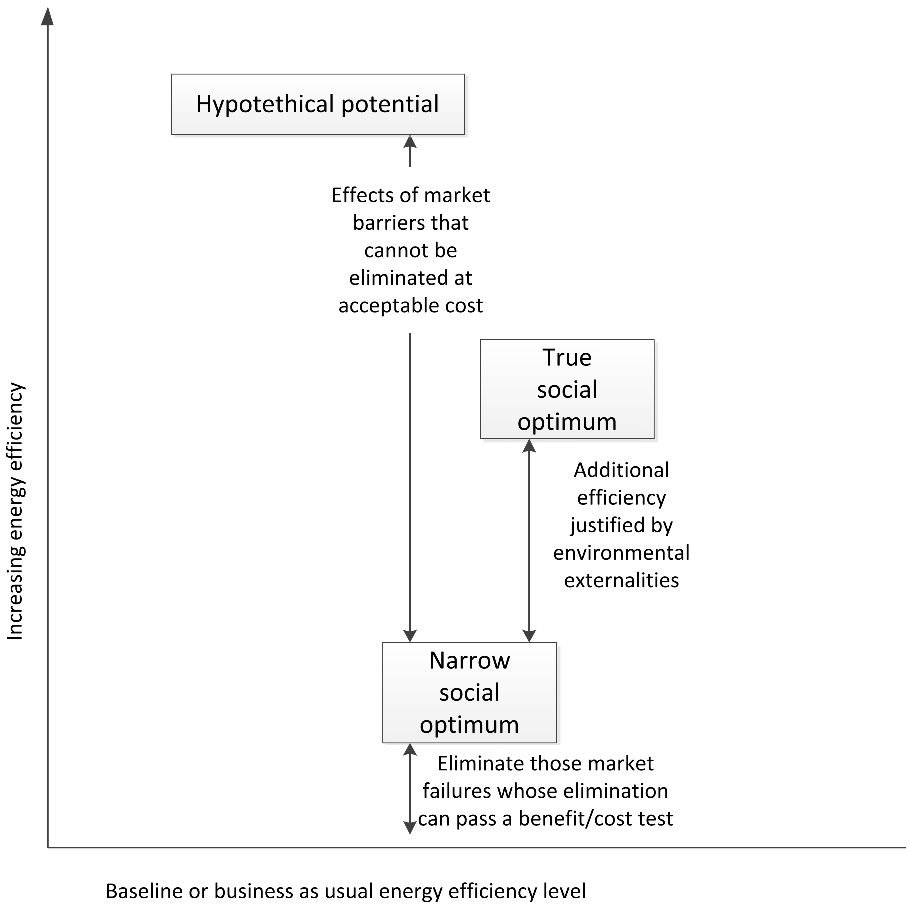

Fig. 1 Potentials and barriers to energy efficiency, adapted and simplified from Jaffe and Stavins (1994)

1997). Different types of barriers have been developed and discussed in relation to markets, institutions, organizations or individual behaviour (Sorrell et al. 2004), thus drawing upon research from different fields. A barrier model, as defined by Weber (1997), is characterized by "*what* is an obstacle to *whom* reaching *what* in energy conservation". One of the advantages of using the conceptual model developed by Weber is that it places energy use in a social context and thus broadens the view from a purer technical or economical potential perspective. For example, an economic agent in a specific social setting may look for and implement energy-saving measures while he or she may not be, in another, independent of actual potential. The model explains this occurrence in terms of barriers—perhaps related to hierarchies and power structures that slow innovation in the organization, lack of management attention etc.—that hinder this economic agent from achieving higher energy efficiency.

The concept of barriers can be used to explain the difference between a hypothetical potential and what is actually observed, as seen in Fig. 1. A *hypothetical potential* changes in reality towards the *narrow social optimum*, as eliminating barriers come at a cost, and not all barriers are cost efficient to remove from a societal perspective. A *true social optimum* is reached when environmental externalities are accounted for. In this article, three sets of barriers will be discussed: barriers derived from neoclassical economics, from transaction cost economics and from organizational theory and management.

