Effects of fairway dues on the deployment and utilization of vessels: Lessons from a regression discontinuity design

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Abstract

The objective of this paper is to provide empirical insights into how shipowners' fleet deployment decisions are affected by changes in vessel-specific voyage costs. Voyage cost components which are fixed with respect to sailed distance, e.g., port charges or other infrastructure fees, may significantly influence the competitiveness of a maritime transport service, for instance if the level of such costs necessitate a very high degree of capacity utilization. We investigate empirically the effect of charges on the deployment and utilization of vessels in short-sea shipping by using the most recent reform of the Swedish fairway dues system as a natural experiment. Exploiting a stepwise differentiation of fees with respect to size, we utilize a regression discontinuity approach to elicit plausibly causal effects of increased fees on the deployment and utilization of vessels. The results show that increased voyage costs in the form of raised charges lead to affected vessels being deployed on fewer calls but with a slightly higher degree of capacity utilization. Heterogeneity analyses reveal estimates for port calls are larger for small shipowners and for vessels in high-frequency traffic. Overall, the results of the study highlight that charges levied on ships affect the supply structure of short-sea shipping by inducing shipowners to mitigate increased costs through adjusted deployment strategies.

Keywords

Short-sea shipping; Capacity utilization; Fleet deployment; Regression discontinuity; Infrastructure pricing

JEL Codes

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1 Introduction

Voyage cost components which are fixed with respect to trip distance or time, including port fees and other infrastructure charges, are an important factor determining shipping's competitiveness on short-sea voyages (Ng, 2009; Pettersen Strandenes and Marlow, 2000). High levels of dues or charges may disincentivize the use of maritime transport, particularly when volumes are not sufficiently large to support a high frequency of service and when distances are not long enough to recuperate port-related costs through cost savings at sea relative to alternative modes of transport. Fixed voyage cost components may also influence decisions regarding vessel deployment and the utilization of vessels' cargo carrying capacity, since the level of fixed costs determines the minimum level of capacity utilization needed for economic viability. This study investigates empirically the effect of ship-specific voyage costs on the deployment and utilization of vessels, using the most recent reform of the Swedish fairway dues system as a source of cost variation.

The literature concerning fleet deployment is focused on the profit-maximizing or cost-minimizing assignment of vessels to (typically liner) shipping routes using mathematical programming models (Wang and Meng, 2012, 2017; Zhu et al., 2018; Ng, 2015). Common decision variables in the literature are fleet size and composition, route schedules and frequency of service. While port charges are often included in formulating the deployment problem, identical fixed or stochastic values are assumed for modelling purposes. The question of how charges or dues may affect vessel deployment and utilization has not been subject to empirical study. Because such charges may vary by ship type and route, and may significantly impact vessel-specific voyage costs, they ought therefore to be important factors in determining the efficient deployment of a fleet. The purpose of this study is to provide empirical insights into the effects of changed infrastructure charges on the deployment and capacity utilization of cargo vessels across different segments.

As a natural experiment, this study considers the fairway dues charging system in Sweden, focusing in particular on the structure of the system following its most recent reform. The Swedish Maritime Administration (SMA) charges shipowners for the use of fairways, based on several vessel-specific factors including vessel size and the number of port calls. In 2018, the charging system was overhauled when a new set of principles entered into force which for some shipowners meant significantly higher fees. A major difference compared with the previous system was that the unit of vessel size (according to which fees are differentiated) was changed from gross tonnage (GT) to net tonnage (NT) and was no longer measured continuously but instead vessels were sorted into discrete size classes. This charging reform provides an ideal natural experiment to better understand the effects of fixed voyage costs on the deployment and utilization of vessels on a shipping market dominated by short-sea traffic.

The methodology employed to evaluate the impacts of fairway dues on commercial maritime traffic in Swedish ports is a regression discontinuity (RD) approach. The choice of methodology is motivated by the fact that charges in the post-reform years (2018-2020) are differentiated at known cut-off values, and vessels whose size is just above or below these values can be considered good comparisons. Under a set of testable assumptions, the research design allows estimating treatment effects in a non-experimental setting (Lee and Lemieux, 2010). Utilizing quasi-random variation arising from the stepwise fee structure, the research design circumvents problems of endogeneity which arise if vessel charges are affected by the deployment and payload of vessels. Having tested the validity of the RD design, we estimate a set of model specifications and present estimates of fairway dues' impact on vessels' call frequency, tonnes loaded/unloaded per port call, total tonnes loaded/unloaded per vessel and market entry probability. We also investigate the variation in impacts by vessel traffic frequency and among shipowners with single-vessel fleets versus multi-vessel fleets.

The results show that higher scheduled fees[1] induce vessels to be deployed on fewer port calls, indicating that there is indeed an observed negative effect of fees on the deployment of vessels. The estimated effect of higher fees on the capacity utilization of vessels implies that there is a compensating effect in that vessels which face higher fees exhibit a slightly higher degree of capacity utilization. The implied elasticity of annual port calls and volumes carried per port call with respect to fees is -0.58 and 0.17, respectively. Heterogeneity analyses reveal estimates for port calls are larger for small shipowners and for vessels in high-frequency traffic.

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[1] Scheduled fee refers to the level of fairway dues per call assigned to a particular vessel based on factors such as its size and environmental performance rating.

The insights presented have implications for future policy regarding the charging of maritime infrastructure fees, port charges or canal dues. These policy implications are particularly generalizable to countries which use a similar national charging system for maritime infrastructure. The understanding of other policy measures, unrelated to infrastructure charges but relevant in the sense that they impose differential impacts on different types of vessels, may also be enhanced by the results of this study. The proposed (European Commission, 2021) measure of including maritime transport in the European Union's Emissions Trading System (ETS) will, if imposed, lead to different cost impacts for different kinds of vessels. While more specific research on the subject is needed, the results of this study can be taken as an indication of whether and how shipowners will be incentivized to redeploy fleets considering changed vessel-specific voyage costs following the introduction of maritime transport in the EU ETS.

The results also contribute to multiple strands of relevant literature. Determinants of capacity utilization in shipping has been the subject of several studies, including Adland et al. (2018) who study the effects of vessel-specific factors and market conditions on the utilization of capacity in iron ore trades. Others have studied capacity utilization in short-sea shipping, e.g., Styhre (2009) and Hjelle (2011). This paper provides new insights to this literature by studying the effects of vessel-specific fixed voyage costs on capacity utilization. The paper also represents a contribution to the fleet deployment literature (Wang and Meng, 2012, 2017; Zhu et al., 2018; Ng, 2015) by showing empirically the effect of vessel-specific charges on deployment decisions among different shipowners.

The paper is organized as follows: In the following section, we give additional background on the fairway dues reform, which constitutes the natural experiment considered for the analysis. Then, we provide information on the dataset used for our analysis. Following this, we explain and test the validity of our research design, after which we present our results. Finally, we provide a discussion of the results and concluding remarks.

