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Abstract

Property rights-based management is widely used to improve efficiency in natural resource sectors such as fisheries. In catch share programs, harvesting rights are allocated to individuals or firms and traded in markets, with prices reflecting both economic outlooks and regulatory constraints. To address equity and social concerns, many programs impose restrictions on transferability, such as limits on consolidation, geographic trade, or harvesting technology, which reduce efficiency. Although such tradeoffs between efficiency and social objectives are common, there is limited empirical evidence on how these constraints affect quota valuation, which are often not publicly observable. We analyze how transferability restrictions affect quota values in a large Norwegian catch-share fishery. Using a novel dataset linking all vessel and quota transactions from 2009 to 2017, we estimate a hedonic pricing model that recovers the capitalized value of quota rights embedded in fishing-bundle transactions. This allows us to quantify the equity–efficiency tradeoff associated with Norway's coastal cod quota policy. In particular, we find large and systematic differences in marginal quota values across regulatory groups, where quotas associated with tighter consolidation caps have substantially lower marginal valuations. Geographic restrictions also affect markets, though their effects are modest relative to the impact of consolidation caps.

Keywords: Fisheries; Catch-share systems; Quota valuation; Regulatory constraints; Resource rents
JEL Codes: D40, L10, Q22

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1 Introduction

The global shift toward increased privatization in natural resource industries—such as forestry, water management, land use, and fisheries—has sparked debates over how resource management systems balance economic efficiency and social equity. In fisheries, this shift often takes the form of catch share programs, which assign clearly defined, tradable harvesting rights to individuals or firms. Economists have long prescribed property rights as the preferred tool for managing common-pool resources efficiently. This approach has been widely adopted in fisheries management, although the pace of adopting catch shares in global fisheries has slowed considerably in recent years.[1] Catch share programs have been found to both reduce overfishing and improve the economic efficiency of the fishery, and in some cases, they also contribute to broader societal goals.[2] However, they have raised concerns about who benefits from these programs and how access to the resources is distributed. In many catch-share fisheries, resource managers introduce constraints on quota trade—such as limits on consolidation or geographic restrictions—to mitigate potential negative social outcomes, particularly for fisheries-dependent coastal communities. These regulatory restrictions, motivated by equity concerns, limit trade and often reduce efficiency, thereby lowering the value of harvest rights, which reflects economic value creation, or resource rent, obtained from the fishery. Understanding how such restrictions affect quota prices is essential for evaluating the trade-offs between economic efficiency and broader social objectives in resource management.

In the context of resource management, quota prices reflect both current economic performance and the market's expectation of future profitability. Specifically, they represent the net present value of expected rents given current and future regulations and market conditions. They also serve as indicators of the privatized value of the resource. Despite their importance, public information on quota prices remains limited in most fisheries. This lack of transparency makes it difficult to empirically assess the efficiency of catch shares and to quantify how regulatory constraints, such as restrictions to improve social equity, affect the market valuation of harvest rights. As a result, our ability to evaluate the implications of regulatory design in catch share programs, particularly when balancing economic efficiency with equity objectives, remains limited.

In this study, we build a novel dataset by linking detailed register data from several public sources, covering all vessel and quota transactions in a Norwegian quota-regulated fishery from 2009 to 2017. Leveraging this rich transaction-level data, we estimate a hedonic pricing model to identify how specific regulatory constraints, such as consolidation limits and geographic trade restrictions, affect quota values. Our empirical strategy exploits variation in the design of the management system for Norway's northern coastal cod fishery, a major fishery in terms of both economic value and employment, where quotas are transferable but subject to a range of regulatory restrictions. Because most transactions involve joint transfers of vessels and quotas, we model the value of these fishing bundles to isolate how the market prices harvesting rights under different regulatory regimes. Although vessels often hold quotas for multiple species, cod dominates bundle value, and we control for other quota holdings to isolate the valuation of cod rights.

Our results show that cod quotas have a positive and statistically significant value across all regulatory groups. More interestingly, the marginal value per kilo of cod quota differ sharply by regulatory group from about 25 to 140 NOK per kilogram, with higher values where consolidation is least restricted. These gaps show that consolidation caps substantially depress the capitalized value of harvest rights. Because the market value of harvest rights should reflect the resource rent generated in the fishery, these differences point to substantial efficiency costs of regulatory constraints on consolidation, as reflected in lower capitalized quota values. We show that these results are robust across a wide range of empirical specifications.

We next explore the role of regulations by investigating how geographic restrictions on quota trade affect the market value of quotas. Specifically, we compare quota values between regions facing different trading restrictions. Although the data suggest some regional differences in marginal quota values, the estimates are modest and imprecisely measured. Nonetheless, the differences are consistent with lower quota prices in regions with broader opportunities to purchase quotas from other regions. The results are consistent with geographic trading restrictions contributing to market segmentation and regional differences in quota

[1] See Kroetz, Nøstbakken, et al. (2022) for details.

[2] See e.g., Costello et al. (2008), Grainger and Costello (2016), and Homans and Wilen (2005).

valuation. However, these regional effects are weaker and less precisely estimated than the effects associated with consolidation caps, which emerge clearly and robustly across all specifications. From an efficiency perspective, when marginal values differ across regions, reallocating quota from lower- to higher-valued fishers would increase overall resource rent generation.

Regulatory restrictions on trade are a common feature of tradable permit programs, including those for air pollutants, water quality, and fisheries (see e.g. Tietenberg, 2007). Such restrictions—whether through spatial segmentation, sectoral boundaries, or consolidation limits—can reduce efficiency by limiting gains from trade (Stavins, 1995). Recent empirical studies show how program design features can impede trading, as in Chinese carbon trading pilots with partial sector coverage (Munnings et al., 2016) and California's groundwater adjudication, which imposed spatial and temporal limits on rights trading (Ayres et al., 2021).[3] We add to this literature by estimating how consolidation limits and geographic trade constraints shape quota valuations.

Equity concerns are prevalent in tradable permit programs, as documented by Narassimhan et al. (2018) in their review of emissions trading systems, which highlights mechanisms like free allocation and revenue earmarking to address distributional and competitiveness issues. Another way equity objectives can be pursued is through trading restrictions. In a study closely related to ours, Kroetz, Sanchirico, et al. (2015) examines a policy experiment in the Alaska halibut and sablefish fisheries, where both restricted and unrestricted permits were issued. They find that trading restrictions reduce resource rents by up to 25%. Our study complements and extends this work in several ways. First, we analyze a different institutional setting where quota prices are not publicly observable. Instead of relying on market price data, we use a hedonic valuation approach based on detailed tax register data to estimate the capitalized value of quotas embedded in vessel and quota bundle transactions. This allows us to quantify the market's valuation of quotas under different regulatory restrictions, even in the absence of transparent quota markets. Second, we examine a different set of regulatory restrictions and quantify their effects across multiple sub-markets. In doing so, we contribute to a growing literature that quantifies the efficiency costs of integrating social objectives into tradable permit systems.

Our research also contributes to the literature on the determinants of quota prices in catch share programs. Prior empirical studies have shown that quota prices reflect expectations about future resource rents, and are influenced by factors such as the status of fish stocks, catch limits, and market conditions (see e.g., Newell et al., 2005; Jin et al., 2019). Although the theoretical literature has long recognized how regulatory constraints can affect economic efficiency and quota prices in catch-share fisheries (Arnason, 2012), there are relatively few empirical studies that quantify these effects. We add to this literature by estimating quota values in a fishery where transfers are constrained by multiple regulatory restrictions. Using a hedonic valuation approach and a novel and rich dataset of public register data, we infer quota values from vessel transactions in one of Norway's most economically important fisheries. In doing so, we provide new evidence on how regulatory design affects quota price formation in practice, and contribute to the ongoing policy debate about the future of the Norwegian quota system.

Distributional equity is a central concern in the design of catch share programs, both internationally and in Norway. While these programs are credited by economists with improving economic efficiency and reducing overfishing, they have also been criticized for causing disruptive social effects and for generating an unequal distribution of benefits across stakeholder (Abbott et al., 2022; Birkenbach et al., 2019). Hoshino et al. (2020) review the effectiveness of individual transferable quotas (ITQs), a type of catch shares, in achieving multiple fisheries management objectives. The study finds that, while ITQs have led to some social benefits, these are often unevenly distributed. Similarly, Abe et al. (2024) show that a quota consolidation scheme has led to increased ownership concentration and geographic concentration in the Norwegian cod fishery. Our study contributes to this literature by using a novel approach to estimate the capitalized value of resource rents in a setting where quota prices are not publicly observable. By linking regulatory constraints to differences in quota valuation, we offer new empirical evidence on how policies motivated by social equity objectives, such as consolidation caps and geographic trade restrictions, affect both the distribution and efficiency of resource use. These findings are relevant to ongoing debates about how to design market-based resource management

[3] See also the early work on tradable emissions permits and geographic segmentation by Gangadharan (2004).

systems that are both economically efficient and socially inclusive.

