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Is There Business Potential for Sustainable Shipping? Price Premiums Needed to Cover Decarbonized Transportation

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Abstract: The shipping sector is encountering remarkable costs concerning decarbonization of the maritime business. Both the International Maritime Organization and the European Union are developing tools to limit greenhouse gas emissions of shipping. Given all the tools and planned regulations, it seems that energy efficiency and cost cutting would be a feasible strategy of the future. However, in addition to cost cutting, shipping with net-zero or zero emission fuels might be a way to promote sustainable shipping services. A growing consumer segment is ready to pay for sustainability-marketed consumer goods, and it is possible that people would be ready to pay for net-zero or zero emission shipping as well. Our objective is to pinpoint, how big price premiums would be needed to cover the costs of shipping with sustainable, and typically more expensive, maritime fuels. We do this by calculating the amounts of fuel needed to ship specific good categories at first, and then we estimate the costs of shipping these goods with alternative fuels. We analyze Finnish maritime foreign trade during the year 2018, the time prior to the outbreak of COVID-19 pandemic. We estimate fuel consumption to the value and quantities of goods. Our findings indicate that a shift to low carbon and carbon neutral fuels would have a limited effect to the price of most goods.

Keywords: price premium; sustainable shipping; decarbonization; decarbonized transportation; biofuels; electro fuels; greenhouse gas emissions; carbon dioxide emissions; carbon pricing; Standard International Trade Classification

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1. Introduction

Decarbonization can be seen as a business strategy and goal for numerous actors within the value chains. In a study by New York University Stern School of Business, it was found that in the studied consumer goods market, sustainable products have a market share of over 16%, and that an average price premium of 40% is paid for sustainable consumer goods in the United States [1]. Based on the earlier research of Kronthal-Sacco et al. [2], the US dollar-based sales of sustainability-marketed consumer packed goods of the studied product categories grew by 29% in the United States between the years 2013 and 2018. There is seemingly a market for sustainability and sustainable products in the consumer sector, and a considerable share of consumers is ready to pay a price premium for sustainable products. In our study, we present that by changing conventional fossil fuels to alternative fuels such as biofuels or synthetic electro fuels, the needed price premiums for covering the costs of these shipping services are reasonable, especially for some of the shipped product categories.

When consumers are asked about their willingness to pay more for sustainable and green products, most of the people tend to say that they are ready to pay a price premium for these goods over conventional products [3,4]. Schniederjans and Starkey [5] studied the intention and willingness to pay for t-shirts that were transported and delivered to the store with a truck utilizing energy efficient fuel found that there is willingness to pay more for green transportation. Joshi and Rahman [6] conducted an extensive literature review about the reasons why customers choose green products, identifying both individual factors such as values and environmental concerns as well as situational factors such as price and availability behind the willingness to purchase sustainable products. Testa et al. [7] present another kind of classification of green consumption drivers, and their classification consists of seven drivers to green consumption. These seven drivers are: (1) socio-demographic aspects, (2) intrapersonal values (environment), (3) intrapersonal values (non-environment), (4) personal capabilities, (5) behavioral factors, (6) products and produces related factors, and (7) factors that relate to context of the time of purchase. The difference between intrapersonal values (environment) and intrapersonal values (non-environment) is that intrapersonal values might be strictly connected to the environment or alternatively to other aspects (non-environment). Overall, green purchase intention and environmental attitude have a positive correlation, and people with positive attitude towards environment are more likely to purchase green products [3,4]. Products have to offer intangible or tangible benefits that are important to the customer to get him or her willing to pay and to purchase the actual product or service [4]. The greater the product utility, the more a consumer is ready to pay for the product [8]. Drozdenko et al. [9] studied homeowners' willingness to pay for certain goods and found out that people were willing to pay on average a 9.5% price premium for a green $200 MP3 music player. When considering the purchasing intention of an electric vehicle, the environmental performance was found to be more important predictor than price value [10]. In many of the cases, consumers' purchase intentions are different to their actual purchase decisions and actions, and not all purchase intentions turn to actual purchases [4,11,12].

Kronthal-Sacco and Whelan [1] also found out that category consumption is higher for low-functional products such as dairy products that are sustainability-marketed. At the same time, sustainability-marketed products with high functionality (e.g., detergent) do not meet that strong demand in its category. It is likely that organic foods are preferred over conventional products, because of their health benefits [13]. Aschemann-Witzel and Zielke [14] conducted an extensive literature review and discovered that people are ready to pay on average 30% price premium of organic food. Even though these kinds of personal benefits are important, majority of the people are ready to pay extra for socially responsible features that do not directly benefit themselves based on the meta-analysis conducted by Tully and Winer [15].

Eco-labeling offers informative base increasing positive perception towards green products over conventional ones, and eco-label certification builds trust on purchasing green products [3]. Certification logos of organic products were tested in the study by Janssen and Hamm [16] and consumers' willingness to pay was the highest for products that were equipped with well-known and trusted logos. Certifications work as useful and informative tool for consumers [12]. If the consumers are well informed about environmental issues, a third-party certification is an effective way to gain competitiveness [17].

Sustainability typically refers to economic, environmental, and social sustainability. It can be seen as a challenge to have an impact on the sustainability practices utilized throughout the supply chains. For instance, diffusion of social practices and environmental practices through supplier development initiatives, such as knowledge sharing, joint initiatives, technical support, incentives and investments, have been studied [18]. Examples about environmental practices diffused through the initiatives were: energy efficiency, logistics integration, reducing water consumption, and eco-labelling. Altogether 23 environmental practices and 23 social practices diffused were identified in the study [18]. Some of the recognized social factors that have diffused and were identified were: working conditions, human rights, product responsibility, and proper salaries and fairly reward [18]. In another study, researchers have even developed a taxonomy for sustainable development practices that support individual companies in managing their supply chain relationships [19]. Both [18,19] have emphasized the importance of diffusion of sustainable practices along the supply chain.

Sustainability reporting of shipping companies is also a discussed topic in the literature. For instance, Drobetz et al. [20] discovered a positive relationship between shipping companies' amount of corporate social responsibility disclosures and their financial performance. Simultaneously, in their branding activities, shipping companies communicate especially about their economic and environmental performance [21]. In addition to these, also the social responsibility in form of healthy and safe working environment has been reported by the shipping companies in their sustainability reporting [22].

Aligning profits and sustainability is a major challenge for corporations [23]. It is questioned, whether sustainable actions lead to better financial results, especially because of the increased operating costs to run a firm with sustainable practices [24]. However, many studies have found a positive relationship between corporate financial performance and actions considering sustainability and corporate social responsibility [24–27]. It has been argued that investments in sustainable supply chain activities lead to higher performance and competitive advantage over companies that do not invest in sustainable supply chain [28]. As an example, Yuen et al. [29] studied maritime transport firms utilizing low-cost strategy or differentiation strategy and found out that there is a positive link between corporations' actions on corporate social responsibility and their financial performance. The effect was stronger for firms utilizing differentiation as their main competitive strategy.

Fossil marine fuels cause harm for both local environment and the global atmosphere in the form of different types of emissions. Especially nitrogen oxides (NO_x), sulfur oxides (SO_x) and particulate matter emissions cause problems on the local level. Sulfur and nitrogen emissions are linked to the local problems, and for that reason the sulfur content of marine fuels is strictly regulated. In addition, there are specific emission control areas to limit the sulfur and nitrogen emissions locally. When considering sulfur emissions, there are typically two options for vessels to continue their shipping operations especially on emission control areas, either starting to utilize fuels with low sulfur content or equipping their vessels with equipment called scrubbers.

In addition to local emissions, global environmental effects of shipping are remarkable, especially when it comes to greenhouse gas emissions. Carbon dioxide (CO_2) and methane emissions cause harm for the environment and societies. During the year 2018, ships generated over one billion tonnes of CO_2 emissions, which was about three (3) percent of total anthropogenic CO_2 emissions [30]. Especially, there is a link between CO_2 emissions and global warming. Partly for these reasons, there is a demand to decrease global greenhouse gas emissions, and different regulators have already set goals and rules for minimizing the emissions. For instance, the International Maritime Organization (IMO) has set a target of decreasing 40% of CO_2 emissions per transport work by 2030 and 70% by 2050, as well as decreasing 50% of greenhouse gas emissions by 2050 in comparison to the year 2008 [30]. Simultaneously, the European Union (EU) has announced its Fit for 55 package and goal, which is targeting to reduce emissions by 55% by 2030 in comparison to year 1990 emission levels [31].