4.1 Information barriers

The first perspective discussed in this paper is that of neoclassical economics. Rational actors, such as private firms, are expected to systematically adopt available measures for increasing energy efficiency in order to maximize profits. If the market is unable to exploit to the cost-saving potential of certain measures, this is due to market barriers and/or failures that hinder their uptake[4].

Market failures can be divided into three main categories: incomplete markets, imperfect competition and information asymmetries. Thollander and Ottosson (2008) argued that the latter are more interesting to study in an energy efficiency context, which will also be the focus of this article.

One reason as to why information barriers are of importance in the field of energy efficiency is that information related to energy use and efficiency can be said to have the qualities of a public good. As such, it is typically underprovided by ordinary market activity, giving rise to information barriers. For example, an adopter of a measure with unclear savings is taking a risk, the result (and information) of which other potential adopters receive the benefits, leading to an under-supply of information regarding that particular measure (Sorrell et al. 2004).

With respect to information, different types of goods are expected to affect market failure to different extents. Economists typically divide goods into three categories, namely search goods, experience goods and credence goods (Nelson 1970; Stern 1986). With the first type of good, it is possible for the customer to acquire information

[4] The distinction used in this paper is that of Jaffe and Stavins (1994): market failures are a subset of market barriers, characterized by the fact that their removal passes a cost/benefit test from a societal perspective. See also Fig. 1.

on quality, performance etc. of a good before purchase. Experience goods need to be used by the customer before quality attributes, performance and other characteristics can be determined. Lastly, credence goods are goods where it is difficult to gather information even after purchase and use. The more difficult it is for a buyer to assess these characteristics, the more severe the barriers (Sorrell et al. 2004) are. Akerlof (1970) demonstrated that markets where it is difficult for buyers to assess the quality of goods, sellers are incentivized to market goods of poorer-than-average quality, leading to a reduction of the average quality of goods. As will be argued later, these are characteristics also of shipping markets.

Examples of information asymmetries include split incentives, adverse selection and moral hazard: the first being perhaps the most well known of energy efficiency barriers. A common example of a split incentive problem is where the party that would be the adopter of a particular energy efficiency measure could be aware of the possibilities but does not realize them, as another party bears the energy costs and would thus receive the benefits. In the building sector, these are known as landlord-tenant problems (Blumstein et al. (1980) for example, contains several case studies).

The distinction between adverse selection and moral hazard is that they are cases of asymmetric information applying before and after a contractual agreement, respectively (Arrow 1963; Sorrell et al. 2004). Before the agreement, there may be reasons for a vendor of a particular product to under-provide information on quality or performance. After the agreement, moral hazard problems may arise, especially if performance with respect to the contract is difficult to measure. These problems are often described as principal-agent relationships, where an agent is either acting on the behalf of or providing a service for a principal but with partly differing sets of information and goals (Jensen and Meckling 1976; Sharma 1997). This would lead the agent to act opportunistically, i.e. to always optimize performance with respect to his or her own agenda at a cost for the principal.

Principal-agent problems have been shown to have substantial impacts on processes to improve energy efficiency. In a review of case studies in five countries carried out by the International Energy Agency, principal-agent problems alone affected energy use for 3,8 EJ or 85 % of the total energy used in Spain in 2005 (de T'Serclaes and Jollands 2007). Furthermore, from a policy perspective, these problems are said to be difficult to target through single policy interventions. de T'Serclaes and Jollands (2007, p. 192) that principal-agent problems are "pervasive, disbursed and complex" and argues that sector-specific and country-specific sets of policies need to be designed.