This paper proceeds as follows. In the next section, we describe the Norwegian coastal cod fishery, with emphasis on the quota system and the regulations governing catch share trade, which are important for our analysis. Section 3 presents the theoretical framework, where we model vessels as differentiated factors of production and introduce our hedonic pricing approach to estimate the value of catch shares. Section 4 outlines the dataset, while section 5 details our empirical strategy. Section 6 reports the main results, and section 7 concludes by summarizing our findings and discussing their policy implications.

2 The Northern Coastal Fishery for Cod

Permits for harvest, emissions and production are common tools for regulating economic activity in many markets. These permits are often made tradable subject to constraints such as limits on the geographic extent of trade and ownership caps, that reflect broad policy goals. Prices are explicit in many of the markets—for example in emissions trading and water rights—and in these cases, factors that influence valuation are well studied. In contrast, most fisheries managed under catch shares systems lack publicly available quota prices, primarily due to data scarcity. Consequently, empirical evidence on quota valuation and the role of regulatory design in shaping market and distributional outcomes remains limited.

The Norwegian fisheries management system is comprehensive and data rich. The coastal fishery for cod north of the 62nd parallel north, hereafter referred to as the (northern) coastal cod fishery, is one of the most economically important fisheries in Norway. It is suitable for an empirical study of price formation in markets with indirect prices and the influence of regulations because of the large fishing fleet and relatively high volume of transactions during the period we study (2260 transactions between 2009 and 2017, comprising 1751 unique vessels that changed hands), its importance for coastal communities, and the social regulations that govern the fishery. Because of its prominent social role, both historically and today, the fishery is often the main focus in discussions about how the Norwegian quota system can be redesigned to improve efficiency while maintaining social equity. In the following, we describe the aspects of the fishery and the regulatory framework that are relevant for our analysis.

2.1 Regulatory Groups and Harvest Allowances

Vessels participating in the cod fishery can be divided into an oceangoing and a coastal fleet. In the coastal fishery, access restrictions were implemented in 1990 following stock collapse. Access permits were allotted to eligible vessels, and harvest restrictions determined by vessel length and historical catches. The fishing ground mainly covers the coast off Norway's northernmost counties: Nordland, Troms, and Finnmark. Coastal vessels are generally smaller than the oceangoing trawlers and use conventional gear such as nets and longlines, which is why the fleet is often referred to as the conventional coastal fleet. Vessels typically target three main species of fish: cod, haddock and saith, with cod being the most valuable. In 2019, the coastal fleet landed cod worth NOK 3 billion (roughly 260 million euros), which amounted to 14 percent of the total value of all wild-caught fish landed in Norway. For saithe and haddock, the corresponding values were NOK 342 million (34 million euros), and NOK 29 million (3 million euros), respectively.[4]

Every year, part of Norway's total allowable catch (TAC) of cod, haddock and saith is first allocated between two regulatory categories of vessels: those that fish using conventional gear and the trawlers.[5] The conventional group's share increases when the TAC is lower — a mechanism proposed by the fishers' association in 1989, which argued that since trawlers are more mobile, they are better able to switch to other species when the cod stock is low. Among the conventional vessels, there is an open group, a group for conventional oceangoing vessels, and the coastal group. The coastal group receives the majority share of TAC for all three species. In 2016, the coastal fleet received 165 thousand tonnes of Norway's total cod TAC of 334 thousand tonnes, while the trawling group was allotted 102 thousand tonnes.

[4]We have converted NOK to Euros using the average exchange rate for 2019 (NOK/EUR = 0.103).

[5]Norway's TAC is determined in negotiations with Russia based on recommendations from the International Council of the Exploration of the Sea (ICES).

Originally, when the cod fishery was closed in 1990, there was only a single coastal group consisting of all vessels below 28 meters (the length above which they were considered oceangoing vessels) sharing the coastal fleet's TAC. In 2002, this group was subdivided into four subgroups based on physical length, and each regulatory group received a share of the coastal group's TAC under a system known as the 'Finnmark Model'[6] The reform aimed to make the distribution of the quota base fairer across vessels sizes and contribute to the overarching political objective of preserving a diverse coastal fleet. Since then, regulators have used the groups to influence the fleet structure by allocating catch share and applying differential regulation, such as different quota consolidation levels.

In 2009, the basis for assigning vessels to regulatory groups changed from actual physical length to the 'license length' associated with each vessel's quotas. The license length reflects the physical length of the vessel to which the quota was registered when the Finnmark model was introduced in 2002. Since then, vessels may have been upgraded or replaced, or quotas transferred to other vessels. As a result, the actual physical length of a vessel may now differ from its license length, which is given by the quota it holds. In some cases, the actual vessel length even exceeds the initial maximum length of 28 meters. For example, a 27–meter vessel may hold a quota with a license length of 12 meters, and thus belong to the 11–14.9 meter regulatory group. The 2009 change therefore made group membership largely independent of current vessel characteristics. From 2009 to 2017, group membership was demarcated at license lengths of 10.9, 14.9, 20.9, and 27.9 meters.

The proportion of the national TAC for cod allocated to the conventional coastal group is distributed across these four groups, with relative shares remaining stable over time. The regulatory group with license lengths under 11 meters receives the largest share of the TAC, while the group with license lengths between 20.9 and 27.9 meters receives the smallest. Most vessels, however, belong to the smallest length groups. In 2017, for instance, the TAC for the conventional coastal fleet was roughly 200 thousand tonnes of cod. Of this, the four groups—ordered by increasing license length—could harvest 53, 52, 51, and 34 thousand tonnes of cod respectively.[7] For reference, the smallest group included around 1100 vessels, while the others comprised 334, 126 and 60.

An individual vessel's share of the TAC is determined by the number of quota units (QU) it holds.[8] Every QU is tied to an access permit for the fishery.[9] The number of QUs attached to each access permit varies, both across different permits and, for a given permit, according to the species covered. In the coastal cod fishery, an access permit will typically have QUs for a bundle of species; cod, haddock, and saithe. The more QUs a vessel holds, the larger the share of the regulatory groups' TAC for these species it receives, and the more it is permitted to harvest. There is, however, no fixed relationship between a vessel's QUs and how much cod it can harvest. To determine the harvest allowance of a vessel in tonnes, its QUs must be multiplied by a conversion key.[10]

In principle, the conversion key can be calculated by dividing the collective quota (TAC) of the regulatory group, measured in tonnes, by the aggregate number of QUs in the fishery (NOU 2016: 26). In practice, however, the key is contingent not only upon the regulatory group of the license, but also on the actual physical length of the vessel that holds the license. Further, the Directorate of Fisheries sets the conversion keys dynamically throughout the fishing season and over the years to ensure that the entire TAC is caught for each group. The conversion key therefore can vary across regulatory groups, within groups, during the fishing season, and from year to year. Note that the differences between conversion keys within the regulatory

[6]The grouping was based on a proposal from the Finnmark branch of the Norwegian fishers' association. The quota system was originally designed such that quota and vessel sizes were integrated, with group membership and quota shares determined by physical vessel length. For details on the distribution of quota shares in 2002, see §3 of *Forskrift om regulering av fisket etter torsk med konvensjonelle redskap nord for 62° N i 2003* [Regulation on the cod fishery with conventional gear north of 62° N in 2003] (FOR-2002-12-18-1683).

[7]See *Forskrift om regulering av fisket etter torsk med konvensjonelle redskap nord for 62° N i 2017* [Regulation on the cod fishery with conventional gear north of 62° N in 2017] (FOR-2016-12-21-1826)

[8]Quota unit is a term we have translated from the Norwegian term *"kvotefaktor"*, which is used, for example, in the statute regulating the coastal cod fishery (Forskrift om regulering av fisket etter torsk, hyse og sei nord for 62° N i 2023, 2023)

[9]Access permits are granted to the owner of a vessel, and apply only to that specific vessel for a specific fishery, as stipulated in Section 4 of the Participation Act (Deltakerloven, 1999), the law that regulates the commercial harvest of Norwegian fish stocks.

[10]Referred to in Norwegian as a *"kvoteenhet"* in the regulations.

groups are typically much smaller than between the groups. Also, in 2017, all regulatory groups except the one under 11 meters had identical conversion keys within groups.[11]

In Table 1 we show how the average conversion key has changed during our study period for each of the four regulatory groups. On average over the period represented, a single quota unit from the smallest regulatory group corresponds to a higher catch allowance than quota units from the other groups. This pattern likely reflects that overallocation of individual quotas relative to the group quota is typically greater in the smallest group than in the others.[12]

Table 1
Average Yearly Conversion keys, by Regulatory Group in the Northern Coastal Fishery for Cod

Year	**Under 11 m.**	**11–14.9 m.**	**15–20.9 m.**	**21–27.9 m.**
2009	16.7	14.4	14.4	13.6
2010	21.1	18.5	17.9	18.2
2011	21.1	18.5	17.9	18.2
2012	22.5	19.1	19.1	19.5
2013	30.4	25.1	25.1	23.7
2014	26.3	25.2	25.2	24.2
2015	28.7	22.4	22.4	21.2
2016	18.2	20.1	21.8	20.7
2017	20.7	18.9	19.4	17.6
Average	22.9	20.2	20.4	19.7

Note. Source is Directorate of Fisheries, authors' own calculations. Conversion keys are used to convert a vessels' quota units to allowed catch, measured in tonnes.