The IMO and the European Union are both setting new regulations in force for ships, especially concerning the fuel consumption and emissions. Under the IMO regulations, tools such as Carbon Intensity Indicator (CII), Energy Efficiency Design Index (EEDI), Energy Efficiency Existing Ship Index (EEXI), Ship Energy Efficiency Management Plan (SEEMP) and annual Fuel Oil Data Collection System for collecting information about fuel consumption of ships are all measures to be used in limiting CO_2 emissions [32]. Simultaneously, the EU is collecting information about the fuel usage with the aid of the European Union Monitoring, Reporting and Verification (EU MRV) tool targeted at ships over the size of 5000 gross tonnage. The EU is having numerous plans on its pathway towards emission-free shipping. Some of the most remarkable plans for reducing emissions in the shipping sector are: (1) including shipping sector in European Union Emission Trading System (EU ETS), (2) with the aid of FuelEU Maritime packet, there is a target to improve the utilization of fuels that emit zero or minimal amounts of greenhouse gases instead of fossil fuels, and (3) with the aid of updating the EU Energy Taxation Directive it is planned to inset a tax/levy on marine fuels [31]. At least with the current technologies, the possibilities to reduce emissions cost-efficiently are limited (see for example [33]).

The ways to cut carbon emissions in shipping can be divided into five categories: (1) Technical measures, (2) Operational measures, (3) Eco-friendly fuels, (4) Alternative power sources, and (5) Carbon capture and storage systems on board the ship [34]. Out of these options, we focus on eco-friendly fuels concerning biofuels and synthetic fuels. Alternative fuels, technical measures, and operational measures as well as alternative power sources are discussed earlier by Balcombe et al. [35] and Xing et al. [34].

Natural gas was seen as an important alternative for the sector, but liquefied natural gas (LNG) does not solve all the problems that we are encountering. Especially the methane slip has caused concerns in the sustainability of LNG [34]. The IMO and European Union have started to work against emissions, and the utilization of alternative fuels has been noticed as an important way to reduce pollutants. For instance, biofuels and synthetic electro fuels could be part of the solution to get rid of significant amounts of emissions. However, there are various reasons, why so-called alternative fuels have not been launched to the markets of marine fuels. One of the most important reasons is the lacking business potential of the fuels, and especially the high implementation costs of alternative fuel systems in the operating fleet. Retrofit fuel systems are relatively expensive and the real market for alternative sustainable marine fuels is missing. As the costs of shipping are likely to increase during the forthcoming years, new business perspectives are welcomed. Also, many of the fuels and technologies are still on a development stage, with technological and commercial maturity far from market ready [36].

Our research questions are: How big price premiums (PPs) are needed to cover the costs of sustainable shipping? How the introduction the of EU ETS (EU Emission Trading System) would impact in the business? How would the utilization of green transportation affect to the emissions in the shipping sector?

We approach our research questions through a case, analyzing the goods flows of the Finnish maritime foreign trade. The case was chosen as Finnish foreign trade is among the most dependent on maritime transport among all the EU member states, with the share of maritime transport being close to 90% of the volume. Based on our findings, shipping with alternative and more expensive fuels can be covered with moderate price premiums on transported goods. We are underlining that an important indicator to follow in terms of sustainable shipping is the cost of transportation per customer price of the goods transported.

2. Materials and Methods

Our research focus is on analyzing, is there a business case for sustainable shipping, and especially to pinpoint, how big price premiums are needed to cover the costs of shipping goods with alternative fuels. We compare transportation utilizing alternative fuels to a base case in which low sulfur content marine gas oil (MGO) is used in shipping goods to and from Finland. We do know that ships currently utilize also marine fuels with high sulfur content as they operate with scrubbers, but to simplify the calculations, marine gas oil was decided to be a base case and a fuel to which comparisons are made. The used references for calculations are described in Table 1.

The methodology of the study is relatively straightforward calculation in which the key has been to figure out, how much fuel was needed in shipping specific good categories to and from Finland during the year 2018. After understanding the amount of fuel needed in transportation activities, it is possible to estimate the needed price premiums to cover the additional costs caused by transporting these goods with alternative fuels. The main steps of the calculations of this study are described in Table 1. At first, it was estimated how much more expensive alternative marine fuels are when compared to fossil fuels based on [37]. The second step was to calculate how much fuel different types of ships have consumed in their import and export activities during 2018 based on [38,39]. As the third step, transportation profiles were calculated indicating that how large shares of different good categories out of all the shipping activities were actualized with specific kinds of ships by utilizing the information from [40,41]. During the following step, the specific amounts of cargo were distributed to different ship types based on the transportation profiles that were obtained during the previous step. Then, the fuel consumption figures were allocated from different ship types to good categories based on the transportation profiles and information about quantities of different good categories shipped with a specific kind of ship. Finally, the price premiums were calculated with the Equations (1)–(5).

Table 1. Reference table.

Source	Information Received
Solakivi et al., 2021 [37]	How much does it cost to produce alternative fuels
MERIMA 2021 [38]	How much fuel consumption Finnish imports and exports have caused in shipping in total during 2018
Solakivi et al., 2020 [39]	How much different ship types that have visited Finland have caused CO_2 emissions during 2018
Finnish Customs 2021 [41]	How much and what type of cargo has been transported to and from Finland during 2018
Statistics Finland 2020 [40]	How large shares of different good categories are transported with specific kinds of ships in Finland
Own calculation	How much fuel has been consumed in shipping Finnish imports and exports by a Standard International Trade Classification (SITC) good category during 2018
Own calculation	How big price premiums would be needed to transport specific good categories to and from Finland if the fuel was replaced with an alternative fuel

This research was based on analyzing the imports to and exports from Finland transported with ships during the year 2018, obtained from Finnish Customs [41]. The fuel consumption figures were collected from Traficom's model called MERIMA [38], based on which around 1.9 million tonnes of fuel was consumed in shipping Finnish imports and exports during the year 2018. The fuel consumption figures by vessel types were then analyzed based on Solakivi et al. [39], who reported the fuel consumption and emissions at the Baltic Sea by different vessel types visited in Finnish ports during the year 2018. As an outcome, the fuel consumption figures by vessel type were calculated and those are presented in Table 2.

Table 2. Fuel consumption by vessel type in importing and exporting goods to and from Finland during the year 2018. Adapted from [38,39].

Ship Type	Imports (Thousands of Tonnes of Fuel)	Exports (Thousands of Tonnes of Fuel)	Total (Thousands of Tonnes of Fuel)
RoPax	289	451	739
Vehicle carriers	16	25	41
Cargo ships	144	225	370
Container ships	144	225	370
Tankers	128	200	329

The fuel prices for future biofuels and electro fuels are from Solakivi et al. [37], and those fuel prices are collected into Table 3. The price of MGO (marine gas oil) was added into Table 3 as reference to pinpoint that biofuels and electro fuels are typically more expensive than fossil MGO. The MGO price of €507 per tonne is from MERIMA [38].

Table 3. Fuel production costs. Data from [37].

Fuel	Cost per Tonne of Oil Equivalent	Cost per MWh	Price Difference to MGO per MWh
MGO *	€507	€43	
Biodiesel (HVO)	€825.50	€71	€28
Biomethanol	€930	€80	€37
Bio-LNG	€1175	€101	€58
Hydrogen	€2128	€183	€140
e-Methane	€2977	€256	€213
e-Methanol	€3222	€277	€234

* MGO price was added to the table from [38].

In order to understand what kinds of goods are transported with what kind of ship type in Finland, data from the Finnish ports was utilized [40]. First, the total actualized carrying capacities of different ports was calculated for ropax ships, container ships, cargo ships, vehicle carriers, and tankers based on the port visits and carrying capacities of the vessels visited the ports in Finland during the year 2019. At the same time, in order to analyze the cargo capacities in terms of Standard International Trade Classification (SITC) system, the transported goods via Finnish ports were converted from the more general good categories utilized by Statistics Finland to SITC good categories.