Market barriers that are not market failures in the Jaffe and Stavins' framework include a perception of higher risk for energy efficiency measures (thus imposing stricter pay-off criteria), low access to capital, hidden costs for implementation (production disruptions, staff training etc.) and heterogeneity of actors (a measure that is cost efficient on average may not be so in the case of a particular actor) (Sorrell et al. 2004).

4.2 Barriers due to transaction costs

Relying only on neoclassical economic theory for identifying energy efficiency barriers will not be sufficient to explain the full picture. An early criticism was of the proposition that firms always maximize profit and consumers always maximize utility.

Transaction cost economics provides a useful extension also in the context of energy efficiency. Not only are actors bounded in this framework but there are also different kinds of market transactions and corresponding governance structures. Thus, not only market failures are interesting from a policy intervention's point of view but also organizational failures. Two kinds of organizational transaction costs can be discerned: those related to establishing organizations and those related to running organizations. The former includes such aspects as the cost of setting up, maintaining or changing organizational and incentive designs and information technology. The latter include costs of decision making, monitoring the execution of orders, measuring performance of workers, agency costs and cost of information management, as well as physical transfer costs, such as goods and services across some interface. When it comes to market transaction costs, these are associated with search and information costs, bargaining and decision costs, as well as supervision and enforcement costs (Furubotn and Richter 2005). Bounded rationality explains the existence of organizational *inertia*, implying that all other things being equal, actors favour status quo rather than utility maximization (e.g. Kelly and Amburgey 1991). In this extended framework, the discussion becomes more interesting from the viewpoint of the management of a company.

4.3 Organizational barriers

While the transaction cost approach provides more ways in which to analyse and discuss what is going on *inside* the "black box" of an organization, a the third set of barriers, taking an organizational theory or management perspective, can provide even further understanding. However, this area is still rather unexplored and not much research has been produced in the context of energy efficiency. Sorrell et al. (2000) described it in 2000 as being "the least developed", and a decade later, Thollander and Ottosson (2010) still point to a gap in research literature when it comes to understanding actual energy management practices and strategies in companies. Hilliard and Jamieson (2011) similarly found "no field studies of expert cognitive work in demand-side energy management." Bunse et al. (2011) discussed a gap between scientific literature and industrial needs for management solutions. Some positive examples are Selmer (1994) who studied management practices through longitudinal case studies of five companies in the building sector and Cebon (1992) who studied behavioural aspects of energy management at two universities. He argued that while organization in itself cannot be said to be a barrier to energy efficiency, organizational structures affect and constrain what choices actors within an organization make. Rohdin et al. (2007) highlighted the importance of the energy efficiency "champion", or simply "people with real ambition" who will work on energy efficiency despite lack of formal incentives.

Beyond barrier theory, there are also more interdisciplinary approaches to analysing energy efficiency. Palm (2009) used lifestyle categorization from research on households adapted to explain attitudes to energy efficiency in industrial small- and medium-sized enterprises (SMEs). Nässén et al. (2008) combined an econometric approach with interviews to explain stagnating energy efficiency in the Swedish building sector. Ryghaug and Sørensen (2009) studied the Norwegian building industry from the supply-side point of view and concluded that lack of public policy, a conservative industry and low government interest were main causes of why energy efficiency "fails". Shove (1998) criticized the use of barrier models altogether because of its focus on the distinction between social and technical, favouring instead frameworks which "suggests that technical change is an unremittingly social, and thus contextual, localized and temporally specific, process." (p. 1109). She further highlights the social context of energy efficiency:

> "Imagine a designer keen on energy conservation and equipped with up-to-date knowledge about energy saving methods and measures. Let us say that this person works in the public sector, designing housing schemes within a local authority. The designer's capacity to put his or her energy saving knowledge into practice depends, in significant part, upon the organization's internal accounting practices, on the current priorities of local and national government, and upon the division of labour between relevant building and housing professionals. If this designer leaves the local authority and gets a new job in the private sector, the translation of knowledge into practice will be governed by quite different considerations. In this context, the designer's energy related choices would reflect the need to produce marketable properties at a profit, rather than the need to conform to standard cost guidelines or to produce houses that tenants can afford to heat. Thus the same person with the same psychological propensity for risk taking, and confronting the same decisions (in this case, decisions about housing design), will arrive at different solutions depending upon the organizational environment in which he or she happens to operate." (p. 1108)

In her framework and this example, the concept of barriers becomes more difficult to apply.

