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Backshift effects of Sulphur Emission Regulation in Baltic Sea Ro-Ro Traffic

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Abstract

Since the beginning of 2015, the International Maritime Organisation has introduced Sulphur Emission Control Areas (SECAs) to limit the sulphur content of bunker oil. As the price of the low sulphur marine fuel has constantly been higher than that of the heavy fuel oil, this change was expected to increase the cost of sea transport. As such, this would make sea transport less competitive against other transport modes in cases where other modes of transport would realistically be applicable. This research analyses the backshift effect of the SECA regulation in the Baltic Sea Ro-Ro traffic, where land based transport alternatives are available. The findings indicate, that the transport flows are sensitive to changes in cost balance between sea and road transport. However, due to the decline of crude oil and marine fuel prices, no major changes between road and sea transport have occurred.

Keywords: Shipping, Environmental regulations, Sulphur Emission Control Area, Sulphur emission abatement method, Baltic Sea, Finland

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1. Introduction

The global economy is highly dependent on sea transport, as up to 80 per cent of world merchandise trade is seaborne (UNCTAD, 2016). In addition to providing a major contribution to international trade, shipping as a major user of fossil fuels also creates harmful impacts on health and environment. Due to the low quality of the fuel used in ships, even the most modern marine engines produce a range of emissions, which are more of a concern in shipping industry compared to other modes of transport (Cullinane & Bergqvist, 2014).

International and domestic shipping combined account for around 938 million tonnes or 3.1% of global CO_2 emissions (Smith et al. 2015). Ship traffic has also been estimated to contribute to approximately 60,000 premature deaths per year globally (Corbett et al. 2007). Central Europe and the densely populated regions in Asia are the areas suffering most (Sofiev et al. 2018).

In order to reduce the environmental impacts of maritime transport, the International Maritime Organization (IMO) introduced global limits on the maximum sulphur content allowed in bunker oil used in ships under the revised MARPOL Annex VI in 2008. In addition, particularly vulnerable areas have been declared Sulphur Emission Control Areas (SECAs). The SECAs established are the Baltic Sea area, the North Sea area, the North American area and the United States Caribbean Sea Area (IMO, 2018a). Among these areas, the North American area and the Caribbean Sea area are also designated for controlling nitrogen oxides emissions. This article focuses on the Baltic SECA. The Baltic Sea is a busy area for short-sea marine traffic. It was also the first control area for SO_x emissions, with control legislation taking effect from 16 May 2006. A more stringent EU regulation have further reduced the allowed fuel sulphur content to 0.1 % in SECAs since 1 January 2015.

The purpose of this research is to analyse the effects of SECA in the Baltic Sea Ro-Ro (Roll On – Roll Of) traffic. Whereas much of the sea transport volumes in the Baltic Sea consist of cargoes that are not easily transferrable to other transport modes (such as bulk commodities), the Ro-Ro traffic can easily be redirected to other land-based options.

Solakivi et al. (2019) concluded that the major abatement option to address the SECA regulation in the Baltic Sea has been to switch to a low sulphur fuel grade. These fuels, such as the low sulphur marine gas oil (LSMGO) have been around 150-200 dollar per ton more expensive than other fuel grades. As fuel is a major component of the shipping costs (see Solakivi et al. 2018), this is expected to have an effect on the cost competitiveness of sea transport compared to other transport modes, indicating a modal backshift to land-based transport (Notteboom 2011). This research estimates the effect of fuel price on this assumed backshift effect.

Trade flows between Finland and Central Europe were chosen to be analysed, as there are at least three alternatives for the cargo: (1) the direct sea route from the ports in the southern coast of Finland to Northern Germany and Poland; (2) the sea-land connection combining a sea leg from Helsinki to Tallinn and a land transit through the Baltic States; and (3) the sea-land connection combining a sea leg from Turku and Naantali to Sweden, and a land transit through Sweden and Denmark. Section 2 presents the literature on SECA and the key abatement options, together with the implications of SECA on international trade. Section 3 describes the methodology and Section 4 the results of the analysis. Finally, the results are discussed and concluded in Section 5.