2 Background

2.1 Sweden's fairway dues and other similar charging systems

Sweden's fairway dues system is most readily comparable to the systems of Finland and Estonia, who are the only other EU-countries to charge for the use of fairways on a national basis (Van Essen et al., 2019). The Swedish system in place from 2018 distinguishes between vessel-related fees and fees related to vessels' payload. The level of fees chargeable for a particular vessel is differentiated based on the following factors.

- Ship size. Vessels are categorized by NT and sorted into 10 size groups, the smallest comprising vessels with NT 0 – 999 and the largest comprising vessels with NT 100 000 and up. The level of vessel-related charges increases stepwise with NT according to vessels' classified size group. This is illustrated (for size classes 1 - 7) in Figure 1.

- Ship environmental performance according to registered grade (from A to E) in the Clean Shipping Index (CSI), which is an equally weighted composite of five factors. These factors are CO_2 emissions, emissions of sulphur and particles, emissions of nitrogen oxides, waste management, and handling of chemicals. Vessels with CSI grade A, B and C receive a discount of respectively 90, 70 and 10 % of a portion of the vessel-related charge.

- Frequency of calls per month. Ships are charged at the full (vessel-related fee) rate for two calls per month, at 75 percent for the third call, 50 percent for the fourth call and 25 percent for the fifth call. For the sixth call per month and above, no additional vessel-related charge is levied.

- Cargo and passengers onboard. Specific per-tonne rates are charged for cargo categorized as high-value and cargo categorized as low-value.[2] High-value cargo is charged at a per-tonne rate corresponding to approximately 0.25 EUR, twice the amount charged for low-value cargo. A specific rate amounting to approximately 0.19 EUR is charged per passenger carried.

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[2] The categorization is based on the EU Combined Nomenclature, used in trade statistics and tariffs.

For some freight links, fairway dues account for a small proportion of transport costs. Johansson et al. (2020) found in a report evaluating the 2018 reform that fairway dues accounted for between less than one percent and four percent of maritime transport costs. These shares were calculated for a series of freight links considered representative, though the share of fairway dues as a proportion of transport cost is in some cases significantly higher depending on cargo type, distance and other route characteristics. On average, the level of fairway dues did not change much following the reform, though the effect differed among different shipping segments. The cited report found that bulk and tanker vessels were benefited by the reform while ro-ro, container and general cargo vessels were disadvantaged by higher fees.

The system has also been criticized for not appropriately steering toward a socially optimal utilization of infrastructure capacity through pricing fairway dues at the marginal social cost of ships' infrastructure use. According to Vierth and Merkel (2020), charges per vessel bear little relation to the marginal social costs related to icebreaking, accidents, CO2-emissions or emissions of air pollutants. Despite being the only example of environmentally differentiated fairway dues in the world, the degree to which the Swedish charges internalize the environmental costs of shipping is low. There is also a lack of harmonization with environmental incentives embedded in the charges of individual port authorities. Most large Swedish ports apply some kind of environmental differentiation of fees (Vierth and Merkel, 2020), though these measures are not coordinated with those exercised at the national level. As discussed by Homsombat et al. (2013), pollution disincentives are likely to be more effective when set and charged uniformly rather than individually by competing port authorities. This removes the incentive for port authorities to be less stringent in its pollution control in order to gain a competitive advantage relative to rival ports.

The Finnish fairway dues system is similar to Sweden in that vessel fees are determined based on net tonnage, though fees are also differentiated based on vessels' ice class and capacity utilization. Estonian fairway dues are by contrast based on vessels' gross tonnage, though the charging system is similar to the Swedish system in that there is a maximum number of calls for which vessels can be charged (Backer Johnsen et al., 2020). Both in Estonia and Finland, fairway dues have been reduced as part of policy measures to support shipping. In Finland, fairway dues were halved in response to the implementation of a sulphur environmental control area in the Baltic Sea in 2015, which was expected to increase the cost of shipping. In Estonia, the charging of fairway dues was suspended between April 2020 and March 2021. For the remainder of 2021, fairway dues were reinstated but effectively lowered for high-frequency maritime traffic since the maximum number of chargeable calls per vessel was reduced (Teataja, 2021).

Outside the EU, the U.S. Harbor Maintenance Tax (HMT) is a comparable instrument. The HMT is a funding measure for the maintenance of ports and harbors. It is collected as a share (0.125 percent) of the value of shipped imports. The design of the tax has drawn criticism from researchers (McIntosh and Skalberg, 2010; McIntosh et al., 2015) due to the fact that shipment value is uncorrelated with the costs of infrastructure maintenance and since the tax has generated large surpluses. McIntosh and Skalberg (2010) find that a user fee based on variables such as ship tonnage and draft would be more appropriate.

2.2 Effect of charges on maritime transport supply

Previous literature suggests that the demand for short-sea shipping is relatively inelastic with respect to transport cost (Beuthe et al., 2014; Feo et al., 2011; Merkel et al., 2021), though this varies depending on market conditions and type of trade. Assuming weakly elastic demand with respect to cost, a unilateral increase in fairway dues (which typically represent only a small share of transport costs) will not have a large impact on maritime freight demand.

A question which has been subject to less exploration is what the effects of infrastructure charges could be on the supply of maritime transport. It is possible that changes in levied fees, especially if different vessels and segments are affected differently by changes, will affect the structure of supply by incentivizing changes in the deployment and utilization of vessels. Consider a basic model (Ng, 2015) of a shipowner's vessel deployment, where the objective is to minimize the operating and net chartering costs of assigned vessels:

$$min \sum_k \sum_r c^v_{kr} + \sum_k c^i_k v_k - \sum_k c^o_k w_k \tag{1}$$

Here, c^v_{kr} represents the operational voyage cost of a vessel of type k on route r, c^i_k represents the cost of chartering in a vessel of type k and c^o_k represents the revenue obtained from chartering out a vessel of type k. Finally, v_k and w_k represent the number of vessels chartered in and out, respectively. In other words, the problem is to minimize, subject to a set of restrictions, the sum of operational voyage costs and the net chartering costs. If the level of demand D for all legs on a particular route r is taken as fixed, the required transport capacity on the route is:

$$\sum_k x_{kr} q_k \geq D_r \tag{2}$$

Where x_{kr} represents the number of voyages completed by vessels of type k on route r and q_k represents the carrying capacity of type k vessels. The ship owner determines how many vessels to charter in/out, how many vessels of type k to deploy on route r and what frequency of service to supply. Following this simple formulation, it is easy to conceptualize ways in which changed infrastructure charges, e.g. in the form of fairway dues, would affect fleet deployment.

An increase in fairway dues for a specific ship type k translates into higher associated voyage costs c^v_k on routes including one or multiple Swedish ports, which incentivizes substitution to another feasible ship type either by chartering in/out vessels or by shifting currently owned and chartered-in vessels to/from routes that do not involve as many calls at Swedish ports. The profitability of such a strategy depends on the difference in voyage costs between the type of vessel affected by increased charges and other feasible ships, unaffected by increased charges.