After those arrangements, the goods in SITC categories were allocated to different vessel types based on the profiles of transported cargoes and carrying capacities of the vessels by port. The allocation is presented in Table 4.

Table 4. SITC goods and modes of transportation based on the information from ports.

	RoPax	Vehicle Carrier	Cargo Ships	Container Ships	Tankers
0 Food and live animals	0.79		0.03	0.18	
1 Beverages and tobacco	0.82			0.18	
2 Crude materials, inedible, except fuels	0.06		0.88	0.06	
3 Mineral fuels etc.			0.16		0.84
4 Animal and vegetable oils and fats	0.15		0.1	0.06	0.69
5 Chemicals and related products, n.e.s.	0.14		0.37	0.05	0.44
6 Basic manufactures	0.54		0.26	0.2	
7 Machinery, transport equipment	0.72	0.02	0.11	0.15	
8 Miscellaneous manufactured articles	0.8			0.2	
9 Goods not classified elsewhere	0.5		0.33	0.17	

Finally, the tonnes of marine fuel needed in the transportation were distributed to the SITC good categories from the specific ship types based on quantities of exports from Finland and imports to Finland during the year 2018 (Table 5). The tonnes of fuel needed for shipping the goods are given in Table 6.

Table 5. Imports and exports to and from Finland during the year 2018. (Finnish Customs 2021).

	Imports			**Exports**		
	Value, (Million €)	**Quantity, (Million kg)**	**Value per Quantity, (€/kg)**	**Value, (Million €)**	**Quantity, (Million kg)**	**Value per Quantity, (€/kg)**
0 Food and live animals	3627	2333	€1.55	1120	996	€1.12
1 Beverages and tobacco	569	248	€2.29	151	90	€1.68
2 Crude materials, inedible, except fuels	3843	11,844	€0.32	6039	12,833	€0.47
3 Mineral fuels etc.	8451	20,959	€0.40	5041	8859	€0.57
4 Animal and vegetable oils and fats	286	406	€0.70	15	14	€1.09
5 Chemicals and related products, n.e.s.	6235	4731	€1.32	4709	4604	€1.02
6 Basic manufactures	7180	4440	€1.62	16,622	15,143	€1.10
7 Machinery, transport equipment	18,105	1460	€12.40	14,479	1084	€13.36
8 Miscellaneous manufactured articles	5203	511	€10.18	1955	145	€13.48
9 Goods not classified elsewhere	2897	0.5	€6000.54	1403	434	€3.23

Table 6. Fuel consumption in thousands of tonnes of fuel per ship-type and good-type, exports from (imports to) Finland, 2018.

	RoPax (Thousands of Tonnes of Fuel)	**Vehicle Carriers (Thousands of Tonnes of Fuel)**	**Cargo Ships (Thousands of Tonnes of Fuel)**	**Container Ships (Thousands of Tonnes of Fuel)**	**Tankers (Thousands of Tonnes of Fuel)**	**SUM (Thousands of Tonnes of Fuel)**
0 Food and live animals	31 (72)	-	0.361 (1)	9 (23)	-	40 (96)
1 Beverages and tobacco	3 (8)	-	-	1 (4)	-	4 (10)
2 Crude materials, inedible, except fuels	30 (28)	-	137 (89)	39 (39)	-	205 (155)
3 Mineral fuels etc.	-	-	17 (29)	-	157 (113)	174(142)
4 Animal and vegetable oils and fats	0.081 (2.395)	-	0.017 (0.345)	0.042 (1.329)	0.201 (1.799)	0.340 (5.869)
5 Chemicals and related products, n.e.s.	25 (26)	-	21 (15)	12 (13)	43 (13)	100 (67)
6 Basic manufactures	319 (94)	-	48 (10)	152 (48)	-	518 (153)
7 Machinery, transport equipment	30 (41)	25 (16)	1 (1)	8 (12)	-	65 (71)
8 Miscellaneous manufactured articles	5 (16)	-	-	1 (6)	-	6 (22)
9 Goods not classified elsewhere	8.465 (0.009)	-	1.733 (0.001)	3.707 (0.004)	-	13.905 (0.015)
Total (Thousands of Tonnes of fuel)	451 (289)	25 (16)	225 (144)	225 (144)	200 (128)	1126 (721)

From the structure of Finnish imports and exports (Table 5), it can be seen that more food products and mineral fuels are imported to Finland than exported from Finland. At the same time, Finland exports more basic manufactures than imports from other countries. Finland is especially known for its forest industry, and for this reason, special attention has been paid on goods made of wood in our analyses (See the appendices, Appendix A, Table A3).

From Table 6 that covers fuel consumption figures, it can be seen how fuel consumption is asymmetric between imports and exports especially when considering food products, and basic manufactures.

As the last step, the required price premiums to cover the additional costs of shipping the goods with alternative fuels were estimated. The calculations were made for alternative fuels that cost €20–€220 more per megawatt hour than the reference fuel (or €237–€2609 more per tonne of reference fuel). The equations for calculating the price premiums for each of the good categories, C, are given in Equations (1) and (2). Equation (1) is for calculating the price premiums over value of goods, whereas Equation (2) is for calculating the price premiums by weight of the goods transported. From Equations (1) and (2), it can be seen how the reference is made to the price difference to marine gas oil, MGO. The subscript $_c$

refers to a specific SITC good category under investigation. In the equations, it is expected that the alternative fuels are more expensive than MGO, which is used as the reference fuel.

$$PricePremiumPerValue_c = \frac{FC_c * (FP_{alternative} - FP_{MGO})}{V_c} = \frac{FC_c * (\Delta FP)}{V_c} \quad (1)$$

where:

FC_c refers to Fuel consumption in a category.
$FP_{alternative}$ refers to Fuel Price of alternative fuel.
FP_{MGO} refers to Fuel Price of reference fuel.
ΔFP refers to Fuel price difference.
V_c refers to the value of goods in a category.
The structures of both Equations (1) and (2) are similar.

$$PricePremiumPerValue_c = \frac{FC_c * (FP_{alternative} - FP_{MGO})}{W_c} = \frac{FC_c * (\Delta FP)}{W_c} \quad (2)$$

where:

FC_c refers to Fuel consumption in a category.
$FP_{alternative}$ refers to Fuel Price of alternative fuel.
FP_{MGO} refers to Fuel Price of reference fuel.
ΔFP refers to Fuel price difference.
W_c refers to the weight of goods in a category.

The price premiums in terms of value were calculated also for selected SITC subcategories such as Iron and steel (SITC 67), Road vehicles (SITC 78), and Vegetables and fruit (SITC 05). In order to calculate the price premiums for subcategories, the weights of goods shipped to or from Finland in that specific subcategory $_{\text{subc}}$ was utilized for steering the additional fuel costs for each subcategory as presented in Equation (3).

$$PricePremiumPerValue_{subc} = \frac{W_{subc} * FC_c * (FP_{alternative} - FP_{MGO})}{W_c * V_{subc}} = \frac{W_{subc} * FC_c * (\Delta FP)}{W_c * V_{subc}} \quad (3)$$

where:

FC_c refers to Fuel consumption in a category.
$FP_{alternative}$ refers to Fuel Price of alternative fuel.
FP_{MGO} refers to Fuel Price of reference fuel.
ΔFP refers to Fuel price difference.
W_c refers to the weight of goods in a category.
W_{subc} refers to the weight of goods in a subcategory.
V_{subc} refers to the value of goods in a subcategory.

For taking the carbon price into the equation, emission factor f was taken into the analysis. The emission factor used in the model is 3.17 tonnes of CO_2 released per tonne of fossil fuel consumed, as in addition to MGO, fuels with higher sulfur contents and LNG are used in Finnish trade. The emission factor for Finnish trade is positioned between the emission factors of HFO (heavy fuel oil) and MGO. The emission factor used is the same as the one in MERIMA (2021) report considering Finnish trade with ships. Generally, the emission factor for marine gas oil is referred to 3.206 [30,42], and for HFO the emission factor is 3.114 tonnes of CO_2 released per tonne of fuel consumed [30]. Emission factor for LNG is referred to 2.750 [30]. Different factors are collected in Appendix D. The formulas including carbon pricing are presented in Equations (4) (Price premium per value under carbon pricing) and (5) (Price premium per quantity under carbon pricing).

$$PricePremiumPerValueUnderCarbonPricing_c = \frac{FC_c * (\Delta FP - f * CP)}{V_c} \quad (4)$$

where:

FC_c refers to Fuel consumption in a category.
ΔFP refers to Fuel price difference.
f refers to emission factor.
CP refers to carbon price.
V_c refers to the value of goods in a category.

$$PricePremiumPerQuantityUnderCarbonPricing_c = \frac{FC_c * (\Delta FP - f * CP)}{W_c} \tag{5}$$

where:

FCc refers to Fuel consumption in a category.
ΔFP refers to Fuel price difference.
f refers to emission factor.
CP refers to carbon price.
Wc refers to weight of goods in a category.