2. Literature review

2.1. Abatement options

The SECA regulations can be addressed mainly with three alternatives. The first is to use low sulphur fuel. The second option is to use alternative fuels such as LNG. Third option is to keep using current fuel grades, and install a scrubber, a technology where the exhaust gases are cleaned before released into the air. For newer vessels, the shift of fuel does not require any major capital investments in modifying ships, other than possibly a minor adjustment of tanks and engines (Bergqvist et al., 2015). However, some of the older engines are built to rely on the lubrication of the HFO, and are thus unable to be operated with low sulphur fuels. LNG is mainly an option for newbuildings, as using LNG in an older vessel requires modifications (engines replacing, specially designed systems, larger fuel tanks, gas sensors etc.), which are difficult and expensive (Panasiuk & Turkina, 2015). A scrubber on the other hand can be installed in the exhaust system of both existing and new vessels. For a newbuilding, the additional capital cost is allocated to the total lifespan of a vessel, whereas retrofitting existing vessels has to be paid back in a shorter period of time (Lindstad et al., 2017), limiting the viability of the solution. The decision on which abatement approach to choose is thus dependent on several factors, including fuel price, area in which the ship usually operates, remaining useful lifetime of the ship and a ships' sailing pattern (e.g. speed and route choices) (Abadie et al., 2017; Gu & Wallace, 2017).

Today, the majority of the global commercial fleet is using Heavy Fuel Oil (HFO) in their engines (Brynolf et al., 2014). In order to comply with SECA regulations, ships can use low-sulphur fuel, such as low sulphur marine gas oil (LSMGO) that contain less than 0.1 % sulphur. After 2020, HFO will be replaced by ultra low sulphur fuel oil (ULSFO) that can be used when the ship sails outside SECA (Gu & Wallace, 2017). The use of low-sulphur fuel requires comparatively low investments. For a ship operating entirely in a SECA area, the capital cost of converting a ship to burning low-sulphur fuel is between 10,000 and 150,000 EUR, depending on the size and type of the ship (Antturi et al., 2016). However, the operating costs are considerably higher in the medium and long term because LSMGO is more expensive than HFO or ULSFO (Panasiuk & Turkina, 2015; Bergqvist et al., 2015; Gu & Wallace, 2017). Currently, LSMGO is approximately 40 % more expensive than HFO (Bunkerworld, 2018). As the global sulphur cap is to take place in 2020, it is estimated to create uncertainty on the availability and price of low sulphur fuels (Van et al. 2019).

Ships also have an option to use alternative energy sources. LNG is one of the best available options in terms of environmental performance (Bergqvist & Cullinane, 2013). However, it is not without its own challenges, as methane slip has to be considered (Brynolf et al. 2014). From the economic perspective, LNG is also an option with a different influence on operating and capital costs. Using LNG, a ship operator can avoid consumption of expensive LSMGO (Gu & Wallace, 2017), hence reducing operating costs. Currently there is also a high uncertainty on the differential between the prices of LNG and conventional maritime fuels. Only if HFO was to become more expensive than today, could LNG become a more feasible option (Acciaro, 2014). LNG also involves high up-front investments (Fagerholt et al., 2015). LNG vessels are around 15% more expensive to build compared to vessels using regular engines. It is possible to convert existing vessels to use LNG but conversion is very costly (around 12 to 16 million EUR) (Bergqvist et al., 2015). Hence, LNG is mainly used in new vessels. In addition, LNG tanks require more space than conventional fuel tanks, which reduces cargo capacity and thus the earning potential of the vessels, making such investments impossible or uneconomical for many existing ships (Bergqvist et al., 2015). Other alternatives, such as biofuels and methanol are also emerging (Lähteenmäki-Uutela et al., 2017). Biodiesel is renewable and can be produced from various feedstocks, such as vegetable oils, recycled waste vegetable oils and animal fats (Lin, 2013). The supply of biofuels is still limited, therefore does not at least currently provide a serious alternative (Holmgren et al., 2014). The technology related to using methanol as a fuel is still in development stage, meaning uncertain outcome, fuel prices and availability (Bergqvist et al., 2015).