2.2 Quota Consolidation

When the coastal fishery for cod was closed in 1990, it was not possible to consolidate QUs on a single vessel. However, fishers could increase their total quota holdings by acquiring additional vessels with associated quota and operating them alongside their existing vessels.[13] In 2004, however, the Norwegian Ministry of Trade, Industry, and Fisheries, introduced new regulation allowing fishers to consolidate QUs registered to

[11]The following example illustrates how harvest allowance is calculated. Consider a vessel in the regulatory group for vessels with a license length below 11 meters that holds two QUs, around the average for vessels in the fishery in 2017. The roughly 1100 participating vessels collectively held around 2600 QUs in 2017, and this means that a vessel with two QUs had a share of the group's total QUs amounting to 0.0008%. In the 2017 fishing season, the smallest regulatory group was allocated 53 thousand tonnes, which means that an even distribution of the TAC entails a theoretical conversion key of about 20 tonnes per QU. In 2017, vessels were classified into four subgroups in the regulatory group under 11 meter, depending on their actual length, and the distribution key was equal to 23.39 tonnes per QU for vessels with an actual length and a license length below 11 meters. For vessels with an actual length between 11 and 12,9 meters, and a license length below 11 meters, a QU amounted to 18.56 tonnes.

[12]Overallocation refers to a regulatory practice in which the sum of vessel-level quotas within a fleet segment exceeds the segment's aggregate quota. This approach is typically employed when participation in the fishery is uncertain or heterogeneous, allowing regulators to set individual limits that ensure full utilization of the group quota without needing to adjust the total quota or to halt fishing before the end of the year.

[13]For the oceangoing vessels, there are also owner-level consolidation limits. Currently, no such limits apply to quota ownership in the coastal group, and the Ministry of Trade, Industry and Fisheries justified this based on an assessment from 2007 which showed low national ownership concentration levels (Auditor General, 2020)

vessels in the regulatory groups above 14.9 meters, making vessel-level quota consolidation possible in these regulatory groups. This change expanded the possibilities for quota transferability, specifically by enabling fishers in the two regulatory groups above 14.9 meters, to consolidate quota units registered to multiple access permits onto a single vessel. To use this option, all vessels from which they transferred quota had to be permanently removed from the fishery. The ministry introduced this reform to reduce excess capacity in the fishery, while restricting consolidation to the largest groups to preserve a diverse fleet structure. Accordingly, the regulatory system governing quota transferability became known as the structural quota scheme (SQS), with quota units transferred under the scheme referred to as 'structural quotas'. A similar scheme (*Enhetskvoteordningen*) was introduced in the offshore fleet, starting with the cod trawlers in the period 1990–1994.

The amount of QUs a vessel can accumulate is limited by quota caps. These caps were imposed by the ministry to control the rate of consolidation in the coastal fleet.[14] When the SQS was introduced in 2004, the cap for the vessels with a license length above 14.9 meters was initially set at three times the original quota. In 2007, following a pause in the SQS, fishers could also consolidate QUs on vessels in the 11–14.9 m regulatory group, but with a lower cap—twice the original quota. In the largest regulatory groups, the cap was lowered for coastal vessels with quota in both the pelagic and demersal fisheries, while those specializing in either fishery could consolidate up to the previous cap. The caps were lowered in an attempt to mitigate possible negative consequences of quota consolidation for local communities, such as reduced landings and barriers to entry for new fishers (Auditor General, 2020). Between 2007 and 2017, the cap has been raised twice for both groups, in 2013 and 2017.

Table 2 gives an overview of the development of the caps. See Abe et al. (2024) for a more in-depth account of the development of the SQS and its effect on quota consolidation in the coastal cod fishery.

Table 2
Overview Quota Caps Between 2004 and 2017

Year	**Event**	**Regulatory Group**	**Quota Cap**
2004	SQS introduced	$\geq$ 15 m.	3 + 3
2005	Structural pause (no quota consolidation)	All vessel groups	
2007	SQS reintroduced with lowered cap	$\geq$ 15 m.	3 + 1 or 2 + 2
2007	SQS introduced for vessels between 11 and 14.9 m.	11–14.9 m.	2 + 1
2013	Cap raised	$\geq$ 15 m.	4 + 2 or 3 + 3
2013	Cap raised	11–14.9 m.	2 + 2 or 3 + 1
2017	Cap raised	$\geq$ 15 m.	6 + 2 or 4 + 4
2017	Cap raised	11–14.9 m.	3 + 3 or 5 + 1

Note. A consolidation cap of 3+3 implies that a vessel is allowed to triple both its demersal and pelagic quota through consolidation. A cap of 2+1 means that a vessel can double its quota in one of the fisheries.

In table 3, we report the share of vessels that at the end of the year were capped by the quota consolidation restrictions when the SQS first was introduced in 2004 until 2018. Note that we report numbers from all three regulatory groups that could consolidate quota, but the quota caps are identical for vessels in the 15-20.9 m, and 21-27.9 m regulatory groups. For vessels in the 11–14.9m regulatory group, we report no values prior to 2007, as consolidation was not possible. In 2008, six percent of vessels in this group were restricted from further consolidation by the quota cap—–a sharp contrast to the relatively low share in the two other groups for the years after the introduction of the SQS. One explanation for the difference could be that the fishers in the smallest group were more prepared to consolidate quota, having observed the development in

[14]The restriction is stipulated in the regulation for the quota system in the coastal fishing fleet (Forskrift om spesielle kystfiskekvoteordninger, 2004)[Regulation on Special Quota Arrangements for the Coastal Fishing Fleet].

the other groups. Another explanation could be that since this group had been the most restricted, potential gains to consolidation were largest here.

Table 3
Capped Vessels, 2004 to 2018, by Regulatory Group

	11–14.9 m			**15–20.9 m**			**21–27.9 m**		
Year	Vessels	Capped	Share (%)	Vessels	Capped	Share (%)	Vessels	Capped	Share (%)
2004*				413	0	0.00	137	1	0.73
2005				338	0	0.00	117	1	0.85
2006				242	2	0.83	106	5	4.72
2007*	604	0	0.00	229	2	0.87	104	4	3.85
2008	519	33	6.36	227	9	3.96	102	9	8.82
2009	506	38	7.51	208	14	6.73	99	9	9.09
2010	500	44	8.80	201	14	6.97	93	12	12.90
2011	463	65	14.04	193	18	9.33	86	15	17.44
2012	451	72	15.96	182	19	10.44	80	15	18.75
2013*	428	7	1.64	167	0	0.00	79	1	1.27
2014	406	19	4.68	163	5	3.07	67	2	2.99
2015	378	21	5.56	148	7	4.73	63	3	4.76
2016	346	28	8.09	137	10	7.30	60	5	8.33
2017*	334	2	0.60	126	0	0.00	60	0	0.00
2018	333	6	1.80	120	4	3.33	50	1	2.00

Note. Yearly development of coastal fishing vessels participating in the fishery for cod north of 62° N that have reached the maximum number of quotas.
Data source: Auditor General of Norway and the Norwegian Directorate of Fisheries.
* Consolidation cap changed.

Only QUs from the same fishery and regulatory group can be consolidated. In practice, this means that QUs registered to an access permit for the coastal cod fishery with license lengths within the same regulatory group may be combined. For example, a fisher operating a vessel in the 11–14.9 meter regulatory group can purchase another vessel with an access permit from the same group and consolidate the quotas on one vessel, provided they scrap the other.[15] They can also distribute QUs among multiple vessels, provided the vessels hold access permits in the same fishery.

In 2015, the regulator allowed fishers to transfer access permits and the associated quota units directly, rather than through vessel transactions.[16] The change aimed to simplify the process of acquiring access permits, enabling fishers to acquire QUs without having to also purchase vessels. Fishers wanting to consolidate QUs on one vessel still needed to decommission the vessels from which they removed the quota.

Vessel-level quota consolidation comes at a cost. When a quota is first consolidated onto another vessel's quota base, 20 percent of the transferred QUs are deducted from the system. This reduces the remaining

[15] Fishers are free to transfer access permits with QUs between vessels they own, conditional on the receiving vessel meeting minimum operational standards. To avoid scrapping high–value vessels, fishers can therefore transfer QUs to low value vessels, consolidate QUs on the vessel they intend to operate, scrap a less valuable one, and resell the high-value vessel.

[16] This was implemented through an amendment to the Participation Act (Deltakerloven, 1999).

number of QUs the group's TAC is divided by, thereby raising the conversion factor applied to each QU, and increasing its share of the TAC. The deduction mechanism serves two purposes: first, the additional harvest allowance for each QU means that some of the consolidation benefits accrue to the regulatory group as a whole. Second, it aims to discourage excessive concentration of QUs on a single vessel and thereby supporting regulatory objectives for maintaining a balanced fleet structure.

QUs added to a vessel's base quota are classified as *structural* and are subject to sunset provisions. These structural QUs are distinct from the indefinite *base* QUs, to which they are added. Structural QUs registered after 2007 lapse after 20 years, whereas those registered before 2007 lapse after 25 years, counted from 2008. A vessel may therefore hold different sets of structural QUs with different sunset provisions. Upon expiry, structural quotas are set to be redistributed among the vessels in the regulatory group, with the first such return set to occur at the end of 2026. This combined benefit—comprising the initial increase in TAC share from the deduction and the eventual redistribution upon expiry—is often referred to as the *structural gain* for vessels in the regulatory group.