If substitution to vessels unaffected by an increase in charges is economically infeasible, another way of responding to increased fixed voyage costs is to retain the use of vessels of type k but lower the frequency of service. This mitigates costs for the shipowner since a fixed portion of fairway dues are charged per port call. On the other hand, it imposes costs on shippers in the form of increased lead times. Depending on the elasticity of demand with respect to service frequency, this may lead to reduced volumes. If demand is inelastic with respect to service frequency, a lowering of frequency is associated with an increase in capacity utilization.

In the methodology section of the paper, we describe an empirical modelling approach designed to capture the effect of fairway dues on the deployment and capacity utilization of vessels.

3 Data

Our data source is a set of complete records of vessel calls at Swedish ports during the 2016–2020 period, provided by the Swedish Maritime Authority (SMA). For each vessel call, the dataset contains information about the date of arrival, weight of cargo loaded/unloaded, fees paid to the SMA and indicators for nine regional port groups. The data also include a set of vessel characteristics, namely the name of owner, net tonnage, vessel category and the score on the environmental performance index CSI. For each vessel, we collapse the data into yearly outcomes and calculate the total annual number of port calls , total weight of the cargo and the implied average cargo weight per call. Based on the port region indicators, we create dummies for whether the vessel made a call to a port region in a particular year. We calculate the scheduled fee for each vessel in our data set, based on its net tonnage class and CSI score.

For each shipowner, we calculate fleet size by counting the number of unique vessels under ownership. These results are constructed by first determining the number of additional vessels available for the owner of each ship in the sample. This number is calculated based on the number of unique vessels for each ship owner in the data set, over the 2016-2020 period. Although the actual number of additional vessels with the same owner is unobserved, the number calculated here should be a good approximation.

Our main analysis focuses on vessels making port calls in 2018–2020, i.e., the period in which the new fairway dues system was in effect. To analyze any selection of vessels into the analytical sample, we create a variable indicating entry to the Swedish maritime freight market. The indicator equals one for vessels making port calls in 2018–2020 but not in 2016 and 2017. Our sample is restricted to vessels falling into one of three categories: container, roro, and general cargo. We thus omit all other segments of commercial traffic. We additionally trim the data to remove vessels with annual freight volumes below 500 tonnes. The analytical sample consists of vessels with a net tonnage within a bandwidth of 400 from the treatment threshold. To make the sample more homogenous, we restrict attention to the vessels around the first six thresholds of the fairway due system. This restriction removes vessels around the cutoffs at 30,000 NT, 60,000 NT and 100,000 NT.[3] Table 1 shows summary statistics for the post-reform sample and

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[3] A total of 1,002 vessels are dropped, but only 14 of them have a net tonnage within a bandwidth of 400 from

the pre-reform sample. The number of observations (unique vessels) is 2,586 (1,212).

Table 1: Summary statistics

	Mean	SD	Min.	Max.
Log scheduled fee	2.66	(0.85)	1.25	4.96
Port calls	10.66	(17.63)	1.00	196.00
Log freight	9.49	(1.41)	6.23	15.38
Log average freight	7.92	(0.70)	3.59	13.43
Entry (share)	0.18	(0.38)	0.00	1.00
Gross tonnage	4698.71	(5331.07)	1116.00	60876.00
Container (share)	0.05	(0.21)	0.00	1.00
Fleet size	5.11	(13.34)	1.00	65.00
CSI rebate (share)	0.02	(0.12)	0.00	1.00
CSI score	1.50	(12.02)	0.00	139.00
Port region Gävle	0.31	(0.46)	0.00	1.00
Port region Göteborg	0.07	(0.26)	0.00	1.00
Port region Kalmar	0.47	(0.50)	0.00	1.00
Port region Luleå	0.27	(0.44)	0.00	1.00
Port region Malmö	0.50	(0.50)	0.00	1.00
Port region Marstrand	0.18	(0.38)	0.00	1.00
Port region Stockholm	0.38	(0.48)	0.00	1.00
Port region Södertälje	0.25	(0.43)	0.00	1.00
Port region Vänern	0.13	(0.34)	0.00	1.00
N	2586			

Note: The table present variable mean, standard deviation, minimum and maximum. The sample contains the vessels with a net tonnage within a bandwidth of 400 from the treatment threshold. Summary statistics are calculated over all records in the 2018-2020 period.

4 Research design

4.1 Estimation equation

The objective of this study is to estimate the impacts of fairway dues on the deployment and utilization of vessels in Swedish maritime traffic. One challenge when measuring these impacts is that fairway dues are not randomly assigned to vessels. Dues are typically larger the higher the gross or net tonnage of the vessel. We obtain causal identification by exploiting the quasi-variation in fairway dues resulting from the stepwise fee levied by the Swedish Maritime

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a threshold, meaning that the analytical sample is barely affected by this exclusion.

Administration. Figure 1 plots the scheduled fairway dues against the net tonnage of vessels. There are clear jumps at each of the thresholds. The observations located below the steps make up a small subset of vessels subject to a rebate because of high environmental performance. Although the fees are partly determined by vessel characteristics such as size and environmental performance, these factors do not change discontinuously at the net tonnage thresholds. Because the scheduled fee increases discontinuously at the threshold, it is possible to estimate the impact of the scheduled fee using a fuzzy regression discontinuity design.

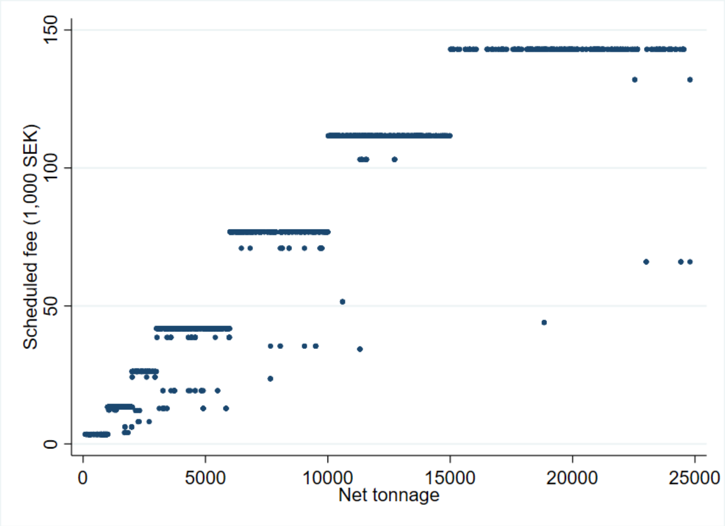


Figure 1: Scheduled fee based on net tonnage

Notes: This figure displays the calculated scheduled fee under the Swedish Maritime Administration's fairway due schedule. The sample consists of all vessels with a net tonnage below 25 000 that made a call in a Swedish port in the post-reform period.