Another widely discussed alternative is to continue using HFO and install an exhaust gas cleaning system, a so-called scrubber that removes sulphur from exhaust gas. Scrubbers can be installed both on new builds and older vessels. There are two types of scrubbers: wet and dry. Wet scrubbers are considered more acceptable for ships due to lower price and smaller size of the units (Panasiuk & Turkina, 2015). Wet scrubber technology includes three types of exhaust gas cleaning systems: open loop, using only sea water; closed loop, using fresh water mixed with caustic soda; and hybrid (Abadie et al., 2017). In the Baltic Sea Region, a closed loop system must be used (Panasiuk & Turkina, 2015). Dry scrubbers use chemicals instead of water in the purification process (Bergqvist et al., 2015).

While scrubbers enable ships to continue using cheap high-sulphur fuel, the installation cost is significant. The cost of scrubbers starts at approximately 1.5 million EUR (Antturi et al., 2016; Lindstad et al., 2017). It is estimated that the payback time for the installation of a scrubber is 2-5 years compared to switching to LSMGO (Bergqvist et al., 2015). Hence, it is not feasible to install a scrubber to vessels at the end of their lifespan (Jiang et al., 2014).

2.2. Implications on seaborne trade

The consequences of SECA – initially suggested leading to modal shifts and substantial increase in costs – is still much debated among the academic community. Some of the previous studies expect a modal backshift from maritime transport to land-based transportation especially in shortsea shipping (e.g. Notteboom, 2011; Odgaard et al., 2013; Fagerholt et al., 2015). In contrast, Holmgren et al. (2014) and Zis and Psaraftis (2017) conclude that such a backshift from sea to road is unlikely to happen unless fuel prices increase.

Fagerholt et al. (2015) posit that environmental regulations affect routing of ships to avoid or to reduce sailing in SECAs. Sys et al. (2016) suggest that SECAs could also provoke potential port shifts if certain zones with more severe emissions caps become less attractive for maritime transport. Other possible side-effect is that ship operators may reduce their speed in SECA to save on low-sulphur fuel and to speed up in non-regulated areas to compensate for the loss of time (Doudnikoff & Lacoste, 2014).

While the contemporary SECA areas have only limited geographical coverage, a global sulphur cap to 0.5% is due to enter in force by 2020 (IMO, 2018b). Given the current narrow scope of regulations, the impacts have spread unevenly across the countries. For countries like Finland, of which coastal waters are located entirely in a SECA area, and in which foreign trade relies largely on maritime transport (around 90%), has argued to bear the heaviest economic burden (Kalli et al., 2015; Antturi et al., 2016; Repka et al., 2017).

The distribution of costs and benefits of SECA regulation has been widely discussed. Countries with high population and close to the main shipping routes have been mainly affected by the sulphur emissions (Sofiev et al. 2018). Therefore, they are assumed to be the main beneficiaries of the regulation. Antturi et al. (2016) studied the costs and benefits of the SECA regulation and concluded that net benefits were negative and that the countries further away from Central European markets, such as Finland and Sweden, bear most of the costs. Repka et al. (2017) estimate that the impact of sulphur regulations will be around 175 million EUR for Finnish seaborne trade in 2013-2025. There are also differences between different vessel types. Fast ships, such as Ro-Ro's and container vessels use more fuel in relation to their transport performance and they suffer economically more than slower ships (Kalli et al., 2015). These increasing operating costs may be passed on to shippers by increasing freight rates, which could trigger a modal shift from sea to road (Notteboom, 2011; Zis & Psaraftis, 2017). Zis and Psaraftis also suggest that certain routes may become less viable economically due to increasing operating costs and loss of market share and, as a result, some ship operators may have to shut down certain services, which leads to even higher modal shifts.

3. Methodology

This study analyses the impact of the SECA regulations on selected transport volumes and route choices. There are three realistic options to transport goods between Finland and the continental Europe, where the relative lengths and shares of sea and land transport modes alter. The first option is a direct sea route from the ports in the southern coast of Finland to Northern Germany and Poland. In this option, the sea leg dominates, and is, therefore, presumably most affected by possible changes in the price of marine fuel. The second option is a sea-land connection combining a short sea leg from Helsinki to Tallinn and a road transit through the Baltic States. The third alternative is a slightly longer sea-land connection from the Finnish ports of Turku and Naantali to Sweden, and a land transit through Sweden and Denmark.