5 Barriers to energy efficiency in shipping—an analysis of interviews

The above framework was used as an underlying guideline for the interviews carried out. The aim was to understand whether this framework was useful as a tool for discussing the shortcomings and barriers regarding energy efficiency as described by the interviewees, and as an implication, that the solutions put forward in other sectors would possibly have an impact also in shipping. In total, 19 interviews were conducted, with some respondents being contacted more than once. In terms of profession, interviewees included chief engineers, master mariners, naval architects, environmental managers, ship operators, general managers, energy efficiency equipment vendors, energy efficiency consultants, shipping company CEOs, ship owners and more. In the analysis, cases described by them will be discussed in terms of the above framework.

This discussion will be divided into the discussed barriers, focusing on market and organizational barriers. In some cases, this division may seem somewhat artificial as examples in practical terms may fall into more than one category. As barriers are an attempt to explain the energy efficiency gap within different theoretical frameworks, this is perhaps not so surprising. Sorrell et al. (2000) also noted that barriers should be seen as perspectives to highlight interesting features rather than discrete variables.

Especially the concepts of principal-agent problems and split incentives overlap. The framework seems well suited to discuss problems found also in shipping. Some special characteristics of shipping might even make increasing energy efficiency even more difficult compared to other sectors, despite a relatively higher energy intensity.

5.1 The role of information asymmetries in shipping

From a shipping market perspective, imperfect information seems to be a significant barrier. The theoretical starting point is that since information is typically underprovided by ordinary market activity, actors lack proper basis for taking economically efficient decisions. An investment decision regarding an energy efficiency measure is from an economic perspective typically a trade-off between initial capital cost and potentially lower future energy costs (Gillingham et al. 2009). Therefore, increasing certainty in the prediction of future savings as well as future energy costs and expected lifetime of the measure, among other aspects, become critical. Throughout the interviews, three main patterns concerning difficulties in implementing measures as a consequence of these aspects could be seen.

> *Firstly*, interviewees in the position of ship operators or owners explained that vendors of energy efficiency measures could approach them with a range of energy saving "devices" but without convincing measures or data available for proving actual savings. One ship owner explained that "if we add them altogether, we can save more than 100 %". Insufficient information, in the sense that they did not believe that they were able to verify or trust the claims regarding the estimated savings was, in this case, a barrier for them in investing in a measure.
>
> *Secondly*, a number of company representatives elaborated on difficulties of assessing energy performance of their own ships—another form of imperfect information. Due to varying weather conditions, the quality of measuring equipment, efficiency of reporting systems etc., there could be so much noise in the information that it becomes very difficult to prove the effectiveness of measures. In one case, a shipping company had proven the efficiency of a measure in a testing environment, as well as on trial runs in a towing tank but could not see the savings in day-to-day operational data. Consequently, they did not continue with the measure on a fleet-wide basis. Interviewees also stated that measurement inaccuracy and noise reduced transparency of energy costs within their respective organization, making it difficult to set unambiguous benchmarks and select best practices.
>
> *Thirdly*, lack of information regarding future energy costs could also be a barrier. A technical project manager in one shipping company explained that it was a company policy to use the last month's bunker oil price to calculate payback times for projects. Even though oil prices were rising, they were also fluctuating, making it difficult to plan projects correctly with dockings and access to the right personnel. Furthermore, the use of payback time itself has been criticized (Narayanan 1985), making application of the concept in energy efficiency questionable.