To increase power in the regressions, we pool the data from the six thresholds in the fairway due schedule. We define the running variable to equal net tonnage minus the nearest threshold. Our main specification includes all vessels with a net tonnage within 400 of each threshold. To estimate the effect of the scheduled fee we use the following two-stage least-squares specification:

$$log(Fee_i) = \pi_0 + \pi_1 1(NT_i \geq 0) + f^a(NT_i) + f^a(NT_i) \times 1(NT_i \geq 0) + \delta X_i + e_i \tag{3}$$

$$Y_i = \gamma_0 + \gamma_1 log(\widehat{Fee_i}) + g^a(NT_i) + g^a(NT_i) \times 1(NT_i \geq 0) + \theta X_i + u_i \tag{4}$$

where Y_i is a measure of maritime transport activity for vessel i, NT_i is the normalized net tonnage and Fee_i is the fee facing vessel i according to the Swedish Maritime Administration's schedule. f^a and g^a are two unknown functions assumed to be smooth in the net tonnage. X_i is a vector of controls. Our preferred specification includes the container vessel dummy in X_i. In specification checks we verify the robustness of our results to a larger set of controls. To implement the regression model, we use a second-order polynomial in the running variable and apply a uniform kernel that puts equal weight on observations. Our graphical results use a bin-width of 16 net tonnage to present the data. In robustness checks, we probe the sensitivity of our results to alternative bandwidths, polynomial degrees, and kernels.

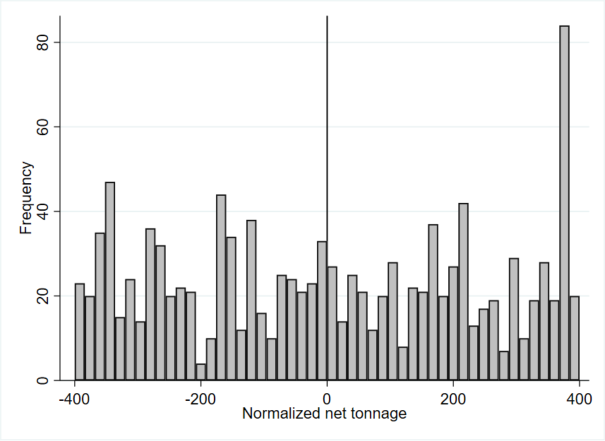
The coefficient of interest γ_1 estimates the impact of the scheduled fee on maritime transport activity. Under the assumption that other determinants of maritime transport activity evolve smoothly at the threshold, the RD estimator of γ_1 measures the local average treatment effect (LATE) of the scheduled fee for vessels with net tonnage equal to the threshold.

4.2 Validity tests

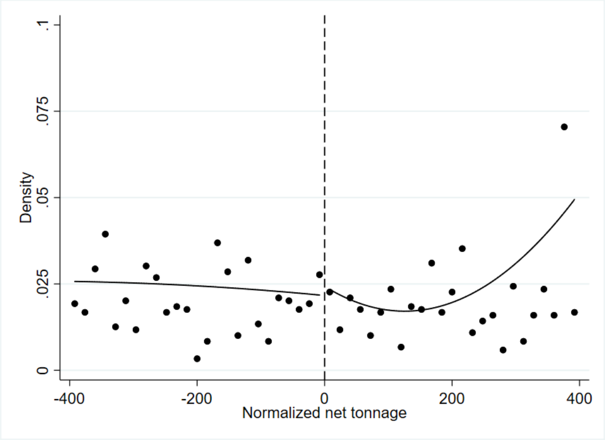
We present three types of tests to validate our RD design. First, we investigate the distribution of observations around the thresholds. One threat to the validity of the RD design is bunching on either side of the threshold. Such bunching could occur since vessels are built using pre-defined weight categories, or if ship owners are able to manipulate vessels' net tonnage classification. Figure 2 shows the distribution of the running variable. There appears to be little bunching at the threshold, consistent with the limited ability of ship owners to manipulate vessel size classification.

Second, we test whether predetermined characteristics of vessels are balanced at the threshold. Panel A of Figure 3 shows the gross tonnage by normalized net tonnage. There is little evidence of systematic changes in this variable at the threshold. Panel A of Table 2 reports regression results checking for discontinuities in all predetermined observables. With the exception of a significant difference in the fleet size and in vessels serving one port region, none of the variables exhibit a statistically significant difference at the threshold.

As a third check we test for discontinuities in maritime transport activity in the period



(a) Panel A: Histogram



(b) Panel B: Density plot

Figure 2: Distribution of running variable

Notes: This figure displays the distribution of normalized net tonnage (net tonnage minus the value of the nearest threshold) around the threshold of the fairway due system. Panel A shows the histogram of normalized net tonnage using a bin width of 16. Panel B plots the frequency of observations by normalized net tonnage using a bin width of 16. The line represents quadratic fits on each side of the threshold. The figures are based on all unique vessels in the sample.