The analysis is done by using both descriptive statistics and multiple regression analysis. The cargo volumes (January 2000-June 2016) of the sea transport legs are described in order to identify whether the SECA regulation (introduced 1.1.2015) had any observable effect on the cargo flows. The cargo flows that were chosen to be analysed were the Ro-Ro traffic flows (basically lorries and trailers), as they are considered the most likely ones to be affected. The cargo flows were obtained from the Marine Traffic Statistics of the Finnish Transport Agency.

In the multiple regression analysis, the cargo flows were explained by the fuel price to identify the effect of fuel price on the route choice. As the units of cargo volumes, fuel price and macroeconomic variables are not reasonably comparable (resulting in an interpretation of units per dollar of increase or decrease), the analysis was conducted as a log-log model, which can be interpreted as percentage changes. The model is depicted in Equation (1).

$$\ln Volume_t = \beta_0 + \beta_1 \ln Fuel_t + \beta_2 lnIP + \beta_3 GDP + \varepsilon_t \qquad (1)$$

where *Volume* refers to the cargo volume (number of trailers or lorries) on the respective route and *Fuel* refers to the price of marine fuel. The prices of MGO and IFO fuel grades were found to be highly correlated (.942). To avoid multicollinearity in the model a compilation of MGO and IFO with an assumption that the share of IFO post-

SECA would correspond to the share (48 %) of Ro-Ro vessels installed with scrubbers was used in the analysis. As the cargo flows are most likely affected by the overall macroeconomic environment, industrial production (IP) and GDP were used as control variables. To minimise the randomness, the time series were seasonally adjusted with single exponential smoothing.

4. The impact of SECA on transport volumes and route choice

4.1. Descriptive results

Figure 1 presents the monthly traffic volumes on selected Ro-Ro connections between Finland and Central Europe during the period 2000-2016. In this context, the term "lorry" refers to all the vehicles that include also the tractor unit, whereas a "trailer" is limited to the units that are transported without the tractor. There are a few observations worth a closer look. In the long run, the lorry traffic on most of the routes has remained on a relatively stable level. The Helsinki-Germany lorry traffic increased significantly in 2007, after which it has gradually declined. On the Naantali-Sweden connection the number of lorries transported declined over 2,000 units in 2009, after which it has been on a monthly level of around 4,000 units. The growth of lorry volumes on the Helsinki-Tallinn connection on the other hand has been strong. In 2000, the monthly volume on the route was under 3,000 units per month, whereas in 2016 the monthly volume exceeded 14,000 units.