When considering the third research question concerning the effect of utilization of alternative fuels on CO_2 emissions of the shipping, a linear model was used. Based on [38], around 5.8 million tonnes of CO_2 emissions are released annually by Finnish seaborne trade. Considering the model, if 100% of the fuel was replaced with a green option, all the 5.8 million tonnes of CO_2 emissions would be reduced. Similarly, if 50% of the fuel would be replaced with green alternative, 50% of the voyages could be completed by green fuels reducing CO_2 emissions by 2.9 million tonnes.

3. Results

The results of this study are described in this chapter. First, the results considering the possible price premiums to cover the costs of shipping SITC-categorized goods with sustainable fuels is Finnish trade are given, after of which the effects of EU ETS and carbon pricing on possible price premiums are taken into the focus. In the end of this chapter, the effects of utilization of sustainable maritime fuels on carbon emissions in the shipping sector are covered.

3.1. Price Premiums Needed to Cover the Costs of Alternative Fuels

The main results of this study are the estimations of price premiums needed to cover the costs of shipping SITC-categorized goods with alternative fuels in Finnish trade. More detailed estimations for SITC system's sub-categorized items are given in Appendix A. The reference year of the analysis is 2018, the time prior the outbreak of COVID-19 pandemic. The results are given in tables in which price differences of sustainable fuel to reference fuel (MGO) are given in comparison to the amount of energy in megawatt hours. In the other words, the fuel price categories indicate how much more a sustainable fuel costs than the reference fuel in the given analysis. If all the goods including both imports and exports were transported with a fuel having a price tag of €60/MWh higher than the reference fuel, the total fuel costs would raise with over 1.3 billion euros altogether, and relatively with 2.2 billion euros, if the transportation was done with a fuel having €100/MWh higher price than the reference fuel.

The price premiums are given in relation to weight and value of Finnish imports (Table 7) and exports (Table 8). These price premium figures refer to the price premiums needed to cover the costs of transporting goods with alternative fuels. The price premiums of over five percentages (light gray) and over 10 percentages (dark gray) are highlighted in the result tables.

Table 7. Price premiums for imports.

	Price Premiums (PP) for Different Good Categories per Tonne and per Value of the Goods Shipped with Alternative Fuel											
	€20/MWh More Expensive Fuel * Utilized.		€60/MWh More Expensive Fuel * Utilized.		€100/MWh More Expensive Fuel * Utilized.		€140/MWh More Expensive Fuel * Utilized.		€180/MWh More Expensive Fuel * Utilized.		€220/MWh More Expensive Fuel * Utilized.	
	PP per Tonne	PP per Value	PP per Tonne	PP per Value	PP per Tonne	PP per Value	PP per Tonne	PP per Value	PP per Tonne	PP per Value	PP per Tonne	PP per Value
0 Food and live animals	€10	0.6%	€29	1.9%	€49	3.1%	€68	4.4%	€88	5.6%	€107	6.9%
1 Beverages and tobacco	€10	0.4%	€30	1.3%	€50	2.2%	€70	3.0%	€90	3.9%	€110	4.8%
2 Crude materials, inedible. except fuels	€3	1.0%	€9	2.9%	€16	4.8%	€22	6.7%	€28	8.6%	€34	10.6%
3 Mineral fuels etc.	€2	0.4%	€5	1.2%	€8	2.0%	€11	2.8%	€14	3.6%	€18	4.4%
4 Animal and vegetable oils and fats	€3	0.5%	€10	1.5%	€17	2.4%	€24	3.4%	€31	4.4%	€38	5.4%
5 Chemicals and related products, n.e.s.	€3	0.3%	€10	0.8%	€17	1.3%	€24	1.8%	€30	2.3%	€37	2.8%
6 Basic manufactures	€8	0.5%	€24	1.5%	€41	2.5%	€57	3.5%	€73	4.5%	€90	5.5%
7 Machinery, transport equipment	€11	0.1%	€34	0.3%	€57	0.5%	€80	0.6%	€103	0.8%	€126	1.0%
8 Miscellaneous manufactured articles	€10	0.1%	€30	0.3%	€50	0.5%	€70	0.7%	€90	0.9%	€111	1.1%
9 Goods not classified elsewhere	€8	0.0%	€23	0.0%	€38	0.0%	€53	0.0%	€68	0.0%	€83	0.0%

* The reference fuel is MGO. The price premiums of over five percentages (light gray) and over 10 percentages (dark gray) are highlighted in the result tables.

Table 8. Price premiums for exports.

	Price Premiums (PP) for Different Good Categories per Tonne and per Value of the Goods Shipped with Alternative Fuel.											
	€20/MWh More Expensive Fuel * Utilized.		€60/MWh More Expensive Fuel * Utilized.		€100/MWh More Expensive Fuel * Utilized.		€140/MWh More Expensive Fuel * Utilized.		€180/MWh More Expensive Fuel * Utilized.		€220/MWh More Expensive Fuel * Utilized.	
	PP per Tonne	PP per Value	PP per Tonne	PP per Value	PP per Tonne	PP per Value	PP per Tonne	PP per Value	PP per Tonne	PP per Value	PP per Tonne	PP per Value
0 Food and live animals	€10	0.8%	€29	2.5%	€48	4.2%	€67	5.9%	€86	7.6%	€105	9.3%
1 Beverages and tobacco	€10	0.6%	€29	1.7%	€49	2.9%	€68	4.0%	€88	5.2%	€107	6.4%
2 Crude materials, inedible, except fuels	€4	0.8%	€11	2.4%	€19	4.0%	€27	5.6%	€34	7.3%	€42	8.9%
3 Mineral fuels etc.	€5	0.8%	€14	2.5%	€23	4.1%	€33	5.7%	€42	7.4%	€51	9.0%
4 Animal and vegetable oils and fats	€6	0.5%	€18	1.6%	€29	2.7%	€41	3.8%	€53	4.8%	€64	5.9%
5 Chemicals and related products, n.e.s.	€5	0.5%	€15	1.5%	€26	2.5%	€36	3.5%	€46	4.5%	€57	5.5%
6 Basic manufactures	€8	0.7%	€24	2.2%	€41	3.7%	€57	5.2%	€73	6.7%	€89	8.1%
7 Machinery, transport equipment	€14	0.1%	€43	0.3%	€71	0.5%	€100	0.7%	€128	1.0%	€157	1.2%
8 Miscellaneous manufactured articles	€10	0.1%	€29	0.2%	€49	0.4%	€68	0.5%	€88	0.7%	€108	0.8%
9 Goods not classified elsewhere	€8	0.2%	€23	0.7%	€38	1.2%	€53	1.6%	€68	2.1%	€84	2.6%

* The reference fuel is MGO. The price premiums of over five percentages (light gray) and over 10 percentages (dark gray) are highlighted in the result tables.