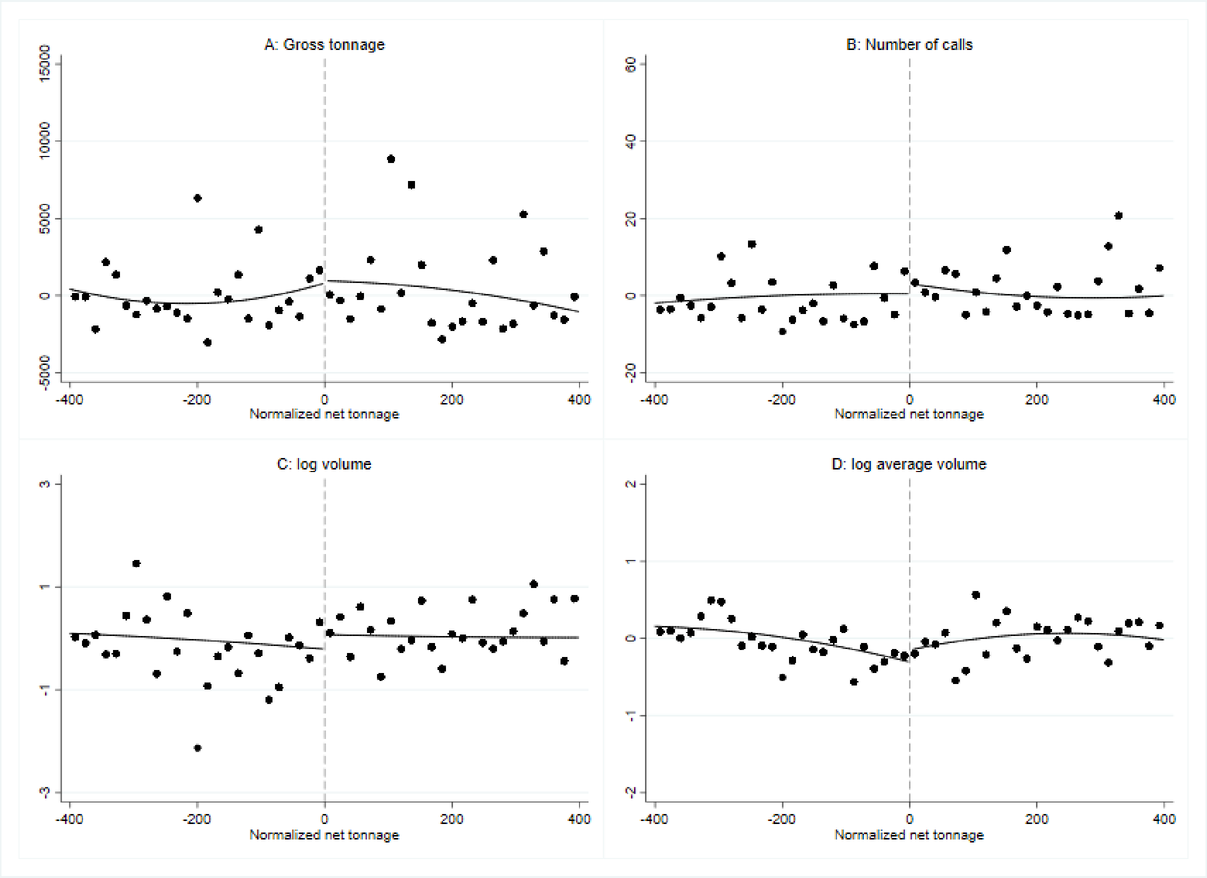


Figure 3: Validity test of RDD

Notes: This figure plots residualized values after controlling for the container vessel indicator , over normalized net tonnage. Points to the left (right) of 0 are below (above) the cutoff for increased scheduled fee. The line represents quadratic fits on each side of the net tonnage cutoff. The points are based on a bin width of 16. Sample refers to vessels within 400 net tonnage of a threshold.

Table 2: Balancing tests

	(1)
Panel A: Background characteristics	
Gross tonnage	173.15
	(1125.03)
CSI rebate (share)	-0.05
	(0.03)
CSI Score	-3.81
	(3.07)
Fleet size	-3.82**
	(1.74)
Port region Gävle	-0.07
	(0.08)
Port region Göteborg	0.06
	(0.05)
Port region Kalmar	-0.05
	(0.09)
Port region Luleå	-0.02
	(0.08)
Port region Malmö	-0.10
	(0.09)
Port region Marstrand	-0.03
	(0.06)
Port region Stockholm	0.10
	(0.08)
Port region Södertälje	0.18**
	(0.07)
Port region Vänern	-0.07
	(0.06)
Pre-reform outcomes	
Number of calls	2.78
	(2.95)
log volume	0.28
	(0.21)
log avg. volume	0.15
	(0.11)

Note: This table shows the regression discontinuity estimate of the effect of being above treatment on the variable indicated in the left column. The estimate is based on the main equation. In Panel A, the sample consists of the 1,174 unique vessels with call records in the 2018-2020 period. In Panel B, outcomes refer to the pre-reform period (2016-2017) and the sample consists of 1,465 vessels observed in both the pre-reform period and the post-reform period. Heteroskedasticity robust standard errors are in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

predating the fairway due schedule. If there are discontinuities in the activity outcomes at the threshold in the period before the fee schedule was implemented, this suggest that other determinants of transport activity change discontinuously at the threshold. Panels B-D of Figure 3 plots the number of calls, average freight volume and total freight volume against the normalized net tonnage. The outcomes refer to the pre-reform period 2016-2017 for the sample of vessels also observed in the post-reform period. There is no evidence of a discontinuity in any of the outcome variables. Panel B of Table 2 corroborates the graphical results: no RD estimate is statistically significant.

5 Results

5.1 Main results

Figure 4 presents graphical evidence on the changes in the scheduled fee at the treatment threshold. There is a significant increase in the fee facing vessels at the threshold. Table 3 shows the first stage estimates based on the main equation using different bandwidths. The scheduled fee jumps by 1.0-1.3 log points depending on bandwidth. The instrument is strong in all specifications, according to the F-statistics displayed at the bottom of the table.

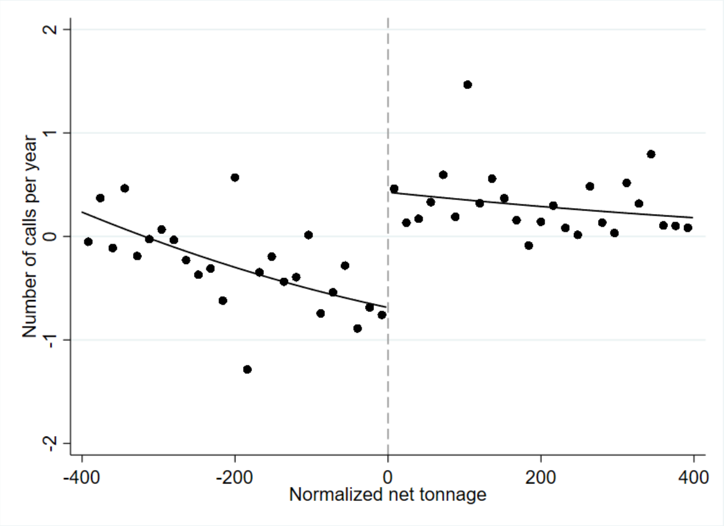


Figure 4: Scheduled fee

Notes: This figure shows residualized values of the log scheduled fee, after controlling for the container vessel indicator, over normalized net tonnage. Sample refers to vessels within 400 net tonnage of a threshold.

Table 3: First stage: Effect on Log Scheduled Fee of Crossing the Threshold

	(1) 100	(2) 200	(3) 300	(4) 400	(5) 500
Above threshold	1.32***	1.01***	1.12***	1.15***	1.34***
	(0.18)	(0.12)	(0.10)	(0.09)	(0.08)
Observations	573	1,173	1,831	2,586	3,333
R^2	0.41	0.33	0.28	0.26	0.25
F-statistic	56.3	64.8	130.5	172.0	277.0

Note: This table presents first stage estimates of being above the threshold on the scheduled fee. The dependent variable is the log of the scheduled fee facing the vessel, based on the Swedish Maritime Adminstration's fairway due schedule. Columns 1-5 present results for the sample of vessels with a net tonnage within 100, 200, 300, 400 and 500 of the cutoff. All regressions include controls for fleet size, regional dummies for the destination port, and an indicator for general cargo vessels. Heteroskedasticity robust standard errors are in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4 shows the RD estimates of the impact of the scheduled fee on our set of maritime transport activity outcomes: number of port calls per year; the average freight volume per call in a year; the total freight volume per year; the probability of market entry. Column 1 shows a negative effect on the scheduled fee on the number of port calls made in a year. A ten-percent increase in the scheduled fee reduces the number of calls by 0.58, which is 5.8 percent of the control group mean. The second columns shows that a higher scheduled fee causes a statistically significant increase in the freight volume per call. The point estimate implies that a ten-percent higher fee raises the average freight volume carried by 1.7 percent. Column 3 present the results for the total freight volume carried over a year. The point estimate suggests a null effect of the scheduled fee but is imprecisely measured. Columns 4 tests if the scheduled fee changes the probability of entering the market. There is no evidence of an impact on the likelihood of market entry.