QUs with a license length under 11 meters cannot be consolidated in the manner described above. The regulatory authorities have justified the exclusion of the smallest fleet from the SQS by emphasizing its importance for sustaining employment and settlement in Norway's rural coastal regions. However, fishers have been permitted to use the harvest allowance of two vessels on a single vessel under the so-called *co-fishing scheme*.[17] The scheme was introduced as a temporary measure to improve profitability and operational safety for small-scale fishers in 2010 (NOU 2016: 26, 2016, p. 52). It enabled two fishers, each operating a small vessel, to pool their harvest allowance on a single vessel. For the 2011 fishing season, regulators authorized self co-fishing, allowing fishers to pool QUs from two vessels they owned onto one active vessel. While this change made the co-fishing scheme functionally similar to the SQS, fishers wishing to consolidate quota still needed to keep both vessels approved and operational.[18]

In figure 1, we show the development of vessels participating in the co-fishing scheme over time. The number of co-fishing vessels has increased every year since the scheme was introduced in 2010. By 2017, 55% of active vessels in the under 11 m. group participated in the co-fishing scheme. More than half of these vessels were under the same ownership.

2.3 Vessel and Quota Markets

The quota market is closely linked to the vessel market in the coastal cod fishery. In the vessel market, fishers can purchase new vessels from a shipyard or purchase a used one. A fisher buying a new vessel for participating in the coastal cod fishery typically transfers QUs from an existing vessel they own, or they buy used vessels from other fishers with QUs that they transfer. Used vessels with access permits and QUs are purchased either to be used directly by the buyer, for transferring to another vessel, new or used, or for consolidation of QUs. A fisher without an existing access permit and QU must purchase a vessel that holds both to participate in the coastal cod fishery.[19] Only active fishers are allowed to own vessels with an access permit to the coastal fishery for cod.

A geographical restriction on trading access permits was introduced alongside the SQS in 2004. Until 2016, both buyer and seller of a vessel holding an access permit to the coastal cod fishery had to have resided in the same county for at least twelve months prior to the transaction. The intention was to avoid geographical shifts in quota ownership as a result of the SQS, upholding regional objectives in the Marine Resource Act (2009). A permanent exemption applied to fishers residing in the *special region*, consisting of Finnmark and a set of designated municipalities in northern Troms county.[20] Fishers in this region were allowed to

[17]Known as *Samfiskeordningen* in Norwegian.

[18]Regulations require that passive vessels remain registered and approved for participation in the coastal cod fishery, so owners must maintain two vessels to preserve the ability to consolidate quota. See Endring i forskrift om torskefisket (2011) [Change in regulation on the cod fishery with conventional gear north of 62° N in 2011] for regulatory details.

[19]New permits are only granted for recruitment purposes under strict conditions.

[20]Known in Norwegian as "*Tiltakssonen i Finnmark og Nord-Troms* in Norwegian, comprising one of the seven municipalities in the northern part of Troms county and all of Finnmark county. Trade was also allowed between fishers living in counties that, in regulatory terms, were considered part of the same region.

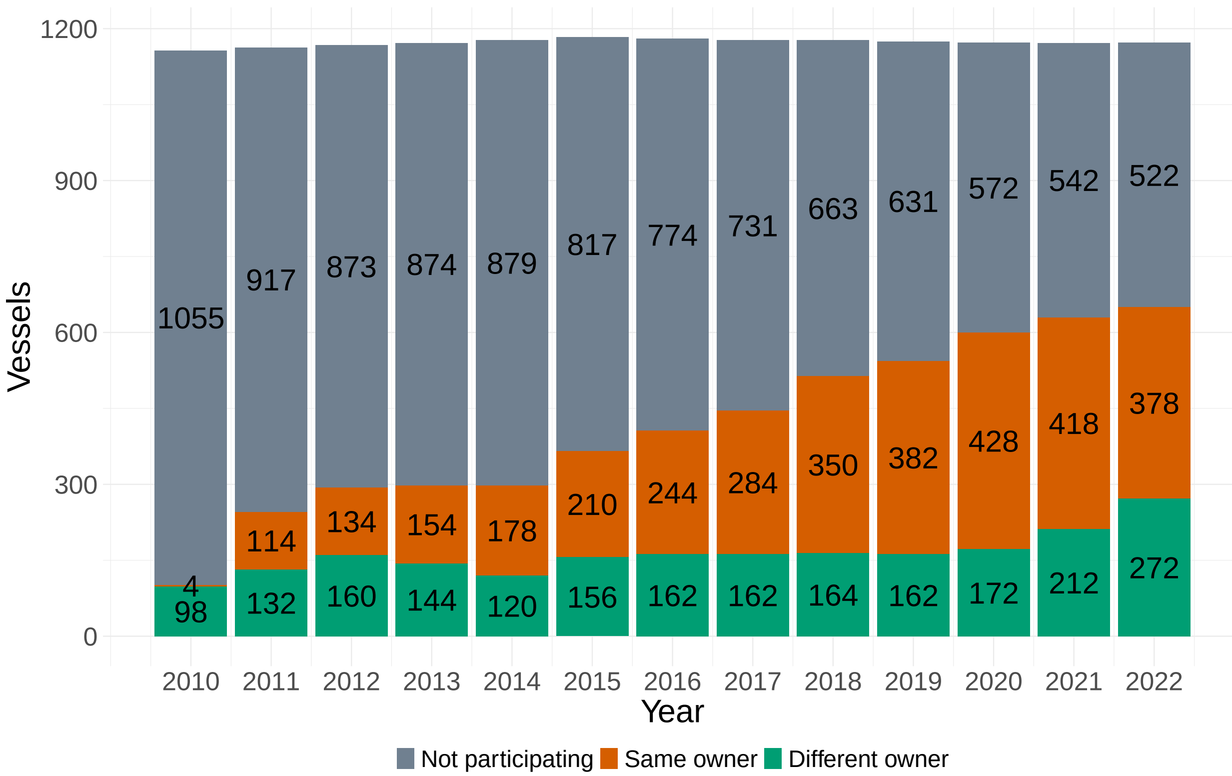

Figure 1: Vessels Participating in the Co-fishing Scheme by Participation Type
Note. In 2010, there were four vessels registered with the same owner participating in the scheme, despite this not being officially allowed that year. Source: Directory of fisheries, authors' own illustration.

purchase vessels with cod quota from any county. The exemption was intended to facilitate quota inflows and support economic activity in the northernmost coastal communities.

In June of 2016, the county-based restriction were replaced with a broader north–south division of the country.[21] Under the new system, cod-quota vessels could be purchased freely within each of the two larger regions, while fishers in the special region continued to have unrestricted access to vessels with quota from all regions. According to regulators, the change was meant to increase flexibility in the fishing industry and reduce administrative costs, without significantly altering the geographical distribution of vessels participating in the coastal cod fishery. These regulatory features later allow us to examine whether and to what extent broader access to quota supply lowers local quota values in Section 5.

3 Theoretical Model

In this section we develop the theoretical framework that underpins our empirical analysis of quota valuation. We employ a hedonic pricing approach, where we conceptualize transactions involving vessels and quotas as *fishing bundles*. Our objective is to estimate the market value of quota units by decomposing the observed book value of fishing bundle transactions. In the next subsection, we formalize this approach by extending the hedonic methodology to the context of catch share valuation in a single-species fishery.

3.1 Catch Share Valuation in a Hedonic Framework

Our analysis builds on the hedonic modeling framework, as established by the empirical work of Griliches (1961) and the theoretical contributions of Rosen (1974). Following the strand of literature that emerged from Palmquist (1989) on the treatment of land parcels in agriculture, we treat fishing bundles as differentiated factors of production, with their characteristics determining productive capacity. The components of these bundles—vessels and quotas—are themselves composite factors of production. Vessels have characteristics such as engine type and length, while quota is defined by the number of QUs for a single species.[22]

A key motivation for our approach is that, for most of our study period, changes in quota ownership were only possible through changes in the ownership of the vessel to which the quota was registered. Consequently, the transaction values we observe reflect the joint value of two separable and differentiable production inputs, traded together as a fishing bundle. While vessels can be traded independently, quota units are only transferred alongside vessels, creating an implicit market for quota that operates through the explicit vessel market. Unlike land-attached permits in hedonic land pricing models (e.g., Petrie and Taylor, 2007), quota units in our setting are not permanently tied to a specific vessel. Once acquired, they can be reallocated to other vessels, making the bundling constraint temporary and specific to the point of exchange. We therefore treat QUs both as a distinct productive input traded together with the vessel and as a constraint on agents' production—in our case, harvest allowance. To the best of our knowledge, this is a novel approach within the hedonic literature.