It can be seen that especially goods with low value to weight -ratio face relatively higher price premiums when compared to refined and high-valued goods. From Table 7, it can be seen that especially crude materials and food products together with basic manufactures tie higher price premiums per value than other good categories. While machinery and transport equipment and miscellaneous manufactured goods tie highest costs per kilograms of goods transported—the price premium costs per value of these goods are the lowest for these products together with SITC-category number nine (9) covering the goods that are not classified elsewhere. From Table 7, it can be noticed that imported food would cost around 5 euro cents more per kilogram or 3.1% more per value, if transported with fuel that costs €100/MWh more than the fuel in the base case. Simultaneously, machinery and transport equipment would be 0.5% more expensive if the costs of fuel with a price tag of €100/MWh higher than the reference fuel would be steered straight to the price and value of these products. By doing so, for an average machinery and transport equipment, whose value is €20,000, the price premium would be 100 euros to transport the product with this sustainable fuel (€100/MWh higher than the reference fuel price) to Finland. At the same time, shipping of basic manufactures with that same fuel would raise the price of the product by 2.5% than when transported by utilizing the fuel of the base case to Finland. For mineral fuels, the costs of transportation per quantity are the lowest, given their large volume of almost 21 billion tonnes out of which a significant amount is transported with tankers. However, the low value to quantity ratio of mineral fuels leads to situation in which price premiums per value are relatively high when transported with alternative fuel. More specific price premiums were calculated to the good categories called (1) Food, beverages and live animals, and (2) Online store, and those can be seen in the appendices (Appendix A; Tables A1 and A2).

When it comes to exports from Finland, food, crude materials, mineral fuels, and basic manufactures tie the highest price premiums per value of cargo. At the same time, miscellaneous manufactured articles and machinery and transport equipment require lower price premiums per value of transported goods, but the highest price premiums per weight of goods are for these good categories. Finland exports relatively small quantities of mineral fuels, and for this reason, the exports of mineral fuels when considering the costs of marine fuel needed in transportation are relatively high. Exporting a tonne of mineral fuels would cost 15 euros more than importing the same amount of mineral fuels with a marine fuel that costs €100/MWh more than the reference fuel. More specific price premiums for SITC subcategories exported are given in Tables A3–A5 in Appendix A. Overall, in exports higher price premiums are required than in imports, especially because more fuel is used for exporting the goods than importing the imports. This is mainly because of the differences in the distances of transporting imports and exports. Generally, imports were located closer than were the export destinations. In 2018, the imports required 86 billion tonne-kilometres, while exports caused 163 billion tonne-kilometres for Finnish trade transported with ships [38]. However, both imports and exports require relatively low price premiums when alternative fuels are used. This refers to the situation in which there is a business opportunity for sustainable shipping. The sensitivity analysis of this study is given in Appendix C, Table A7.

The comparison between price premiums in imports and exports are highlighted in Figure 1. Figure 1 points out differences in price premiums if alternative fuel that costs €100 more per MWh is utilized—the columns point out that transporting of food requires relatively high price premiums whereas the price premiums for high valued goods such as machinery and transportation equipment are relatively low.

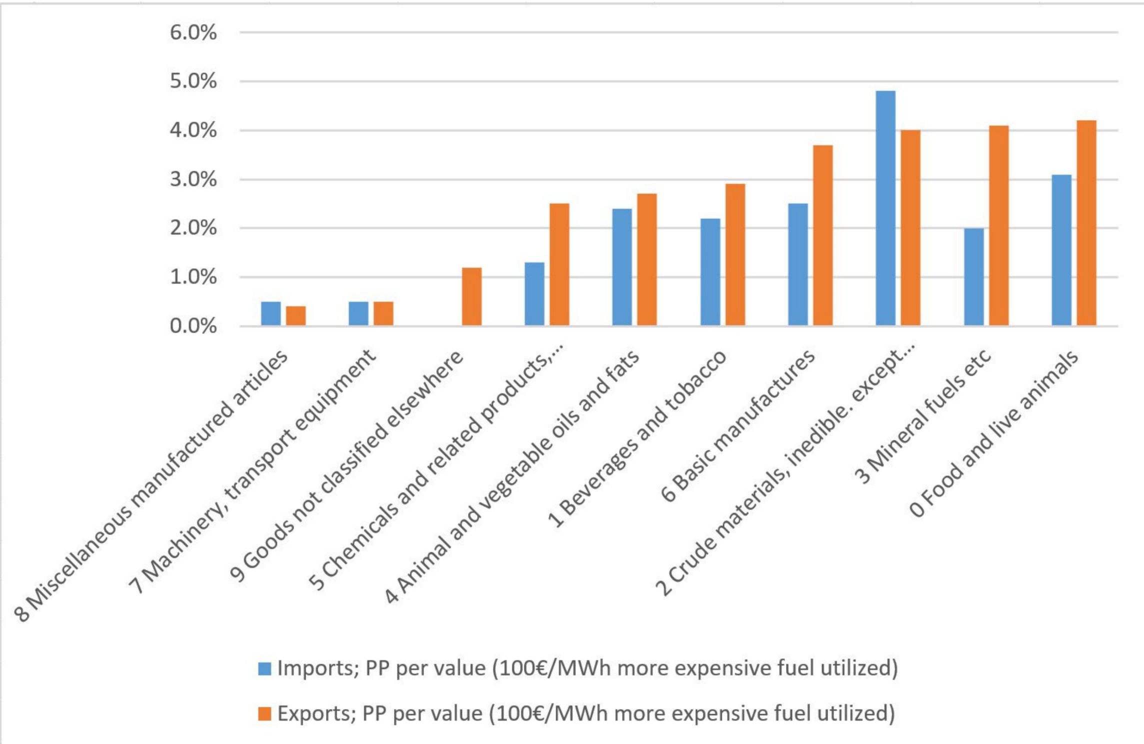

Figure 1. Price premiums per value for imports and exports when €100/MWh more expensive fuel is utilized in shipping.

3.2. Price Premiums for Carbon Price of €100 per Tonne CO_2

As shipping will be likely taken into EU ETS, the concept of carbon price was also tested as a part of the calculations. Based on the report from "For the getting to zero coalition", it is expected in their scenarios that the carbon price per tonne of CO_2 released will average to around US$173 (approximately €150) by 2050 [43]. The most dramatic effect of carbon price can be seen in the relative price premium of utilization of fuel that costs only marginally more than the reference fuel. If carbon price of €100 per released tonne of CO_2 would be taken into use, this would lead to the total carbon price of €590 million for Finnish trade. Simultaneously, the total price premium needed to cover utilization of sustainable fuel that costs €20/MWh more than the reference fuel would drop relatively from €440 million to negative 150 million euros in Finnish trade. This would mean that the industry would save €150 million in comparison to utilization of fossil fuel used in the base case, if a sustainable fuel with a price tag of €20/MWh higher than the reference fuel was utilized under carbon price of €100 per released tonne of CO_2. The price premiums for both weight and value of the products are negative for all the good categories when a sustainable fuel having price tag of €20/MWh higher than the reference fuel is utilized under carbon price of €100 per tonne of CO_2 released. When it comes to goods transported with a sustainable fuel that costs €20/MWh more than the fuel utilized in the base case, food would cost €3 per tonne less under carbon price of €100 per tonne of CO_2 released, as can be seen in Table 9. Similarly, utilization of sustainable fuel that costs €60/MWh more than the reference fuel would lead to the situation in which the price premium of €1.3 billion would decrease relatively to €730 million in Finnish trade. More detailed analysis about the price premiums under carbon pricing for SITC 6, Basic manufactures, are given in the appendices in Appendix B, Table A6.

Table 9. Price premiums for exports having carbon price of €100 per tonne of CO_2.

	Price Premiums (PP) for Different Good Categories per Tonne and per Value of the Goods Shipped with Alternative Fuel.											
	€20/MWh More Expensive Fuel * Utilized.		**€60/MWh More Expensive Fuel * Utilized.**		**€100/MWh More Expensive Fuel * Utilized.**		**€140/MWh More Expensive Fuel * Utilized.**		**€180/MWh More Expensive Fuel * Utilized.**		**€220/MWh More Expensive Fuel * Utilized.**	
	PP per Tonne	**PP per Value**	**PP per Tonne**	**PP per Value**	**PP per Tonne**	**PP per Value**	**PP per Tonne**	**PP per Value**	**PP per Tonne**	**PP per Value**	**PP per Tonne**	**PP per Value**
0 Food and live animals	−€3	−0.3%	€16	1.4%	€35	3.1%	€54	4.8%	€73	6.5%	€92	8.2%
1 Beverages and tobacco	−€3	−0.2%	€16	1.0%	€36	2.1%	€55	3.3%	€75	4.4%	€94	5.6%
2 Crude materials, inedible, except fuels	−€1	−0.3%	€6	1.3%	€14	3.0%	€21	4.6%	€29	6.2%	€37	7.8%
3 Mineral fuels etc.	−€2	−0.3%	€8	1.4%	€17	3.0%	€26	4.7%	€36	6.3%	€45	7.9%
4 Animal and vegetable oils and fats	−€2	−0.2%	€10	0.9%	€21	2.0%	€33	3.0%	€45	4.1%	€57	5.2%
5 Chemicals and related products, n.e.s.	−€2	−0.2%	€9	0.8%	€19	1.8%	€29	2.9%	€40	3.9%	€50	4.9%
6 Basic manufactures	−€3	−0.2%	€14	1.2%	€30	2.7%	€46	4.2%	€62	5.7%	€78	7.1%
7 Machinery, transport equipment	−€5	0.0%	€24	0.2%	€52	0.4%	€81	0.6%	€109	0.8%	€138	1.0%
8 Miscellaneous manufactured articles	−€3	0.0%	€16	0.1%	€36	0.3%	€55	0.4%	€75	0.6%	€95	0.7%
9 Goods not classified elsewhere	−€3	−0.1%	€13	0.4%	€28	0.9%	€43	1.3%	€58	1.8%	€73	2.3%

* The reference fuel is MGO. The price premiums of over five percentages (light gray) and over 10 percentages (dark gray) are highlighted in the result tables.