Table 4: Impact of fairway dues on maritime transport activity

	(1) # calls	(2) log avg. volume	(3) log volume	(4) Pr. Entry
Log(fee)	-5.82**	0.17**	0.03	0.01
	(2.42)	(0.08)	(0.15)	(0.04)
Observations	2,586	2,586	2,586	2,586
R^2	-0.05	0.15	0.01	0.01
Mean dep. var.	10.05	7.89	9.46	0.17

Note: This table presents the estimates from the main RD regression model on four maritime transportation outcomes: number of port calls per year (column 1); log average freight volume per call in a year (column 2); log total freight volume per year (column 3); the probability of market entry (column 4). All regressions include an indicator for container vessels. For each regression, the outcome mean for the control group (vessels below the threshold) is shown. Heteroskedasticity robust standard errors are in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Figure 5 displays graphical evidence of the impacts on maritime transport activity. The graphics confirm the regression-based findings in Table 4. Vessels just above the threshold make fewer port calls and move more freight per call. There is no clear difference in annual freight volumes or entry probability for vessels on either side of the threshold.

The results in Table 4 imply elasticities for port calls and average freight volume of -0.58 and 0.17, respectively. The finding that total volumes per vessel are insignificantly related to the level of ship-specific fees is in line with previous literature estimating the cost or price elasticity of maritime transport demand (Beuthe et al., 2014; Feo et al., 2011), lending support to the hypothesis that the demand for maritime transport overall is fairly inelastic.

5.2 Heterogeneity

This section investigates heterogeneous responses to fairway dues. We begin by examining differences across vessels segmented according to fleet size. Table 5 shows the effect of the scheduled fee on transport activity outcomes, estimated separately for vessels who constitute

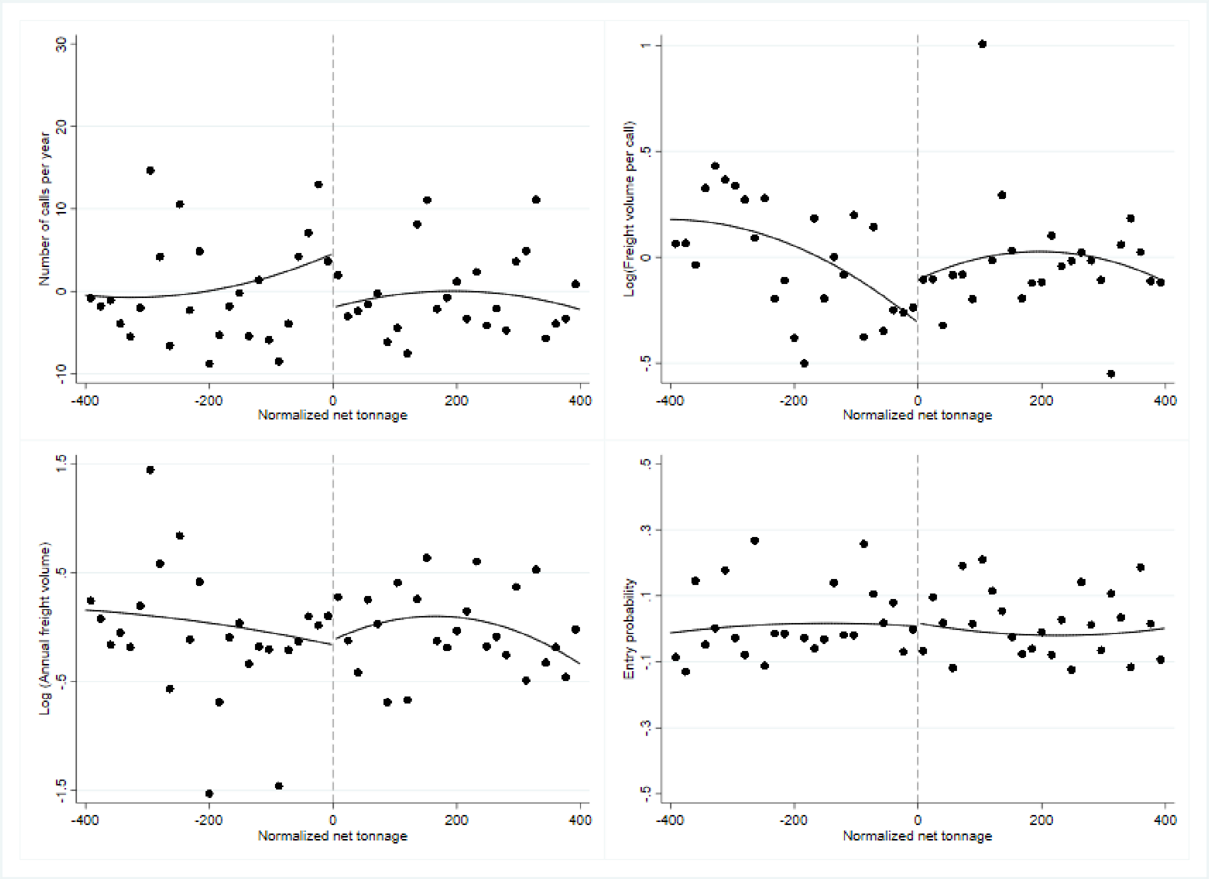


Figure 5: Reduced form: Effects on maritime transport activity at the thresholds

Notes: This figure plots residualized values of the outcomes, after controlling for the container vessel indicator, over normalized net tonnage. Points to the left (right) of 0 are below (above) the cutoff for increased scheduled fee. The line represents quadratic fits on each side of the net tonnage cutoff. The points are based on a bin width of 16. Sample refers to vessels within 400 net tonnage of a threshold the single vessel of an owner and for vessels owned by companies with multiple vessels in their fleet. Results for single-vessel fleets are shown in columns 1-4. The effect on port calls is stronger compared to the main results, with an elasticity with respect to scheduled fee of -0.84. The effect on average freight volumes remains positive but is now statistically insignificant, perhaps because of the reduction in sample size. There is no evidence of an effect on the probability of entry for these vessels. Columns 5-8 display results for vessels in multiple-ship fleets. Impacts on port calls are negative and statistically significant at the ten percent confidence level. The implied elasticity of -0.43 is roughly half the size than that for vessels in single-ship fleets. One possible reason for the heterogeneous response is that fairway dues make up a higher share of total costs for owners of single-fleet vessels compared to owners of multiple vessels.