The theoretical foundation for the transactions values we observe is the hedonic price function, $P(\cdot)$ defined over the characteristics of the bundled assets. Let $\mathbf{Z} = \{z_1, \ldots, z_n\}$ denote the vector of vessel characteristics and let q denote the number of quota units bundled with the vessel. Because vessels and QUs are separable inputs whose value derive from distinct production attributes, we can write the hedonic price function as:

$$P(\mathbf{Z}, q) = P_v(\mathbf{Z}) + P_q(q), \tag{1}$$

where $P_v(\mathbf{Z})$ is the implicit value of the vessel and $P_q(q)$ is the implicit value of the associated QUs. This additive structure reflects the assumption that the components of the fishing bundle are technologically separable and trade in a market in which buyers and sellers take the hedonic schedule as given. The function $P(\mathbf{Z}, q)$ is determined in equilibrium by the interaction of all buyers and sellers of fishing bundles. We next describe the formation of this long-run market equilibrium in the fisheries context.

[21] After 2016, the three northernmost counties formed one region, while all others formed the southern region. The special region lies entirely within the northern region and remained exempted.

[22] In practice, quota units may be structural and time-limited, represent multiple species, and be subject to different regulatory constraints, all of which may affect their productive capacity.

Consider a fisher wishing to participate in a single-species fishery regulated by a total allowable catch (TAC) and individual catch shares. Participation requires assembling a fishing bundle consisting of vessel and quota. The vessel is characterized by a vector of productive attributes (e.g., engine type), $\mathbf{Z} = \{z_1, \ldots, z_n\}$, while harvest rights are determined solely by the amount of quota, q, measured in quota units. The observed transaction value of a fishing bundle therefore depends on both $\mathbf{Z}$ and q through the hedonic price function, $P(\mathbf{Z}, q)$.

We assume the existence of a well-functioning rental market for vessels and quotas.[23] Let $R_v = R_v(P_v(\mathbf{Z}))$ and $R_q = R_q(P(q))$.The total rental value of a fishing bundle is therefore:

$$R(\mathbf{Z}, q) = R_v(\mathbf{Z}) + R_q(q). \tag{2}$$

We assume that all relevant vessel characteristics are observable to renters and that vessels can be rented without institutional or contractual constraints. As in hedonic models of land markets (e.g., Palmquist, 1989), where land parcels may enter or exit agricultural use depending on relative returns, vessels may enter or exit the fishery depending on the equilibrium rental return they offer. The number of potential fishers is also endogenous: as rental prices adjust, some agents choose alternative occupations.

The total quantity of quota Q is fixed within each season and determined by the fishery's TAC. We assume a competitive quota market where QUs, representing shares of Q, can be freely rented, traded, and reallocated across vessels owned by the same fisher, subject only to the regulatory constraint that transfers must occur simultaneously with a vessel transaction. In this setting, any agent can in principle participate in the fishery by assembling a fishing bundle from the two markets. Fish harvest is sold in a competitive output market at an exogenous price p.

A participating fisher's harvest depends on the inputs employed. In line with standard fisheries economics (see e.g., Clark, 1990), we model harvest as a function of effort. Let $\mathbf{X} = \{x_1, ..., x_m\}$ denote non-vessel inputs such as labor (crew) or days at sea. Effort is given by $E = g(\mathbf{X}, \mathbf{Z})$, where g is increasing and concave in each argument, with $x_i \geq 0$ and $z_j \geq 0$ for all i, j. Harvest is then $h = f(E)$, where f is increasing and concave. Although stock size is an important determinant of harvest in bioeconomic models, we abstract from stock dynamics here to focus exclusively on the equilibrium valuation of productive efforts within the hedonic framework. This assumption is justified in sustainably managed fisheries where stock levels are relatively stable, as is the case in our empirical application over our study period.

3.2 The Fisher's Maximization Problem

Fishers seek to maximize profits from participating in the fishery. A potential renter observes a fishing bundle consisting of a vessel with characteristics $\mathbf{Z} = \{z_1, \ldots, z_n\}$, and a quota allowance q. The fisher combines this vessel with non-vessel (variable) inputs $\mathbf{X} = \{x_1, ..., x_m\}$ to generate effort, which through the harvest function is then translated into harvested fish. Because the fishery operates under a TAC, we assume that individual quota constraints bind in equilibrium: each fisher harvest exactly up to their quota allowance, so $h = q$.

To examine the fishers willingness to pay for a fishing bundle—and in particular, for quota units—we consider the fisher's profit maximization problem in three steps. First, we determine optimal use of non-vessel inputs for a vessel with fixed characteristics and a given quota allowance, yielding what we call *operating profits*. Second, we consider how the fisher adjusts vessel characteristics, taking the optimal use of non-vessel inputs as given; the resulting *vessel profits* equal operating profits minus the rental cost of the vessel. Finally, we examine the optimal choice of quota q, given optimal vessel characteristics and their associated rental costs.

The first two steps follow the hedonic literature on land valuation. However, our setting introduces a binding output constraint, quota, which itself is a characteristic of the fishing bundle. The shadow price of relaxing this constraint is central to our analysis.

[23]This assumption simplifies the analysis by allowing us to express equilibrium conditions in terms of flow values rather than capital stocks and is, under standard competitive assumptions, analytically equivalent to an explicit treatment of the full capital market for vessels and quotas.

Step 1: Choosing non-vessel inputs

Given a fishing bundle with vessel characteristics $\mathbf{Z} = \{z_1, \ldots, z_n\}$ and quota allowance q, the fisher chooses non-vessel inputs $\mathbf{X} = \{x_1, ..., x_m\}$ to maximize operating profits. Operating profits equal revenue from harvested fish, sold at market price p, minus the total cost of non-vessel inputs $\sum_{i=1}^{m} c_i x_i$, where c_i are input prices taken as given. Harvest is determined by $h = f(E(\mathbf{X}, \mathbf{Z}))$ and is constrained by the quota allowance q. Because the TAC binds, we assume harvest equals quota in equilibrium. The fisher's optimization problem can then be formulated as:

$$\max_{\mathbf{X}} \quad \pi_{op} = hp - \sum_{i=1}^{n} c_i x_i \tag{3}$$
$$\text{s.t.} \quad h = f(E(\mathbf{X}, \mathbf{Z})) = q$$

Substituting for h in (3), the problem reduces to:

$$\max_{x} \quad \pi_{op} = p \cdot f(E(\mathbf{X}, \mathbf{Z})) - \sum_{i=1}^{m} c_i x_i \tag{4}$$
$$\text{s.t.} \quad f(E(\mathbf{X}, \mathbf{Z})) = q$$

The corresponding Lagrangian is:

$$\mathcal{L} = p \cdot f(E(\mathbf{X}, \mathbf{Z})) - \sum_{i=1}^{m} c_i x_i - \lambda(f(E(\mathbf{X}, \mathbf{Z})) - q) \tag{5}$$

Where λ is the shadow value of relaxing the quota constraint. As we show below, λ represents the fisher's marginal willingness to pay for an additional quota unit.

The first order conditions yield demand functions for non-vessel inputs:

$$x_i^* = x_i(p, \mathbf{Z}, c_i, q), \quad i = 1, ..., m. \tag{6}$$

Given a vessel with characteristics $\mathbf{Z}$, the fisher adjusts non-vessel inputs, such as crew, fuel, or days at sea, to maximize operating profits subject to the quota constraint. Substituting these optimal non-vessel input demands into the objective function yields the optimized operating profit function $\pi_{op}^*(\mathbf{Z}, q)$, which represents the maximum profit attainable for a vessel with characteristics $\mathbf{Z}$ and quota allowance q.

Step 2: Choosing vessel characteristics

In the second step, the fisher chooses vessel characteristics $\mathbf{Z}$, taking as given the optimal non-vessel input choices from Step 1. Vessel profits equal operating profits minus the rental cost of the vessel:

$$\begin{aligned} \pi_v(\mathbf{Z}, q) &= \pi_{op}^*(\mathbf{Z}, q) - R_v(\mathbf{Z}) \\ &= p \cdot f(E(\mathbf{X}^*, \mathbf{Z})) - \sum_{i=1}^{m} c_i x_i(p, \mathbf{Z}, c_i, q) - R_v(\mathbf{Z}) \end{aligned} \tag{7}$$

where the second line expands π_{op}^* into its structural components.

The fisher chooses the vector $\mathbf{Z}$ to maximize $\pi_v(\mathbf{Z}, q)$ as given by (7).

$$\begin{aligned} \frac{\partial \pi_v}{\partial z_i} = \frac{\partial \pi_{op}^*}{\partial z_i} - \frac{\partial R_v(\mathbf{Z})}{\partial z_i} &= 0 \\ \frac{\partial R_v(\mathbf{Z})}{\partial z_i} &= \frac{\partial \pi_{op}^*}{\partial z_i} \end{aligned} \tag{8}$$

The first-order condition in (8) shows that a fisher chooses each vessel characteristic so that its marginal rental cost equals its marginal contribution to operating profits. Because non-vessel inputs are themselves chosen optimally in Step 1, this marginal contribution is evaluated holding fixed the optimal input mix implied by the quota constraint. This result mirrors the standard hedonic interpretation of willingness to pay for characteristics in land or housing markets, but with an important difference: in our setting, the quota constraint directly shapes the optimal demand for non-vessel inputs, which in turn affects the marginal profitability of vessel characteristics. As a result, quota interacts with vessel characteristics through the production technology, altering their implicit value in equilibrium.