Problems of information asymmetries seem to appear in many forms in shipping, both in terms of markets and within organizations. A large numbers of actors can be involved in providing a shipping service, separated geographically and managerially, potentially opening up for many problems related to information, and concurrently, principal agent problems.

Examples include freight contracts where the cargo owner pays bunker prices, when management of technical maintenance is separated from the commercial management with responsibilities for the fuel bill or when a ship is procured. In the last example, the phenomena of adverse selection implies that potential energy efficiency measures are not accounted for in the value of the ship, as the transaction costs involved for the procurer in using the discounted values of an energy efficiency investment is too large. Moreover, these values may be small compared to the total asset value of the ship. Moral hazard tells us that the shipyard is expected to maximize on those areas that are not specified and monitored by the procurer. Akerlof's market of lemons (Akerlof 1970) tells us that in markets where the buyer knows more about the quality of a good than the seller (that is, they are experience or credence goods), average quality of goods will deteriorate. In this theoretical context then, energy *in*efficient ships are a natural consequence of information asymmetries. This was a concern raised by several interviewees, as they perceived that it could be difficult to assess the performance of their ships in different operational condition.

A technical management optimizing the financial performance of their department may wish to reduce expenses for maintenance, at a higher total cost for the company due to higher fuel consumption (Buhaug et al. 2009). In the principal-agent formulation, this is expected if actions taken by the agent are invisible to the principal, giving rise to a moral hazard problem. This could also be described as a problem of split incentives as discussed below.

The solution model proposed by agency theory is that contracts should be better constructed. An example from shipping is the case where a ship operator may have financial incentives not to slow down in respect to contractual speed, as he receives demurrage while waiting in port before the contractual arrival time, while the cargo owner pays costs of fuel. The "virtual arrival" process, where vessels upon receiving information of a delay at their upcoming port reduce speed in order to arrive in time for unloading is an example of resolving contractual issues that affect energy efficiency. An external verification service would calculate what the fuel consumption and arrival time would have been should the ship have continued on its initial contract speed. This kind of process could then be used to share savings between cargo owner and ship operator, with the operator still receiving demurrage.

Split incentive problems seem to be widespread in shipping. Sorrell et al. (2000) put it: "It is necessary to ask, what are the personal incentives for investing in energy efficiency?". As many measures in shipping are operational, *investing* in this sense could be broadened to include also day-to-day decisions. A consultant working on improving energy efficiency in shipping companies explained in an interview that usually, there is a paradox in that no one in the shipping organization is truly accountable for energy costs and cost reduction. Moreover, a master mariner explained that there could be large variations in the company between the performances of different crews when it comes to fuel efficient operation (vessel trim, speed profile, route planning etc.), but as the crew is generally not evaluated on or held accountable for energy efficiency, little incentives exist for improvement.

5.2 Organizational barriers

Throughout this project, the authors met interviewees that worked or were working in organizations where they felt that they were discouraged to work on energy efficiency. A senior chief engineer specifically mentioned that he had been strongly discouraged by management in several positions he held across different shipping companies from making any efforts in improving the energy efficiency profile of the ship where he was working, with the exception of the company where he was currently employed. He had now been able to receive funding for several projects, all which had had short payback times for the company. This is in line with the argument from Cebon (1992) above that the organization itself places constraints on actions of employees and also similar to the case of the designer described in the quote above from Shove (1998). Literature on resistance to change in organizations can also provide insight in this context (Nevis 1987):

> "If we look at how managers define their jobs, we see responsibility for initiating change as one of the major tasks. At any given level of hierarchy, a manager does not expect those who are subordinate to that level will initiate change, and when subordinates do, they generally have a hard time with it" (p. 145).