Table 5: Impact of fairway dues by fleet size

	Single-vessel fleet				Multiple-vessel fleet			
	(1) # calls	(2) log avg. volume	(3) log volume	(4) Pr. Entry	(5) # calls	(6) log avg. volume	(7) log volume	(8) Pr. Entry
Log(fee)	-8.60**	0.09	0.04	-0.06	-4.03*	0.24*	-0.11	0.12*
	(3.89)	(0.10)	(0.20)	(0.06)	(2.10)	(0.13)	(0.25)	(0.07)
Obs.	1,701	1,701	1,701	1,701	885	885	885	885
R^2	-0.09	0.10	0.02	-0.04	-0.04	0.21	-0.02	0.07
Mean	10.25	7.89	9.46	0.17	9.60	7.91	9.46	0.17

Note: This table presents the estimates from the main RD regression model on four maritime transportation outcomes: number of port calls per year; log average freight volume per call in a year; log total freight volume per year; the probability of market entry. All regressions include an indicator for container vessels. Results in columns 1-4 is estimated separately for vessels who constitute the single vessel of an owner. Results in columns 5-8 is estimated separately for vessels owned by companies with multiple vessels in their fleet. For each regression, the outcome mean for the control group (vessels below the threshold) is shown. Heteroskedasticity robust standard errors are in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Next, we investigate heterogeneity depending on vessel traffic frequency. Table 6 displays results for vessels bisected according to call frequency in the pre-reform period. This sample thus consists only of vessels deployed in both the pre- and post-reform periods. It is therefore not possible to obtain estimates for market entry probabilities. Columns 1-3 present results for vessels with below-median port call frequency in the pre-reform period. Columns 4-6 present results for those with above-median frequency. Impacts on port calls are concentrated among vessels in high-frequency traffic. The estimate for this sample is highly precise and considerably larger than that for low-frequency traffic – both in absolute value and relative to the sample average port call frequency. One explanation for the differential responses is that reducing the number of port calls is more costly for vessels which typically make fewer port calls. Ship owners that significantly lower their service frequency may risk losing market shares and negate on pre-committed frequency levels. A given reduction in call frequency makes a greater proportional difference in service frequency for vessels already making few calls.

Table 6: Impact of fairway dues by call frequency

	Low-frequency traffic			High-frequency traffic		
	(1) # calls	(2) log avg. volume	(3) log volume	(4) # calls	(5) log avg. volume	(6) log volume
Log(fee)	-0.27	0.22	0.12	-11.89**	0.08	-0.10
	(0.45)	(0.15)	(0.20)	(4.62)	(0.11)	(0.16)
Observations	1,039	1,039	1,039	1,090	1,090	1,090
R^2	0.01	0.16	0.07	-0.22	0.11	-0.00
Mean dep. var.	2.85	7.84	8.64	18.70	7.87	10.43

Note: This table presents the estimates from the main RD regression model on four maritime transportation outcomes: number of port calls per year; log average freight volume per call in a year; log total freight volume per year; the probability of market entry. All regressions include an indicator for container vessels. Results in columns 1-3 is estimated separately for vessels with below-median call frequency in the pre-reform period. Results in columns 4-6 is estimated separately for vessels with below-above call frequency in the pre-reform period. For each regression, the outcome mean for the control group (vessels below the threshold) is shown. Heteroskedasticity robust standard errors are in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.3 Robustness

In this section, we test the robustness of our findings. First, we check if the results hold up under alternative regression specification choices. Table A1 presents regression estimates for the three main outcome variables using alternative bandwidths and for both uniform and rectangular kernels. Results for the number of calls remain negative and statistically significant across almost all regression specifications. Estimates for the average freight volume carried per call are similar in size across specifications are positive and precisely measured in specifications using a wider bandwidth. According to Table A2, augmenting the main specification by the full set of vessel controls do not alter the results by much. Again, estimates are similar across specifications that use wider bandwidths. Table A3 displays results using alternative bandwidths and polynomial degrees. Impacts on the number of calls are generally robust to the choice of bandwidth and polynomial degree. Results for the average freight volume carried vary across specifications but are positive in all linear specifications. Second, we estimate a set of placebo tests by running the RD model on outcomes in the pre-reform period on the sample of vessels also observed in the post-reform period. During the pre-reform sample period, fairway dues did not increase discontinuously with net tonnage thresholds, meaning any significant results found when applying our RD model on this sample would indicate an underlying problem with our analysis. Reassuringly, there is no statistically significant impact for the placebo sample in Table 7.

Table 7: Placebo test: 2SLS estimate on outcomes in the pre-reform period

	(1) Number of Calls	(2) Log (Avg. volume)	(3) Log (Volume)
Log(fee)	2.23	0.12	0.23
	(2.32)	(0.09)	(0.16)
Observations	1,465	1,465	1,465
R^2	0.01	0.10	0.02
Mean dep. var.	11.10	7.87	9.54

Note: This table presents the estimates from the main RD regression model on four maritime transportation outcomes: number of port calls per year; log average freight volume per call in a year; log total freight volume per year; the probability of market entry. All regressions include an indicator for container vessels. The estimates are based on outcomes in the pre-reform period (2016-2017) for the subset of vessels also observed in the post-reform period. For each regression, the outcome mean for the control group (vessels below the threshold) is shown. Heteroskedasticity robust standard errors are in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

6 Discussion

This study finds that vessels subject to higher infrastructure charges tend to be deployed on fewer port calls and that the average volume of freight loaded/unloaded per port call is increased for these vessels. On the other hand, there is no discernible effect of higher fees on annual carried volumes per vessel. This indicates that ship owners respond to higher fixed voyage costs primarily by reducing the service frequencies of affected vessels. Since the total level of carried volumes per vessel appears unaffected by the level of fairway dues, there is no indication that higher fixed voyage costs necessarily lead to an overall reduction in maritime transport flows.

The results are interesting for a variety of reasons. First, they highlight that in the empirical case of Sweden, the costs of increased fairway dues may have been partly passed on to firms utilizing maritime transport in and out of Swedish ports in the form of reduced service frequency. Service frequency tends to be considered an important factor for freight mode choice and the competitiveness of short-sea shipping (Bergantino and Bolis, 2008; Bergantino et al., 2013). This effect ought to be understood and taken into account by relevant policy makers when faced with future choices regarding the level and structure of levied fees for the use of maritime infrastructure.

To generalize the findings of the paper further, it could be said that the results show empirically how the structure of short-sea shipping supply reacts to changes in vessel-specific voyage costs. The much discussed and recently proposed policy measure of including maritime transport emissions in the EU ETS (European Commission, 2021) would lead to differential impacts for different vessels. To take an extreme example, the suggested breakpoint for inclusion into the ETS in terms of ship size is 5 000 GT, which means that otherwise similar vessels just above or just below this threshold would diverge in terms of operational voyage costs. The results of this paper indicate that such an impact could lead to behavioral changes in terms of fleet deployment in relevant segments of vessel traffic, which ought to be considered when appraising the consequences of such a policy ex-ante.