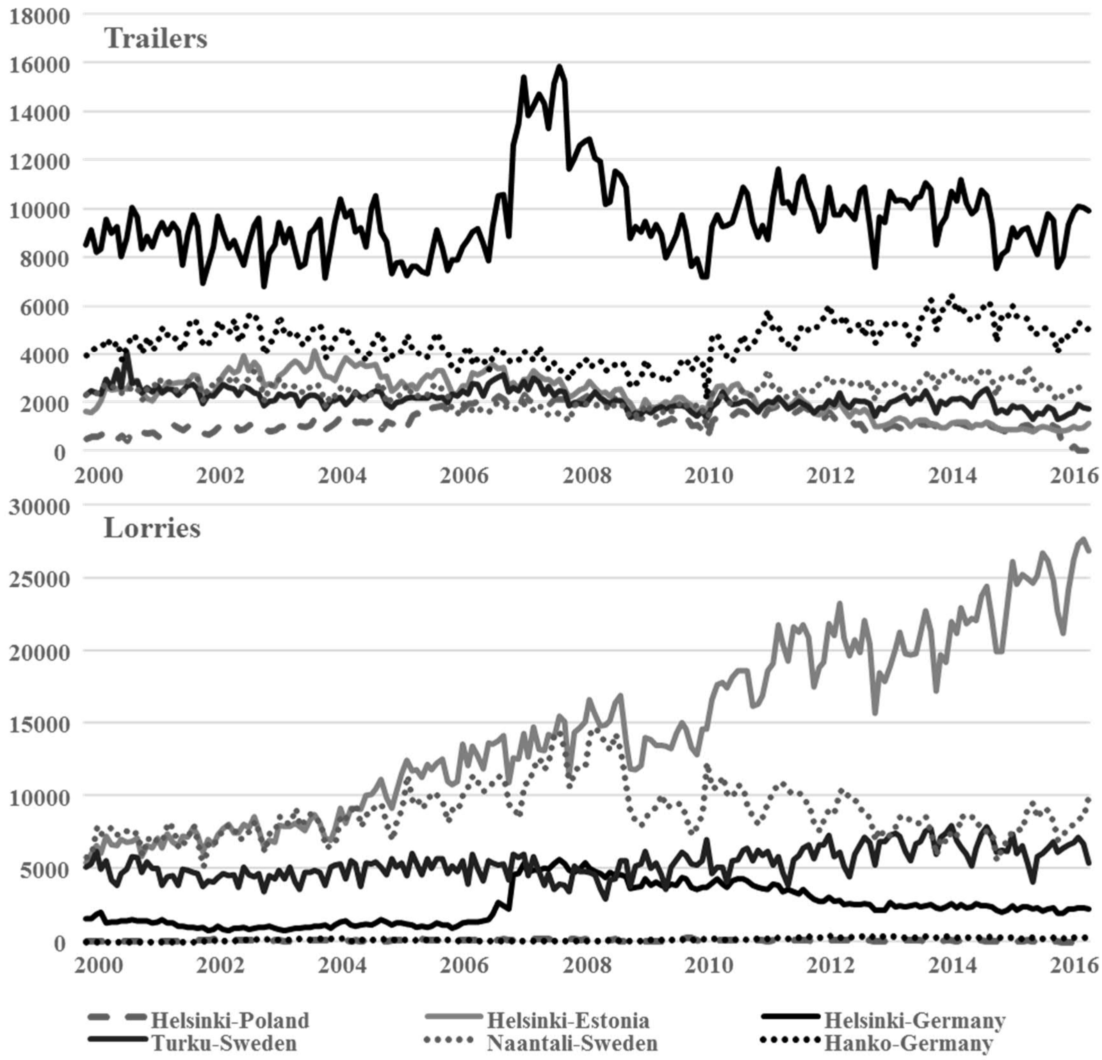

Figure 1. Monthly volumes of lorries and trailers (number of units), including both export and import in selected Ro-Ro connections between Finland and Central Europe 2000-2016 (Source: Finnish Transport Agency, 2017)

The number of lorries on the Helsinki-Estonia connection is remarkably high, considering the trade volume between Finland and Estonia. According to the trade statistics, around 60 % of the Finnish foreign trade is intra EU trade. Of this, around 4 % points is trade with Estonia, while trade with Latvia and Lithuania add around 1 % point each (Finnish Customs, 2019). At the same time, the share of Estonian connection as a destination for the Finnish Ro-Ro traffic is close to 40 %. In practice, this means that a large share of the cargo using the connection is in fact transit traffic with a final origin or destination somewhere else, presumably in continental Europe.

The major trailer volumes seem to be concentrating on the Helsinki-Germany and Hanko-Germany connections. There has been a lot of variation especially on the Helsinki-Germany connection, where both the export and import volumes have at highest been over 7,000 units per month in 2007 and 2008, whereas the current volumes are around 5,000 units per month. The Hanko-Germany -connection has had a rather stable volume between 2,000 and 3,000 units per month. Of the other connections the trailer volumes on the Helsinki-Tallinn and Turku-Stockholm connections have on the other hand been on decline.

Assuming that the SECA regulation would have had a direct effect on the Ro-Ro connections, an observable change in the transport volumes should have occurred. Instead, no changes in the trade volumes can be identified. There is neither a clear increase nor decrease in the volumes right after the introduction of the regulation, nor any observable change in the slopes of the traffic volumes. From the descriptive statistics point of view, it thus seems challenging to identify any major impacts of the SECA regulation on the transport volumes or route choices.

4.2. Model-based results

To further analyse the impacts of the SECA regulations, or from the wider perspective, the impact of fuel price changes on the transport flows and route selection, the cargo flows were subjected to regression analysis, as described in Section 3. The regression coefficients are presented in Table 1.