3.3. *CO_2 Emission Reduction of Sustainable Shipping*

With the current fuel mix, the CO_2 emissions of the Finnish seaborne trade are estimated to be around 5.8 million tonnes annually. The emission reduction potential of cost-effective use of alternative maritime fuels is presented in Table 10. In case 5% of the current transport volume would be transported with carbon neutral fuels, the annual emission reduction would be around 300,000 tonnes of CO_2. If 16% of goods (the market share of sustainable consumer goods) would be transported, the emission reduction would be around 900,000 tonnes. Even if the highest valued quarter of goods would transform to carbon neutral fuels, the reduction would be 1.5 million tonnes, which would correspond to around 5% of the current net emissions of Finland.

Table 10. Emission reductions when goods are transported with sustainable fuels.

Amount of goods transported with sustainable fuels	5%	10%	16%	20%	25%
Reduction of carbon emissions (million tonnes)	0.3	0.6	0.9	1.2	1.5

4. Discussion

On average, transportation corresponds to around 5% share of the total costs of the product [44]. In many of the good categories, especially the high-valued goods this share is even less. For this reason, approaching sustainability and emission reductions entirely from the perspective of additional costs is a too narrow perspective. For many goods, sustainable shipping could also be considered as a source of competitiveness. Previous research shows that there is a significant demand for sustainability-branded consumer goods, and an increasing share of people is ready to pay a price premium of sustainable products. In the consumer goods market, the current market share of sustainable products is around 16% [1,2]. If this share would be applied for shipping, over 0.9 million tonnes of CO_2 emissions could be reduced in Finnish seaborne trade annually. At the same time, our research has highlighted that transporting high-valued goods with sustainable marine fuels (i.e., carbon neutral or emission-free fuels) instead of fossil fuels causes only a marginal increase in the relative costs of these goods.

Therefore, there is obviously a business case for sustainable fuels. The analysis revealed that for many good categories, the cost impact of utilizing carbon neutral fuels would be minor. Especially considering that the price premiums paid for high-valued goods are rather substantial, it would seem that in many cases there is major business potential for sustainable shipping. Therefore, this article emphasizes the need to expand the traditional cost-driven perspective towards identifying also the business potential of sustainability also in transport operations.

However, it must be kept in mind that there are significant differences between industries and product categories—For some sectors, sustainable shipping may turn out to be highly beneficial, but for low-value goods such as raw materials the costs may turn out to be too high for transporting raw materials and other low-value goods. Based on our analyses transporting of food to and from Finland with alternative fuel that costs €100/MWh more than the reference fuel would cause less than five percentage (5%) increase in the price tag of average food products, whereas less than a percentage increase in price tags of machinery and transport equipment would be needed to cover the costs of transporting goods with that same fuel instead of reference fossil energy.

The forthcoming EU ETS is also something to be taken into consideration. When there is carbon price of €100 per released fossil CO_2 tonne, the price premium for a sustainable fuel that costs €20/MWh more than the fossil fuel in the base case is negative, so it would be cheaper to use this alternative and sustainable fuel than utilize the reference fossil fuel in shipping.

With the increasing emphasis towards climate change and greenhouse gas emissions, the shippers and shipping companies are facing increasing pressure to limit the environmental impact of their operations. In addition to considering the emissions of their operations as a business risk, they are facing increasing regulatory pressure to reduce their emissions.

Our results indicate that for many goods, sustainable (maritime) transport would be an incremental cost increase. Therefore, they are recommended to consider the business potential of emphasizing sustainability in their supply chain, also considering transport. Increased sales or collected price premiums mean that paying for sustainable transport would be a source of additional income for some of the shippers. Shippers need to analyze what the premium would be from switching to carbon-neutral shipping and how that could enhance their offering and market share. This would require shippers to be able to track the emission-footprint of their goods in the logistic chain, which should not be a challenge but will require investments in ICT.

At the same time, shippers should consider the risk logistic emissions accumulate for the supply chain. Although the analysis shows the sustainability premium to be minor for refined goods, it shows a significant premium for raw materials. In specific cases, this constitutes a significant risk for the shippers' competitiveness. Yet, at the same time, it also points to an opportunity to increase refinement of goods at the source of raw materials.

For shipping companies, offering sustainable transportation services could be a way to differentiate in a highly competitive market in the future. Sustainable shipping services, meaning the utilization of a sustainable marine fuel, might be a way to get additional orders from the markets. Even as the current market is still very much cost-oriented, it is expected that in the future sustainability is likely to obtain the role of order qualifier, basically forcing the service providers towards sustainability in many segments. As a strategic choice, the forerunners are likely to gain market shares from the followers.

For consumers, sustainable shipping creates an option to purchase products that are shipped with a sustainable way. Carbon labelling is increasingly being used in consumer goods, indicating for example what kind of energy has been used. Products shipped with a sustainable manner (i.e., carbon neutrally or zero-emission) could be labeled as such. The fact that sustainability branding especially helps products with low functionality would seem to favor shipping since consumers are likely to pay little attention to how the product has been shipped would it be in container, roro or break-bulk.

The results of this research can also be discussed from the perspective of institutional theory. The shipping industry has traditionally been slow to adapt voluntarily towards more sustainable practices, which has highlighted the role of regulatory pressures in forcing the industry to adapt. As the shippers are becoming increasingly sustainable and setting sustainability requirements also to their suppliers including service providers, this most likely means that the market demand will be an increasing pressure for the shipping companies to become more sustainable. Further, as the sustainable shipping options are provided, and more importantly, requested, it will most likely create new norms, especially for the segments that transport the more highly valued goods. Ultimately, sustainability will most likely also become an industry standard through mimication of successful forerunners. At the same time it is too optimistic to assume that the change would go through the entire industry voluntarily. For the segments that transport low-valued goods, coercive regulatory pressure is still needed.

The study focused only on describing the possible price premiums considering the fuel expenses. The possible capital expenditure for the engines running with sustainable fuels was left out from the calculations. It has to be kept in mind that the calculations were done with customs values of the goods, and different types of taxes were not included into the model. Especially the capital expenditures needed for retrofitting the ships and equipping new ships with engines that run on sustainable fuels could be done in order to understand the industry-wide effects in the future studies. The analysis were also targeted to the first leg (exports) and last leg (imports) of the transportation chain. The total transportation chains from the place of origin to the final destination could be studied in the future research. The calculations were also conducted by utilizing the weight of goods transported as the unit of analysis. As an example, methods that are more sophisticated could be utilized for analyzing the price premiums needed to transport goods that require relatively large amounts of space to be shipped correctly. The space requirements were not considered in this study, and this is a dimension that could be taken into the analyses in the future studies.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Price Premiums for SITC Subcategories

Food imports are extremely important for Finland and the country imports significantly more food products (approximately 2.3 million tonnes) than it exports (approximately a million tonnes). Price premiums for shipping goods with low-value such as sugars, cereals and vegetables are high. However, the highest premiums per value for food products are for feeding stuff for animals. As an example about a price premium, for an average bottle of beverage that weights 1 kg the price premium when transported with a fuel having a price tag of €100/MWh more than the reference fuel would be (1 kg * 1.860 €/kg * 2.7%) 0.05 euros. Price premiums needed per value of food product imports are presented in Table A1.