Building on this condition (8), note that vessel characteristics enters the non-vessel input problem in Step 1 as parameters. The envelope theorem therefore implies:

$$\frac{\partial \pi^*_{op}}{\partial z_i} = \frac{\partial \mathcal{L}}{\partial z_i},$$

where $\mathcal{L}$ is the Lagrangian in (5). Substituting the expression for $\mathcal{L}$ yields:

$$\frac{\partial R_v(\mathbf{Z})}{\partial z_i} = p\frac{\partial h(\cdot)}{\partial z_i} - \sum_{j=1}^{m} c_j \frac{\partial x^*_j}{\partial z_i} - \lambda \frac{\partial h}{\partial z_i}$$

This expression highlights the channels through which vessel characteristics affect profits. Characteristics that increase harvest productivity ($\partial h/\partial z_i > 0$) raise revenue and therefore command higher rents. Characteristics that reduce demand for costly non-vessel inputs ($\partial x^*_j/\partial z_i < 0$) also increase profitability. Both channels are dampened by the quota constraint through the shadow value λ, which reduces the marginal value of characteristics that increase potential harvest when quota is binding.

To illustrate, consider the age or efficiency of a vessel's engine. Improvements in fuel efficiency reduce fuel use per unit of harvest, implying $\partial x^*_{\text{fuel}}/\partial z_i < 0$, so the characteristic receives a positive marginal rent in equilibrium $\partial R_v/\partial z_i > 0$. Similarly, hull improvements that enhance operational performance—by improving stability, ease of handling, or effective time fishing—raise harvest for a given level of inputs, implying $\partial h/\partial z_i > 0$. More generally, vessel characteristics that lower input requirements or increase effective effort will have a positive implicit price in the hedonic function.

Step 3: Choosing quota

We now consider the fisher's willingness to pay for quota. Let $z^*_i(q)$ denote the optimal choice of vessel characteristic i when the quota allowance is q, and let $\mathbf{Z}^*$ be the vector of these optimal choices. Substituting $\mathbf{Z}^*(q)$ into (7) yields the optimized vessel-profit function:

$$\pi^*_v(q) = \pi_v(\mathbf{Z}^*(q), q). \tag{9}$$

This function captures the maximum attainable profit from jointly optimizing over non-vessel inputs (Step 1) and vessel characteristics (Step 2), conditional on holding q units of quota.

In the final step, the fisher chooses quota to maximize total profits net of quota rental costs. The fishers' quota choice problem is:

$$\max_{q \geq 0} \quad \pi(q) = \pi^*_v(q) - R_q(q). \tag{10}$$

Assuming differentiability, the first-order condition is:

$$\frac{\partial \pi}{\partial q} = \frac{\partial \pi^*_v}{\partial q} - \frac{\partial R_q(q)}{\partial q} = 0$$

Because $\pi^*_v(q)$ depends on quota both directly and indirectly through the optimal vessel characteristics, differentiating π^*_v yields:

$$\frac{\partial \pi^*_v}{\partial q} = \frac{\partial \pi^*_{op}}{\partial q} + \frac{\partial \pi^*_{op}}{\partial \mathbf{Z}} \cdot \frac{\partial \mathbf{Z}^*}{\partial q} - \frac{\partial R_v}{\partial \mathbf{Z}} \cdot \frac{\partial \mathbf{Z}^*}{\partial q}$$

However, from step 2 (equation 8) we know that, at the optimum,

$$\frac{\partial \pi^*_{op}}{\partial \mathbf{Z}} = \frac{\partial R_v}{\partial \mathbf{Z}}.$$

These terms cancel out, leaving:

$$\frac{\partial \pi^*_v}{\partial q} = \frac{\partial \pi^*_{op}}{\partial q}.$$

After the cancellation noted above, we obtain the following optimality condition:

$$\frac{\partial R_q(q)}{\partial q} = \frac{\partial \pi^*_{op}}{\partial q}$$

A fisher will therefore choose quota such that its marginal rental price equals the marginal contribution of quota to operating profits. Because the optimization over vessel characteristics in Step 2 already satisfies the first-order conditions, the envelope theorem implies that any indirect effect of quota on vessel rental costs—operating through adjustments in optimal vessel characteristics—is already internalized in the fisher's choice. Only the direct marginal effect of quota on operating profits matters for determining the optimal quota level.

If the quota rental cost is linear, $R_q(q) = r_q q$, and noting that $\partial \pi^*_{op}/\partial q = \lambda$ from Step 1, the rental price condition simplifies to:

$$r_q = \lambda \tag{11}$$

This equation shows that the fisher's willingness to pay for an additional unit of quota equals the shadow value of relaxing the harvest constraint, that is, the marginal increase in maximum operating profits from expanding the quota allowance.

Equilibrium and hedonic interpretation

In equilibrium, a profit maximizing fisher is willing to pay a rental price for a fishing bundle such that the conditions derived above are satisfied. The hedonic rental schedule for bundles, $R(\mathbf{Z}, q)$, results from the interaction of many such fishers and bundle owners, each of whom may supply or demand bundle characteristics depending on relative prices and their own valuation.

On the supply side, owners provide vessel characteristics and quota units at prices determined in their respective markets, and respond to bids from prospective renters. From the owner's perspective, some characteristics—such as engine type or hull type—are fixed in the short run, while others—such as the number of quota units attached to a vessel—are choice variables. Owners adjust endogenous characteristics to maximize rental income, subject to adjustment costs. In equilibrium, the marginal cost of adjusting a characteristic equals its marginal contribution to the bundle's rental value.

Agents in this market may participate on both sides: a fisher who already owns a bundle may demand additional characteristics (e.g., more quota) if the marginal value exceeds its market price, or supply characteristics if the opposite is true. Thus, equilibrium prices reflect the aggregation of marginal valuations across a population of heterogeneous agents who simultaneously constitute the supply and demand for bundle characteristics. All agents take the hedonic price schedule as given.

In practice, we observe transaction prices for vessel-quota bundles in our data. Within our theoretical framework, these transaction values correspond to the capitalized analogue of the equilibrium rental price $R(\mathbf{Z}, q)$. Our empirical objective is to recover the implicit prices of bundle characteristics, with particular focus on estimating the marginal implicit price of quota, r_q. This allows us to infer the market valuation of quota units conditional on vessel characteristics and other observables. Following (Palmquist, 1989), we treat the observed transaction prices as points on the hedonic price schedule for a differentiated factor of production, the fishing bundle, where each bundle is priced according to its attributes. In the next section, we describe how we assemble our transaction data.

4 Data

To carry out the hedonic analysis, we construct a transaction dataset for the coastal cod fishery by combining register data from the Directorate of Fisheries with annual tax records from the Norwegian Tax Authorities. This section describes the two primary data sources, our matching procedure, sample selection and cleaning rules, and the final transaction sample used in the empirical analysis.

4.1 Primary Data Sources

We use detailed tax records covering the universe of individuals and firms registered with fishing as their primary occupation or industry from 2009 to 2017. These records report asset values by category (e.g., vessels, quota), and in some cases the historical acquisition cost. Since vessels are depreciable while most quotas are not, fishers sometimes have incentives to inflate the reported vessel component of the bundle. Moreover, not all entities report vessel and quota values separately. For these reasons, we rely on the total book value of asset transactions for each tax entity and year. We adjust the reported book values for inflation to reflect 2015 Norwegian Kroner (NOK) using the Consumer Price Index (CPI).

The Directorate of Fisheries provides complete vessel and quota ownership histories. Each vessel is identified by a vessel ID, its owners by personal or organizational identifiers, and ownership periods by validity dates. We link quota holdings to vessels through the Directorate's vessel–quota registry, which records which quota units are attached to each vessel at any point in time. From these records we construct a comprehensive timeline of vessel ownership, vessel characteristics at the time of transfer (e.g. length, width, hull material, engine power), and the set of QUs associated with the vessel at each transfer date.

Vessels can carry QUs belonging to only one regulatory length group at any given time. However, vessels themselves are not technologically tied to specific groups; the group assignment derives entirely from the attached QUs and access rights. This is crucial for our empirical strategy and motivates comparing quota valuations across groups after controlling for vessel characteristics.

4.2 Constructing the Transaction Dataset

We merge the vessel-quota ownership records with the tax data using the unique owner identifiers. We match asset acquisitions to vessel and quota transfers by year, generating an initial dataset of ownership changes with associated book values. Because these matched entries may not perfectly reflect arm's-length transactions, we apply a set of rules to identify genuine market transactions. These rules are based on vessel and quota registries, ownership histories, and name matching. For example, we remove transfers between family members and cases in which a vessel changes organizational form without an economic sale.

To ensure accuracy, we conduct extensive manual reconciliation. This includes correcting mismatched years, removing records incorrectly registered as vessels or quotas, and adjusting implausible book values.[24]

The final dataset contains one observation per tax entity per year in which at least one vessel is transferred. Each observation represents the transaction of a "fishing bundle": the vessel(s) traded and all quota units attached at the time of transfer. For our study of the coastal cod fishery, we restrict the sample to transactions that include at least one access permit for coastal cod, while also retaining transactions for vessels that at any point during our sample period held such a permit.