Table 1. Results of the regression analysis

		Fuel	IP	GDP	R^2
Helsinki-Tallinn	Trailer	-0.698***	0.849**		0.176
	Lorry	0.342***		4.456***	0.398
Helsinki-Germany	Trailer	0.106**	0.248***	1.353**	0.251
	Lorry	-0.634***	0.809***		0.374
Hanko-Germany	Trailer	0.252***		0.981*	0.450
	Lorry	0.551***			0.499
Helsinki-Poland	Trailer		1.499***		0.167
	Lorry				
Naantali-Kapellskär	Trailer				
	Lorry	-0.284***	0.401***	2.597**	0.194
Turku-Stockholm	Trailer	0.253***	0.360***		0.179
	Lorry	0.250***	0.268**		0.142

Most of the cargo volumes were found to be statistically significantly connected to the fuel price. Only the Helsinki-Poland connection (both the trailer and lorry volumes) and Naantali-Sweden (Kapellskär) trailer volumes were not statistically significant. Overall, all volumes seem to be rather inelastic towards the fuel price, as none of the coefficients exceeds 1.0 in value.

Although the relationship is not simple and straightforward, it would seem that with an increase in fuel price, the volume of lorries between Helsinki and Germany declines (-0.634), whereas the volume of lorries between Helsinki and Tallinn increases (+0.342). The effect on the trailer volumes are the opposite. With a 1% increase in the fuel price, the trailer traffic in the Helsinki-Tallinn connection declines by 0.698%, whereas the number of trailers on the Helsinki-Germany route increases by 0.1%.

Given that the coefficients refer to percentage changes, one has to take also into account the absolute volumes on the routes. The lorry volume on the Helsinki-Germany connection are less than 2,000 units per month, whereas the corresponding monthly volume on the Helsinki-Tallinn connection exceeds 12,000 units. In absolute terms, it would seem that the fuel price is having a larger (and positive) effect on Helsinki-Tallinn than on Helsinki-Germany connection. As such, this would indicate that the price increase in the marine fuel is to some extent (in an inelastic way) directing cargo flows towards a shorter sea leg, and correspondingly a longer road haul through the Baltic States. This relationship is confused, however, by the fact that the volumes between Hanko and Germany seem to be increasing.

The Turku/Naantali–Sweden connection provides some confusing results. The coefficients of the Naantali-Sweden and Turku-Sweden lorry traffic are almost identically large, but with different signs. The latter connection is almost 30% longer than the former, so the increase in fuel price should benefit the shorter route which, however, does not seem to be the case.

5. Conclusions and discussion

This research estimated the impacts of the SECA regulation on the route selection of the unit cargo (especially Ro-Ro) flows between Finland and Central Europe. For this purpose, the cargo flows between major Finnish Ro-Ro destinations were subjected to regression analysis, with marine fuel price, the volume of industrial production and GDP as independent variables.

Based on the descriptive analysis of the time series, it would seem that there were no remarkable changes in the cargo flows at the time of the introduction of the SECA regulation, or during the months before and after it. One of the explanations for this could be tracked back to the price development of marine fuels. As shown in Figure 2, during the introduction of the regulation, the prices of marine fuels (and of crude oil) were on the decline.