Table A1. Imports Price premiums needed per value for a good category Beverages, Food and live animals.

	Value per kg	Price Premiums Needed per Value of Goods					
		€20/MWh More Expensive Fuel * Utilized.	€60/MWh More Expensive Fuel * Utilized.	€100/MWh More Expensive Fuel * Utilized.	€140/MWh More Expensive Fuel * Utilized.	€180/MWh More Expensive Fuel * Utilized.	€220/MWh More Expensive Fuel * Utilized.
11 Beverages	€1.860	0.5%	1.6%	2.7%	3.8%	4.8%	5.9%
00 Live animals	€40.704	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%
01 Meat and meat preparations	€4.127	0.2%	0.7%	1.2%	1.7%	2.1%	2.6%
02 Dairy products and birds' eggs	€2.843	0.3%	1.0%	1.7%	2.4%	3.1%	3.8%
03 Fish and fish preparations	€4.559	0.2%	0.6%	1.1%	1.5%	1.9%	2.4%
04 Cereals and cereal preparations	€1.284	0.8%	2.3%	3.8%	5.3%	6.8%	8.4%
05 Vegetables and fruit	€1.418	0.7%	2.1%	3.4%	4.8%	6.2%	7.6%
06 Sugars, sugar preparations and honey	€0.716	1.4%	4.1%	6.8%	9.5%	12.3%	15.0%
07 Coffee, tea, cocoa, spices	€3.863	0.3%	0.8%	1.3%	1.8%	2.3%	2.8%
08 Feeding stuff for animals	€0.518	1.9%	5.7%	9.4%	13.2%	17.0%	20.7%
09 Miscellaneous edible products and preparations	€2.732	0.4%	1.1%	1.8%	2.5%	3.2%	3.9%

* The reference fuel is MGO. The price premiums of over five percentages (light gray) and over 10 percentages (dark gray) are highlighted in the result tables.

Finland also imports relatively much of products that can be ordered via online stores. Different types of office equipment and telecommunication gadgets are popular imports. In addition, clothes and accessories and bags are widely imported. Selected import good categories are presented in Table A2. For a cell phone that is transported with a sustainable fuel that costs €100/MWh more than the reference fuel, the price premium is almost non-existent.

Table A2. Imports. Price premiums needed per value for online store.

	Value per kg	Price Premiums Needed per Value of Goods					
		€20/MWh More Expensive Fuel * Utilized.	€60/MWh More Expensive Fuel * Utilized.	€100/MWh More Expensive Fuel * Utilized.	€140/MWh More Expensive Fuel * Utilized.	€180/MWh More Expensive Fuel * Utilized.	€220/MWh More Expensive Fuel * Utilized.
75 Office machines and adp machines	€104.230	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%
76 Telecomm. sound recording equipment	€75.683	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%
77 Electric machinery, nes and parts	€13.047	0.1%	0.3%	0.4%	0.6%	0.8%	1.0%
82 Furniture and parts thereof	€4.598	0.4%	1.1%	1.8%	2.6%	3.3%	4.0%
83 Travel goods, handbags and sim. Contnrs	€17.078	0.1%	0.3%	0.5%	0.7%	0.9%	1.1%
84 Articles of apparel and clothing accessories	€24.650	0.1%	0.2%	0.3%	0.5%	0.6%	0.8%
85 Footwear	€24.712	0.1%	0.2%	0.3%	0.5%	0.6%	0.7%
87 Instruments and apparates, nes	€58.529	0.0%	0.1%	0.1%	0.2%	0.3%	0.3%
88 Photo equipm. optical goods etc.	€37.100	0.0%	0.1%	0.2%	0.3%	0.4%	0.5%

* The reference fuel is MGO.

One of the Finland's core sectors considering exports are the goods under forest industry. Price premiums for forest related goods are collected in Table A3. Products of wood such as pulp and paper are important goods that Finland exports. For a metric ton of pulp the price premium when transported with a fuel that costs €100/MWh more than the reference fuel would be (1000 kg * 0.639 €/kg * 3.0%) 19.2 euros.

Table A3. Exports. Price premiums needed per value for forest industry.

	Value per kg	Price Premiums Needed per Value of Goods					
		€20/MWh More Expensive Fuel * Utilized.	€60/MWh More Expensive Fuel * Utilized.	€100/MWh More Expensive Fuel * Utilized.	€140/MWh More Expensive Fuel * Utilized.	€180/MWh More Expensive Fuel * Utilized.	€220/MWh More Expensive Fuel * Utilized.
24 Cork and wood	€0.369	1.0%	3.1%	5.1%	7.2%	9.3%	11.3%
25 Pulp and waste paper	€0.639	0.6%	1.8%	3.0%	4.2%	5.3%	6.5%
63 Wood and cork manufactures	€0.950	0.9%	2.6%	4.3%	6.0%	7.7%	9.4%
64 Paper, paperboard and articles thereof	€0.735	1.1%	3.3%	5.5%	7.7%	9.9%	12.1%

* The reference fuel is MGO. The price premiums of over five percentages (light gray) and over 10 percentages (dark gray) are highlighted in the result tables.

Finland also exports relatively more (approximately 15.1 million tonnes) basic manufactures than it imports (4.4 million tonnes). Out of basic manufactures, wood and paper products tie the highest price premiums per value of goods, and in addition, non-metallic mineral manufactures and iron and steel are also affected with a price premium. For a metric ton of steel the price premium when transported with a fuel having a price tag of €100/MWh more than the reference fuel would be (1000 kg * 1.167 €/kg * 3.5%) 41 euros. Detailed price premiums for basic manufactures are presented in Table A4.

Table A4. Exports. Price premiums needed per value for Basic manufactures.

	Value per kg	Price Premiums Needed per Value of Goods					
		€20/MWh More Expensive Fuel * Utilized.	€60/MWh More Expensive Fuel * Utilized.	€100/MWh More Expensive Fuel * Utilized.	€140/MWh More Expensive Fuel * Utilized.	€180/MWh More Expensive Fuel * Utilized.	€220/MWh More Expensive Fuel * Utilized.
61 Leather, dressed fur, etc.	€22.022	0.0%	0.1%	0.2%	0.3%	0.3%	0.4%
62 Rubber manufactures, nes	€6.560	0.1%	0.4%	0.6%	0.9%	1.1%	1.4%
63 Wood and cork manufactures	€0.950	0.9%	2.6%	4.3%	6.0%	7.7%	9.4%
64 Paper. paperboard and articles thereof	€0.735	1.1%	3.3%	5.5%	7.7%	9.9%	12.1%
65 Textile yarn, fabrics, made up articles, etc.	€6.583	0.1%	0.4%	0.6%	0.9%	1.1%	1.4%
66 Non-metallic mineral manufactures, nes	€1.345	0.6%	1.8%	3.0%	4.2%	5.4%	6.6%
67 Iron and steel	€1.167	0.7%	2.1%	3.5%	4.9%	6.3%	7.7%
68 Non-ferrous metals	€5.414	0.2%	0.5%	0.8%	1.1%	1.4%	1.7%
69 Manufactures of metals, nes	€4.323	0.2%	0.6%	0.9%	1.3%	1.7%	2.1%

* The reference fuel is MGO. The price premiums of over five percentages (light gray) and over 10 percentages (dark gray) are highlighted in the result tables.

Finland exports high technology equipment to other countries. Technology products need relatively low price premiums when indicated per value of these products as can be noticed from Table A5. For an average road vehicle that weights 1500 kg the price premium when transported with fuel that costs €100/MWh more than the reference fuel would be (1500 kg * 11.523 €/kg * 0.6%) 103.7 euros.

Table A5. Exports. Price premiums needed per value for technology products.