4.3 Quota Units and Regulatory Attributes

For each transaction, we record the number of quota units traded, distinguishing cod quota by regulatory group. Each vessel hold only one quota type at any given time (i.e., belong to only one regulatory group), but transactions involving multiple vessels may include several groups. Of the 2,260 transactions in our sample, 454 involve multiple vessels, and 75 of these included more than one cod-quota type. Several transactions also include quota from other coastal fisheries, such as herring and mackerel.

[24]Most discrepancies originate in tax reporting. For unusually high or low reported values, we cross-reference public sources (industry news, company websites) to verify reported sale prices or infer reasonable adjustments. We manually adjusted approximately 200 transactions and removed about 50 entries.

We also observe whether a quota unit is structural, meaning that it has previously been consolidated and is subject to a sunset clause. Because structural QUs yield income only for a limited number of remaining years, their economic value differs from that of base QUs, which are of indefinite duration. In our empirical analysis, we account for these differences through a lifetime adjustment described in detail in Section 5.

Table 4 summarizes the number of transactions by quota category and type. Roughly half of all observed transactions involve cod quota. The 11-14.9 meter regulatory group records the highest number of sales involving structural quota, while the largest regulatory length group has the greatest share of structural units among its transfers. Because structural quotas are added to base quotas, the second column in Table 4 reports the number of vessels transferred with any cod quota—either base alone or base plus structural. Several transactions also include quota units for other species, most commonly herring, saithe, and mackerel, reflecting the multi-species nature of the coastal fleet. Units for six additional species appear in the "other" category. The diversity of species-specific quota holdings underscores the importance of accounting for non-cod quota when estimating bundle values.

Table 4
Vessels with Quota Holdings in Transaction Data

Quota Category	Base	Structural	Total
Under 11 m	799	0	799
11-14.9 m	210	175	385
15-20.9 m	86	113	199
21-27.9 m	26	56	82
Herring	96	74	170
Saithe North	65	55	120
Mackerel	123	16	139
No quota			1414
Other			102

Notes: Structural quota units are added on top of base units; column three shows transactions with both types. There are quotas from 6 regulatory groups in the "Other" category. Vessels with quota units from the Saithe North regulatory group fish for saithe in the North-East Atlantic ocean. We have combined quota units from the coastal groups for mackerel. The herring category contains quota units for the fleet fishing for Norwegian spring spawning herring.

Descriptive statistics for the main variables in our dataset can be found in table 5. The mean transaction value (in 2015 NOK) is approximately NOK 8.5 million, with substantial heterogeneity across vessels. This variation reflects the diversity of the coastal fleet: our data include sales of new vessels nearly 50 meters long, as well as vessels below 6 meters built in the 1970s. The number of transactions increases over time, from 198 in 2009 to 321 in 2017. Within each regulatory group, the number of quota units traded varies widely, and the largest regulatory groups exhibit the greatest variation.

TABLE 5
Descriptive Statistics for Transaction Dataset

Variable	Desc.	Mean	Std. Dev.	Min.	Max.
Tax value	Book value of combined transaction assets in NOK	8,554,970	24,014,411	10,262	678,085,380
Length	Length of vessel in meters	18	14	5.2	212
Width	Width of vessel in meters	5.6	4.1	1.6	62
Vessel age	Years since construction	35	31	0	440
Engine power	Engine horse power	396	420	10	5,204
Under 11 meter quota	Quota units in the under 11 meter regulatory group	0.76	1.3	0	11
11-14 group quota	Quota units in the 11-14.9 meter regulatory group	0.98	2.9	0	31
15-20 group quota	Quota units in the 15-20.9 meter regulatory group	1	4.4	0	71
21-27 group quota	Quota units in the 21-27.9 meter regulatory group	0.58	3.5	0	39
Mackerel quota	Quota units for mackerel	0.2	1.3	0	26
Herring quota	Quota units for herring	1.2	6.1	0	93
Saithe quota	Quota units for saithe	0.13	0.66	0	7.5
Hull Material	Material type of vessel hull: wood, plastic, alloy, steel or aluminum				

Note. 454 (20%) of the 2260 transactions contain multiple vessels.

4.4 Additional Sample Characteristics

Our dataset includes both single-vessel and multi-vessel transactions. The tax records are annual, so when a buyer acquires multiple vessels within the same calendar year, the book values cannot be assigned to individual vessels. We therefore treat these observations as multi-vessel transactions and aggregate vessel characteristics accordingly—for example, summing widths or hull counts across vessels. This approach is consistent with our interpretation of each observation as a purchased "fishing bundle" whose productive capacity is determined by the combined characteristics of the vessels and the attached quota units.

Table 6 compares average characteristics across single- and multi-vessel transactions. The two groups are similar in most physical attributes and in average transaction value per vessel. The most notable difference concerns quota holdings: more than half of the single-vessel transactions involve no cod quota, compared to roughly 16% in multi-vessel transactions. Because this difference may influence our valuation of quota, we later estimate specifications on subsamples defined by quota presence and by transaction type.

Table 6
Average Vessel Characteristics, by Single-and Multiple-Vessel Transactions

	Single vessel	**Multiple vessels**
Observations	1806	454
Value (mill. NOK)	6.98	5.84
Vessels	1.00	2.47
Quota units under 11 m	0.49	0.66
Quota units 11-14.9 m	0.63	0.90
Quota units 15-20.9 m	0.68	0.77
Quota units 21-27.9 m	0.39	0.57
No quota	1021	72
Age	25.75	28.68
Width	4.31	4.42
Engine power	303	315

Note. Multiple-vessel transactions refer to cases where, within a calendar year, a tax entity acquires more than one vessel. Because the tax data report only annual aggregate acquisition values, these observations may reflect several underlying transactions, but individual transaction-level values cannot be separately identified. All characteristics other than "No quota" are expressed as per-vessel averages within each subsample. For multiple-vessel observations, total bundle characteristics are divided by the number of vessels to ensure comparability with single-vessel transactions. The "No quota" row reports the number of vessels transferred without any quota.

Quota units differ in the number of tonnes of cod they represent, depending on regulatory group and year. We therefore compute group-specific conversion keys using the average tonnes-per-QU from the three years preceding each transaction. These keys vary within and across years due to changes in TAC shares and seasonal adjustments. Converting QUs to tonnes provides a harmonized measure of harvest allowance and supports the empirical strategy used in Section 5.

Altogether, these steps yield a detailed, transaction-level dataset linking vessels, quota holdings, and regulatory attributes. In the next section, we outline how we use this dataset to estimate the value of fishing bundles and to identify how regulatory constraints shape quota valuation.

5 Empirical Strategy and Hedonic Valuation of Fishing Bundles

This section describes how we use the transaction data to estimate the value of vessels and quota units (QUs) in the coastal cod fishery. Our empirical objective is to quantify how regulatory constraints—particularly the consolidation caps that limit the number of quota tonnes a vessel can harvest when fully structured—affect the quota values. These caps vary across regulatory length groups for reasons grounded in social and distributional objectives, and this cross-sectional variation provides the basis for our empirical strategy. We begin by outlining the empirical strategy, then discuss the treatment of structural quotas, the regulatory mechanisms shaping quota valuation, and buyers' investment decisions. We conclude the section by presenting the hedonic model used in estimation.

5.1 Empirical Strategy

A key feature of the coastal cod fishery is that vessels themselves are not tied to any regulatory length group. A vessel's regulatory classification is determined entirely by the quota units and access rights attached to it at any given point in time. If the QUs with a vessel are replaced with QUs from a different regulatory group, the vessel can immediately operate under that group's rules; the physical characteristics of the vessel do not restrict such reclassification. This institutional feature is central to our empirical strategy, because it implies that vessels are, in effect, freely movable across regulatory groups through changes in quota holdings.

Quota units are also technologically identical across groups. Each QU provides the right to harvest a proportional share of the total allowable catch from the same stock, using the same gear. Conditional on vessel characteristics (e.g. length, width, engine power, hull material), there is no technological or biological reason for QUs to differ in marginal value across groups. Hence, any systematic price differences must arise from the regulatory constraints that vary across groups, as detailed in Section 2.

The most important constraints are the consolidation caps, which limit how many quota tonnes a vessel can harvest when fully structured. These caps differ substantially across regulatory groups and reflect policy objectives related to distributional concerns and fleet structure. Because the harvest allowance per QU also varies across groups through conversion keys, the effective consolidation capacity—measured in tonnes of cod a vessel can harvest when at the consolidation cap—differs even more across groups. For example, a vessel in the largest regulatory group in 2017 could expand its quota holdings up to six structural units per base unit and each unit corresponded to more tonnes of cod than in the smaller groups. Hence, two vessels that are physically identical, but associated with different QUs (regulatory groups), face significantly different expansion opportunities.

These regulatory differences imply that, after adjusting structural QUs for their remaining lifetime and converting all QUs into expected tonnes of cod allowance, vessels become comparable across groups. What remains is cross-sectional variation in the regulatory regime. Consequently, differences in buyers' marginal willingness to pay for otherwise identical quota tonnes across regulatory groups identify the economic cost of consolidation caps. This logic provides the basis for the empirical strategy we develop in the remainder of this section.