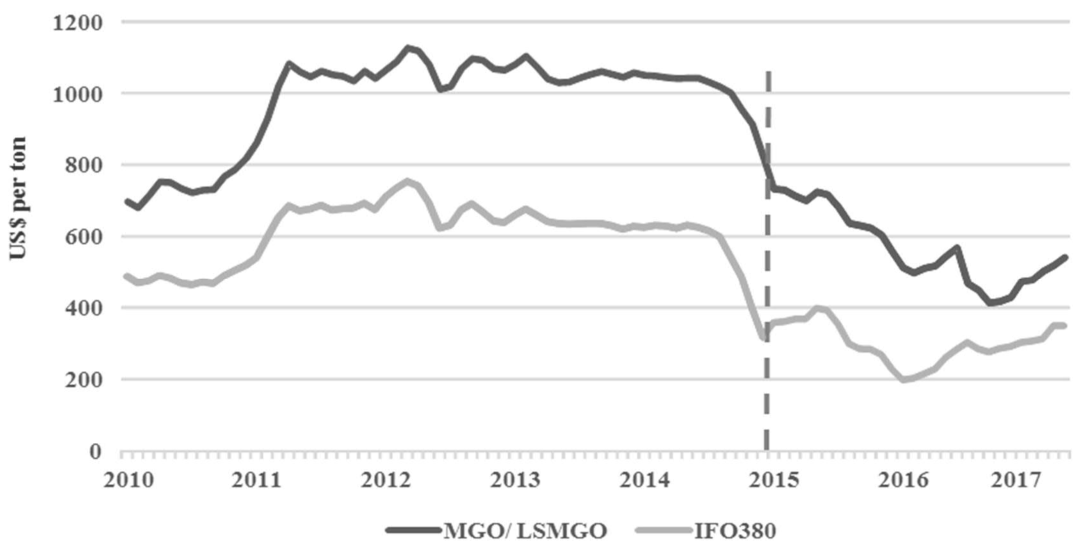

Figure 2. The price development of IFO380 and MGO/LSMGO marine fuels between 2010 and 2017 (Data source: Bunkerworld, 2018)

For the shipping companies, and consequently their customers, this meant that even though the low-sulphur fuel was, and still is significantly more expensive than the higher sulphur fuel grades, the absolute fuel costs were not affected as much as previously expected. In practice, this has meant that the competitiveness of sea transport compared to other transport options has not deteriorated as much.

Another explanation to the absence of any major changes in the transport volumes might be the market conditions of Ro-Ro traffic. Of all types of shipping, the Ro-Ro traffic is characterised as the segment of liner shipping with longer contracts than those of the container traffic (Ojala 2017). As far as the cargo flows to and from Finland are concerned, it seems that the industrial structure of Finland affects the contract types and through them the cargo volumes. The forest industry and its products have a dominant role in the Finland-Central Europe cargo flows and, typically, these flows are governed by long-term contracts. It is, therefore, likely that the sensitivity of cargo flows to changes in the freight rates is affected, particularly in the short term.

Yet another factor contributing to the inelasticity of the cargo flows might relate to scrubbers, as a means of compliance to the SECA regulation. According to Solakivi et al. (2019), almost half of the Ro-Ro vessels in the Finland-Central Europe traffic were equipped with scrubbers, thus avoiding the higher price of low-sulphur fuel and dividing the cost burden to the longer investment period. This fact alone can explain a large part of the observed inelasticity of the cargo flows in relation to the fuel price.

The results concerning the connections between Finland and Sweden might at first sight obscure the picture, as the longer sea leg through Turku appears benefiting from the fuel price increase. However, one has to note that the two alternative connections (through either Turku or Naantali) are not identical, but rather exhibit different characteristics, and therefore different revenue structures. The Naantali-Kapellskär connection has traditionally been operated with Ro-Pax vessels, with a cargo capacity of 2,000 – 3,000 lane meters, and a passenger capacity of a couple of hundred. On the contrary, the Turku-Stockholm connection is served by passenger ferries, such as the Viking Grace, with a cargo capacity of 1,270 lane meters and a passenger capacity of 2,800. Similarly, the Helsinki-Estonia connection is mainly operated through passenger ferries. It would seem obvious, that the price elasticity of passengers is somewhat different to that of cargo, meaning that some sort of cross subsidy between the two exists. To conclude, it might be that the passengers play a role in mitigating the effects of price changes.

The results bring some insights on the backshift effect of environmental regulations in shipping, especially in Ro-Ro traffic. As this research was at least partly able to identify such an effect, the natural continuation would be to analyse the consequences of the effect, and ultimately the consequences of these regulations. In the case of Baltic Sea Ro-Ro traffic, the backshift effects means that some of the cargo may be transferred from a less CO_2 intensive sea transport towards more CO_2 intensive road transport. Further research will hopefully shed light to the scale of such an effect. The policy implications of such a multifaceted analysis should not be underestimated.

The results of the paper are not without limitations. The regression models focus on analysing the elasticity between fuel price and the cargo volume in the selected route, controlling for the effect in GDP development and industrial production. Even as the model is able to identify a connection between the research variables, it excludes some other, more difficultly quantifiable factors, which are discussed in the paper. The lesson of this limitation, as well as one of the results of the paper is that understanding these case dependent factors are essential in analysing the effects of regulatory changes.

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