	Value per kg	Price Premiums Needed per Value of Goods					
		€20/MWh More Expensive Fuel * Utilized.	€60/MWh More Expensive Fuel * Utilized.	€100/MWh More Expensive Fuel * Utilized.	€140/MWh More Expensive Fuel * Utilized.	€180/MWh More Expensive Fuel * Utilized.	€220/MWh More Expensive Fuel * Utilized.
67 Iron and steel	€1.167	0.7%	2.1%	3.5%	4.9%	6.3%	7.7%
68 Non-ferrous metals	€5.414	0.2%	0.5%	0.8%	1.1%	1.4%	1.7%
69 Manufactures of metals, nes	€4.323	0.2%	0.6%	0.9%	1.3%	1.7%	2.1%
71 Power generating machinery and equipment	€12.425	0.1%	0.3%	0.6%	0.8%	1.0%	1.3%
72 Machinery for special industries	€13.523	0.1%	0.3%	0.5%	0.7%	0.9%	1.2%
73 Metal working machinery	€18.573	0.1%	0.2%	0.4%	0.5%	0.7%	0.8%
74 General industrial machines	€13.081	0.1%	0.3%	0.5%	0.8%	1.0%	1.2%
75 Office machines and adp machines	€59.183	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%
76 Telecomm. sound recording equipment	€117.297	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%
77 Electric machinery, nes and parts	€14.580	0.1%	0.3%	0.5%	0.7%	0.9%	1.1%
78 Road vehicles	€11.523	0.1%	0.4%	0.6%	0.9%	1.1%	1.4%
79 Other transport equipment	€37.061	0.0%	0.1%	0.2%	0.3%	0.3%	0.4%

* The reference fuel is MGO. The price premiums of over five percentages (light gray) and over 10 percentages (dark gray) are highlighted in the result tables.

Appendix B. Price Premium with Carbon Pricing

When there is carbon tax of €100 per released fossil CO_2 tonne, the price premiums for a sustainable fuel that costs €20/MWh more than reference fuel are negative, as can be noticed from Table A6.

Table A6. Exports. Price premiums needed per value for Basic manufactures when carbon price is €100 per tonne of CO_2 emissions.

	Value per kg	Price Premiums Needed per Value of Goods					
		€20/MWh More Expensive Fuel * Utilized.	€60/MWh More Expensive Fuel * Utilized.	€100/MWh More Expensive Fuel * Utilized.	€140/MWh More Expensive Fuel * Utilized.	€180/MWh More Expensive Fuel * Utilized.	€220/MWh More Expensive Fuel * Utilized.
61 Leather, dressed fur, etc.	€22.022	0.0%	0.1%	0.1%	0.2%	0.3%	0.4%
62 Rubber manufactures, nes	€6.560	0.0%	0.2%	0.5%	0.7%	0.9%	1.2%
63 Wood and cork manufactures	€0.950	−0.3%	1.4%	3.1%	4.8%	6.6%	8.3%
64 Paper, paperboard and articles thereof	€0.735	−0.4%	1.8%	4.0%	6.3%	8.5%	10.7%
65 Textile yarn, fabrics, made up articles, etc.	€6.583	0.0%	0.2%	0.5%	0.7%	0.9%	1.2%
66 Non-metallic mineral manufactures, nes	€1.345	−0.2%	1.0%	2.2%	3.4%	4.6%	5.8%
67 Iron and steel	€1.167	−0.2%	1.2%	2.5%	3.9%	5.3%	6.7%
68 Non-ferrous metals	€5.414	−0.1%	0.2%	0.5%	0.8%	1.1%	1.4%
69 Manufactures of metals, nes	€4.323	−0.1%	0.3%	0.7%	1.1%	1.4%	1.8%

* The reference fuel is MGO. The price premiums of over five percentages (light gray) and over 10 percentages (dark gray) are highlighted in the result tables.

Appendix C. Sensitivity Analysis

The sensitivity analysis was conducted as a means to present how the results depend on the changed reference fuel (MGO) price. In the sensitivity analysis it was tested that what will happen to price premiums, if the reference priced MGO had different values than what was used in the model throughout the study. As can be seen from Table A7, even if the price of the sustainable fuel is ten times more expensive than the reference fuel (concerning reference price of €20/MWh), the price premiums stay under 10% out of the value of goods transported. This finding clarifies the outcome based on which price premiums are relatively low, when compared to the price difference of sustainable fuel and the reference fuel. The price premiums for the categories of "Machinery, transport equipment" and "Miscellaneous manufactured articles" are encountering price premiums of less than one (1) percentage, even if the sustainable fuel was eleven times the price of reference MGO (€20/MWh). Key finding here is that the absolute price difference between reference fuel (MGO) price and the price of the sustainable fuel is what matters. As can be seen from Table A7, as the price difference is same between reference fuel (MGO) and sustainable fuel, the price premiums are similar. As an example the price premiums on the first and the ninth column (price difference of €120 per megawatt hour), as well as fourth and the second last column (price difference €160 per megawatt hour), the price premium figures are the same. The reason for this can be noticed in Equation (1), which explains that the price difference between the fuels (reference fuel and sustainable fuel) explains the price premiums of selected good categories.

Table A7. Sensitivity analysis for exports.

	Price Premiums for Goods Transported with Alternative Fuels Having Different Price Points.											
	€20/MWh as the Price of Reference MGO						**€60/MWh as the Price of Reference MGO**					
Fuel Price of Alternative Fuel	**€140/MWh. 7X MGO Price. Fuel Price Difference €120/MWh**		**€180/MWh. 9X MGO Price. Fuel Price Difference €160/MWh**		**€220/MWh. 11X MGO Price. Fuel Price Difference €200/MWh**		**€140/MWh. 2.33X MGO Price. Fuel Price Difference €80/MWh**		**€180/MWh. 3X MGO Price. Fuel Price Difference €120/MWh**		**€220/MWh. 3.66X MGO Price. Fuel Price Difference €160/MWh**	
	per kg	**per Value**	**per kg**	**per Value**	**per kg**	**per Value**	**per kg**	**per Value**	**per kg**	**per Value**	**per kg**	**per Value**
0 Food and live animals	€0.057	5.1%	€0.076	6.8%	€0.095	8.5%	€0.038	3.4%	€0.057	5.1%	€0.076	6.8%
1 Beverages and tobacco	€0.058	3.5%	€0.078	4.6%	€0.097	5.8%	€0.039	2.3%	€0.058	3.5%	€0.078	4.6%
2 Crude materials. inedible. except fuels	€0.023	4.8%	€0.030	6.4%	€0.038	8.1%	€0.015	3.2%	€0.023	4.8%	€0.030	6.4%
3 Mineral fuels etc.	€0.028	4.9%	€0.037	6.6%	€0.047	8.2%	€0.019	3.3%	€0.028	4.9%	€0.037	6.6%
4 Animal and vegetable oils and fats	€0.035	3.2%	€0.047	4.3%	€0.058	5.4%	€0.023	2.1%	€0.035	3.2%	€0.047	4.3%
5 Chemicals and related products. n.e.s.	€0.031	3.0%	€0.041	4.0%	€0.052	5.0%	€0.021	2.0%	€0.031	3.0%	€0.041	4.0%
6 Basic manufactures	€0.049	4.4%	€0.065	5.9%	€0.081	7.4%	€0.032	3.0%	€0.049	4.4%	€0.065	5.9%
7 Machinery. transport equipment	€0.085	0.6%	€0.114	0.9%	€0.142	1.1%	€0.057	0.4%	€0.085	0.6%	€0.114	0.9%
8 Miscellaneous manufactured articles	€0.059	0.4%	€0.078	0.6%	€0.098	0.7%	€0.039	0.3%	€0.059	0.4%	€0.078	0.6%
9 Goods not classified elsewhere	€0.046	1.4%	€0.061	1.9%	€0.076	2.4%	€0.030	0.9%	€0.046	1.4%	€0.061	1.9%

The price premiums of over five percentages (light gray) are highlighted in the result tables.

Appendix D. Factors Utilized in the Calculations

Reference	Factor
MERIMA [38]	Emission factor: 3.17 tonnes of CO_2 from tonne of marine fuel in Finnish trade
Faber et al. [30]; Comer and Osipova [42]	Emission factor: 3.206 tonnes of CO_2 from tonne of marine gas oil
Faber et al. [30]	Emission factor: 3.114 tonnes of CO_2 from tonne of HFO
Faber et al. [30]	Emission factor: 2.750 tonnes of CO_2 from tonne of LNG
IMO [45]	Lower calorific value: 42,700 kJ/kg gas oil
Unitjuggler [46]	1 watthour = 3600 joule

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