A general pattern described by interviewees was based on the consideration that people in a shipping organization who may be directly observing and influencing actual energy use, that is the ship crew, may be organizationally far from those responsible for implementing energy efficiency improvements and are rarely accounted for in the decision-making process. On the other end, ship charterers and operators also make decisions that clearly affect energy consumption, through, e.g. speed and other operational provisions in the charter party. In more than one shipping company, interviewees explained that parts of the organization might not have sufficient knowledge or information regarding energy performance of different ships in different loading conditions and speeds, effectively rendering it very difficult for them to take energy-efficient operational decisions on speed for a given cargo and voyage.

6 Addressing barriers in a shipping company

It emerged from the interviews that the availability of energy saving measures is not in itself a barrier. Indeed, the surveys mentioned above made by various organizations suggest that the possibilities for increased energy efficiency, through existing knowledge and technology, are very large. It is also clear from the interviews, because of reasons related to availability of and trust in information and related to contractual forms as well as organizational factors such as the ability to foster innovation, many shipping companies seem to lack the ability to systematically address energy efficiency within their organizations. Thus, a part of the problem is found in the way a shipping company is managed. In many cases, shipping companies should examine their organizations and pursue a process of organizational change to address the energy efficiency challenges they are faced with.

As what was mentioned earlier in this paper, in general, too little research exists to provide understanding of what are appropriate management practices concerning energy efficiency (Sorrell et al. 2000; Thollander and Ottosson 2010; Bunse et al. 2011). This also applies to shipping. In literature on organizational aspects and effects on organizational performance, the issues discussed above have not been explicitly covered. The outsourcing of day-to-day operations to third party ship management has been covered extensively by Mitroussi (2003, 2004). In the theoretical framework already outlined (e.g. Harris and Raviv (1979)) as well as according to empirical findings (de T'Serclaes and Jollands 2007), these kinds of principal- agent arrangements severely impact energy efficiency in the absence of effective monitoring. This would imply that for many shipping organizations, energy efficiency is a contractual problem in the sense of Williamson (1979). That is the problem of "economizing on bounded rationality while simultaneously safeguarding the transaction in question against the hazards of opportunism" (p. 246).

A way forward for shipping companies in addressing energy efficiency more systematically could be through the application of best practices. While it has been argued that there exists no one solution that fits all companies when it comes to managing energy (Russell 2005), many best practices or *standards* for use in organizations to manage work with energy efficiency were developed during the last decade. A Danish standard, DS 2403, was produced in 2001. A Swedish standard, SS 62 77 50, was introduced in 2003 as part of a governmental energy efficiency programme called "Programme för energieffektivisering" (Programme for energy efficiency, (PFE)). A European standard, EN 16001, followed in 2009 and an international ISO standard, ISO 50 001, was released in 2011. The aim of the ISO 50001 standard is "to enable organizations to establish the systems and processes necessary to improve energy performance, including energy efficiency, use and consumption", through setting a framework "[…] upon which an organization can develop and implement and energy policy, and establish objectives, targets and action plans which take into account legal requirements and information related to significant energy use" (ISO 2011). It also requires that an organization incorporates energy efficiency in procurement and design processes. A similar development has started in shipping: the IMO has developed a Ship Energy Efficiency Management Plan (IMO 2012), OCIMF has revised its TMSA to include also energy efficiency (OCIMF 2009) and Intertanko has produced a Guide for a Tanker Energy Efficiency Management Plan (Intertanko 2009). However, there may be room for improvement, particularly of the SEEMP (Johnson et al. 2013).

Finally, some aspects which make it likely that these standards improve the performance of organizations should be mentioned. Specifically from the analysis in this paper, what seems to be required is a greater emphasis on monitoring and follow-up of performance, both internally within the company and with respect to external contracts. Further, an organizational structure should be supportive of innovative ideas. Indeed, previous studies on energy efficiency in other sectors highlight the importance of the energy efficiency "champion" or "people with real ambition" (Rohdin et al. 2007), who will work on energy efficiency despite lack of formal incentives. In an evaluation of the Swedish PFE programme, researchers have noted difficulties in verify "a direct causality" between the implementation of an energy management system, and gains in energy efficiency (Stenqvist and Nilsson 2011). However, companies in the programme claimed that the energy management system had helped establishing an organizational structure with a strong focus on energy efficiency. Eighty percent of the companies claimed that the implementation of the standard had introduced new methods for monitoring energy use that were valuable for their energy efficiency improvements.