Secondly, while many studies of demand elasticity (Beuthe et al., 2014; Feo et al., 2011; Merkel et al., 2021) find results which imply only small effects of increased transport cost on the demand for short-sea shipping, the ways in which policy instruments and levied charges affect the structure of shipping supply has been subject to less attention. The results of this study highlight that even if the demand effects of increased charges are negligible, there may be substantial effects on shipowners, who in turn must make appropriate adjustments to continue meeting demand while mitigating increased costs of vessel deployment.

Third, the results indicate differential responses to increased fees across vessel segments. Reductions in port calls are concentrated to owners of single-vessel fleets. The larger responsiveness could possibly be explained by the higher fee representing a larger fraction of ship owners' total cost. Impacts on port calls are also larger for vessels in high-frequency traffic. This could be taken to indicate that there is more room for reductions in service frequency among vessels already providing a higher initial level of service frequency.

7 Conclusions

Voyage cost components which are fixed with respect to trip distance or time are an important factor determining shipping's competitiveness on short-sea voyages. Fixed voyage cost components such as port fees and other infrastructure charges can also be used as policy levers to promote a shift to more sustainable shipping, e.g. through differentiation of charges with respect to vessels' environmental performance. The responses to changes in the level of fixed voyage cost is therefore an important input to policymakers and researchers when designing and appraising policy. This study exploits sharp discontinuities in the Swedish fairway dues system to estimate plausibly causal impacts of charges on maritime transport activity outcomes. We find that higher charges cause a reduction in the number of port calls and an increase in the amount of freight volume carried per call. Interestingly, the impacts are found to vary among smaller/larger shipowners and vessels in low/high-frequency traffic. Effects of charges on the number of annual calls are larger for vessels deployed in high-frequency traffic. Responses to increased charges in terms of reduced port calls are largest within single-ship fleets. Taken together the results highlight complexities in how the structure of short-sea shipping is affected by policies imposing changes in the operational voyage costs of vessels. The results of this study give some insights into how different actors react to a policy measure which affects the level and structure of costs in Swedish short-sea shipping. It should however be highlighted that the main analysis of the study considers a relatively short time span (2018 – 2020) since the current structure of charges was implemented. The reactions to altered costs documented in this study ought therefore to be interpreted as short-term measures, which could differ significantly from measures adopted in the longer run. Given that there is some rigidity in the supply structure of shipping, it is possible that effects of charges on vessel deployment are more pronounced in the longer run. It would be interesting for future research to better understand this issue.

Appendix

Table A1: Sensitivity to bandwidth and kernel

	Bandwidth 500		Bandwidth 400		Bandwidth 300		Bandwidth 200	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Uni	Tri	Uni	Tri	Uni	Tri	Uni	Tri
No. of calls	-5.86***	-6.43***	-5.82**	-7.69***	-8.66***	-9.85***	-11.10***	-6.34
	(1.86)	(2.23)	(2.42)	(2.69)	(2.99)	(3.29)	(4.25)	(3.90)
log avg. volume	0.25***	0.15**	0.17**	0.05	-0.00	-0.06	-0.20	-0.26
	(0.06)	(0.07)	(0.08)	(0.09)	(0.10)	(0.12)	(0.17)	(0.21)
log volume	0.09	0.00	0.03	-0.14	-0.18	-0.25	-0.32	-0.23
	(0.11)	(0.13)	(0.15)	(0.16)	(0.18)	(0.19)	(0.26)	(0.28)

Note: This table presents the results from 24 regressions with varying choice of bandwidth and kernel. The dependent variable is indicated in the left column. The bandwidth is indicated in the top row and ranges from 500 to 200 in increments of 100. The second row indicates whether a uniform (Uni) or triangular (Tri) kernel is used. The number of observations for each choice of bandwidth is 3,333 (bandwidth = 500); 2,586 (bandwidth = 400); 1,831 (bandwidth = 300); 1,173 (bandwidth = 200). Heteroskedasticity robust standard errors are in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A2: Sensitivity to bandwidth and control

	Bandwidth 500		Bandwidth 400		Bandwidth 300		Bandwidth 200	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Full controls	Main	Full controls	Main	Full controls	Main	Full controls	Main
No. of calls	-5.44***	-5.86***	-4.07***	-5.82**	-5.60***	-8.66***	-4.26**	-11.10***
	(1.42)	(1.86)	(1.55)	(2.42)	(1.78)	(2.99)	(1.96)	(4.25)
log avg. volume	0.24***	0.25***	0.19**	0.17**	0.04	-0.00	-0.01	-0.20
	(0.07)	(0.06)	(0.08)	(0.08)	(0.11)	(0.10)	(0.12)	(0.17)
log volume	0.09	0.09	0.08	0.03	-0.13	-0.18	-0.02	-0.32
	(0.10)	(0.11)	(0.12)	(0.15)	(0.15)	(0.18)	(0.17)	(0.26)

Note: This table presents the results from 24 regressions with varying choice of bandwidth and set of controls. The dependent variable is indicated in the left column. The bandwidth is indicated in the top row and ranges from 500 to 200 in increments of 100. The second row indicates whether the regression is based on the main equation or additionally includes the following set of controls: fleet size, CSI score, gross tonnage and regional port indicators. The number of observerations for each choice of bandwidth is 3,333 (bandwidth = 500); 2,586 (bandwidth = 400); 1,831 (bandwidth = 300); 1,173 (bandwidth = 200). Heteroskedasticity robust standard errors are in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A3: Sensitivity to bandwidth and polynomial degree

	BW 500		BW 400		BW 300		BW 200	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	1	3	1	3	1	3	1	3
No. of calls	-2.18	-7.71**	-3.17**	-8.57**	-4.07**	-10.66***	-7.89***	-3.61
	(1.57)	(3.02)	(1.46)	(3.33)	(1.76)	(3.77)	(2.30)	(4.00)
log avg. volume	0.08	0.02	0.19***	-0.06	0.19***	-0.04	0.14*	-0.03
	(0.05)	(0.10)	(0.05)	(0.12)	(0.06)	(0.15)	(0.07)	(0.20)
log volume	0.17	-0.10	0.22**	-0.13	0.09	-0.24	-0.11	-0.17
	(0.11)	(0.18)	(0.10)	(0.20)	(0.11)	(0.23)	(0.14)	(0.30)

Note: This table presents the results from 24 regressions with varying choice of bandwidth and polynomial degree. The dependent variable is indicated in the left column. The bandwidth is indicated in the top row and ranges from 500 to 200 in increments of 100. The second row indicates whether the polynomial degree is 1 or 3. The number of observerations for each choice of bandwidth is 3,333 (bandwidth = 500); 2,586 (bandwidth = 400); 1,831 (bandwidth = 300); 1,173 (bandwidth = 200). Heteroskedasticity robust standard errors are in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

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