7 Discussion and further research

Our analysis showed that there is an energy efficiency gap in shipping and that such an efficiency gap can be analysed in terms of the theoretical frameworks used in other sector. Moreover, the study has contributed to improve the understanding of the complexity of the issue in the case of shipping. Compared to other sectors, many barriers related to information asymmetries could even be augmented due to the geographically and organizationally fragmented nature of many shipping sectors. From this perspective, it can be argued that energy efficiency is not only a technical challenge but also very much a question of effective management.

The scope of this article is limited to shipping and its organization. It is thus limited in the sense that it does not directly include cargo owners. This would have been relevant as choices made up or downstream very much affect choices available for shipping actors. Similar studies could be done that focused on barriers in a particular market segment, product supply chain or region. The study has also focused on the implications of the existence of barriers to management of shipping companies. Previous studies on shipping, outside academic literature, have emphasized the implications for policy making. The frameworks described and used in this study could also be expanded into this field, particularly transaction cost theory and organizational and management aspects.

From this study, some particular areas may be of particular interest to study further:

- Given the emphasis that transaction cost economics puts on the role of monitoring performance vis-à-vis contracts, understanding further the role and use of monitoring of energy use in various forms of contracts—new buildings, third party management, charter parties etc.—as well as internally, this would be an interesting topic for further research.
- Moreover, it would be valuable to understand further how knowledge and competence on energy issues can be enhanced internally in shipping organizations, for example, through applying various available "best practices". Many best practices exist in the area of systematic energy efficiency management, for example, the ISO 50001 and the IMO SEEMP. Studies could focus on the challenges and effects of their implementation within different types of shipping companies. These studies could address more general critical success factors for organizational change related to energy efficiency, the role of different organizational structures, incentive structures and the impact of contractual arrangements.

8 Conclusions

Pressure on the shipping industry to reduce its environmental impacts will increase and the most cost-efficient route to CO_2 emission reduction will be through increased energy efficiency. Recent assessments have showed that improved managerial practices when it comes to energy efficiency is the only way to reach emission reductions in the short term—the process to replace today's ships with new more energy efficient ships will be slow. Concurrently, there seem to be many barriers that hinder companies from realizing this potential. There is thus a gap between the social need, the potential and what measures are actually being implemented among shipping companies. Our study has contributed to improve the understanding of the complexity of the issue in the case of shipping. A number of key areas as to why this gap exists have been highlighted through interviews and an overview of research in other sectors.

Barriers to energy efficiency in shipping may arise in a shipping organization due to the following:

- Uncertainties and asymmetries in information regarding effectiveness of measures as well as of day-to-day performance
- Fragmentation of responsibilities and action concerning energy use, within firms as well as in contracts between different firms. This is expected to be particularly aggravating in the absence of monitoring.
- Organizational structures that inhibit learning and innovation

Further research is thus necessary to understand the role of energy use and efficiency internally in a shipping organization as well as in its relationship with other organizations. Two ways in which to accomplish this has been suggested:

- Understanding further the role and use of monitoring of energy use in various forms of contracts—new buildings, third party management, charter parties etc., as well as internally.
- Understanding further how knowledge and competence on energy issues can be enhanced internally in shipping organizations, for example, through applying various available "best practices".

An important effect goal of this study was to contribute to further appreciation in the research community of the question of why shipping firms fail to improve energy efficiency so that more studies are carried out in the near future. The matter is urgent from a global societal perspective and concurrently, represents substantial business opportunities.

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