5.2 Base and Structural Quotas

Structural quotas play an important role in the long-run investment decision faced by buyers. Structural QUs—those previously added to a vessel's base quota—are subject to a sunset clause and expire after 20 or 25 years. Base QUs, in contrast, are of indefinite duration. As discussed in the theoretical framework, short-run users (seasonal renters) care only about within-season harvesting opportunities and therefore do not distinguish between base and structural units, nor between structural quota units with different remaining lifetimes. Buyers, however, value the long-run stream of income generated by each quota unit and must therefore account for sunset clauses when forming bids.

We account for the limited remaining lifetime of structural QUs by converting each structural unit into its lifetime-equivalent fraction of a base unit. We treat quota ownership as generating a constant annual net return. A structural unit yields this return only for the years that remain under its sunset clause, whereas a base unit yields the same return indefinitely. Under this valuation logic, we scale each structural QU by the adjustment factor:

$$AF_t = 1 - (1+r)^{-t}, \tag{12}$$

where t is the number of remaining years and r is the discount rate. We take the 3-month Norwegian Interbank Offered Rate (NIBOR) as a conservative lower bound for r.[25] For example, a structural unit with 15 years remaining in 2015, when the risk-free rate was 1.3%, receives an adjustment factor of approximately 0.18.

A more flexible alternative would be to estimate separate coefficients for structural units with different remaining lifetimes. While feasible in principle, doing so would require dedicating scarce degrees of freedom to modeling this decay rather than to identifying group-specific quota values. Given the limited number of quota transactions and the central role of cross-group comparisons in our empirical strategy, the adjustment-factor approach offers a transparent and parsimonious way to incorporate the time-limited nature of structural QUs without stretching the data unnecessarily.

Although structural and base QUs differ in duration, one might wonder whether they should also differ in marginal value because some buyers consolidate quota while others do not. In practice, both types of buyers participate in the same market, and transaction prices reflect their aggregate valuations. A buyer intending to consolidate compares the gain from increasing harvest capacity to the cost of converting indefinite base units into a smaller number of time-limited structural units. As long as the economies of scale from consolidation are sufficiently large to offset this loss, consolidating buyers will be willing to pay the same marginal price for an additional quota unit as buyers who do not consolidate. Once we account for the remaining lifetime of structural QUs through the adjustment factor described above, the option to consolidate does not itself generate systematic differences in the marginal valuation of base versus structural units.

5.3 Regulatory Sources of Cross-Group Variation

The regulatory regime shapes the marginal value of a quota unit by influencing how productively it can be combined with a vessel. In the coastal cod fishery, vessels harvest from the same stock using similar gear and operate under comparable biological and technological conditions. Once we control for observable vessel characteristics, the remaining systematic differences in marginal quota value must therefore stem from regulation rather than technology.

The most important regulatory mechanism is the consolidation cap, which limits how many structural quota units can be added to a vessel's base quota. These caps differ sharply across regulatory length groups and have changed several times since the introduction of the structural quota system. In 2017, for example, vessels in the 11–14.9 meter group could hold up to five structural units per base unit, while those above 14.9 meter could hold up to six. These caps translate directly into differences in vessels' expansion possibilities. A vessel in the smallest group, which lacks access to the structural quota system, cannot expand quota holdings on a given vessel at all; a physically identical vessel in the largest group can expand harvest capacity dramatically. These differences in feasible scale expansion generate cross-group variation in the shadow value of a quota constraint.[26] These patterns indicate significant gains from consolidation and support treating QUs from different regulatory groups as distinct characteristics.

The regulatory environment for the smallest length group differs further because vessels under 11 meters do not have access to the structural quota system. Instead, they may expand harvest capacity through the co-fishing scheme, which allows two vessels to combine their quota allowances and fish them using a

[25] If a quota unit yields a constant net annual income π and the discount factor is $k = \frac{1}{1+r}$, the present value of a structural unit with t years remaining is $\pi\frac{1-k^t}{1-k}$, whereas the value of a perpetual unit is $\frac{\pi}{1-k}$. Their ratio simplifies to $1-(1+r)^{-t}$, which is the adjustment factor.

[26] Annual data from the Directorate of Fisheries' profitability survey confirm that the average operating margin increases with regulatory length group.

single physical vessel. This mechanism effectively creates an implicit consolidation cap of roughly two times the vessel's own quota holdings, similar to the formal cap that applied to the 11–14.9 meter group before 2013. Unlike structural consolidation, however, co-fishing does not require redistributing 20% of quota units to the regulatory group; all quota may be fished by the combined vessel. At the same time, maintaining a second vessel in operable condition is necessary to qualify for co-fishing. These institutional differences justify treating the smallest regulatory group separately when modeling quota valuation.

Consolidation dynamics further reinforce cross-group distinctions. When structural units are consolidated, 20% of the transferred quota is removed from the group, increasing the TAC share of the remaining QUs. A vessel's harvest allowance can therefore grow simply because consolidation occurs elsewhere within its regulatory group. Historical consolidation rates vary substantially across groups (cf. Table 3), giving fishers different expectations about future quota growth. These expectations are capitalized into transaction prices and create additional cross-sectional variation in quota valuation.

Harvest allowances per quota unit also differ across regulatory groups. Because one quota unit represents a fixed share of group-specific TAC, groups with larger TAC allocations per unit confer larger harvest opportunities. Although we standardize QUs by converting them into expected tonnes of cod allowance, differences in consolidation caps and consolidation rates remain, implying that the marginal value of a standardized quota tonne still varies systematically across groups.[27]

To place quota holdings from different regulatory groups on a common scale, we convert all QUs into expected tonnes of cod using group-specific conversion keys. These keys are constructed as the three–year moving average of tonnes-per-unit in the years preceding each transaction and vary across groups, years, and within seasons (cf. Table 1). For example, in 2017 a vessel's per-unit harvest allowance in the largest group increased from 17.6 tonnes at the start of the season to 19.6 tonnes later in the year. Because buyers plausibly base expectations on past conversion rates rather than on the exact key at the transaction date, using historical averages provides a reasonable approximation of expected harvest. This harmonization allows us to compare quota holdings across groups while ensuring that any remaining cross-sectional differences in marginal willingness to pay for quota tonnes reflect regulatory constraints—primarily consolidation caps—rather than mechanical differences in TAC conversion.[28]

Altogether, these institutional differences create cross sectional variation that we use for identification. This variation forms the foundation for quantifying how consolidation caps and related regulatory features affect the marginal value of quota.

5.4 The Quota Investment Decision

Our theoretical framework emphasizes the distinction between short-run users, who rent vessels and quota for a single season, and buyers, who acquire a long-lived fishing bundle. The transactions in our data reflect the latter. Consequently, the willingness to pay for a quota unit incorporates expectations about long-term profitability, regulatory stability, and stock development.

Compared with renters, buyers face greater exposure to regulatory and biological uncertainty. The coastal cod fishery has experienced periodic regulatory changes, including revisions to consolidation rules and geographical restrictions on quota mobility. Political disagreement surrounding the structural quota system suggests that further adjustments are possible. Buyers must also form expectations about future stock abundance and harvesting conditions, which may be affected by climate variability and long-term ecological trends (Kjesbu et al., 2022). These considerations influence the expected stream of income generated by a quota unit and, consequently, its market value.

To account for evolving regulatory and biological expectations, we include year fixed effects in select empirical specifications. These absorb aggregate shocks—such as TAC adjustments, regulatory reforms, or

[27]Importantly, the quota cap is determined by the total number of QUs registered to the access permit. Since access permits are decreasing with regulatory group, this means that there are generally more QUs per access permit in the larger groups, implying a higher effective quota cap.

[28]To assess whether *ex ante* conversion affects our results, we estimate models using both QUs and converted tonnes, and compare the coefficients from the unit model after applying the conversion key ex post.

macroeconomic fluctuations—that affect all quota values in a given year. What remains is cross-sectional variation driven by regulatory features that differ across vessel groups or geographical areas. This variation is what identifies the effects of consolidation caps and regional trade restrictions on quota valuation.

5.5 Empirical Model

We estimate a hedonic model that relates the transaction value of a fishing bundle to the characteristics of the vessel(s) and the associated quota holdings. Following the hedonic framework developed in Section 3, we estimate the price function in Equation 1 by regressing bundle values on vessel characteristics, quota holdings, and a set of additional controls that account for geographical, regulatory, and temporal variation:

$$\ln(\text{value}_{it}) = \alpha + \sum_{j=1}^{4} \beta_j \, q_{ijt} + \gamma Z_{it} + \kappa K_{it} + \sum_{j=1}^{4} \beta_j^g \, (q_{ijt} \times g_i) + \sum_{j=1}^{4} \beta_j^b \, (q_{ijt} \times b_t) + \sum_{j=1}^{4} \beta_j^t \, (q_{ijt} \times t) + d_t + \varepsilon_{it}, \quad (13)$$

where value_{it} denotes the total book value of the fishing bundle purchased by buyer i in year t. The variable q_{ijt} is the quantity of cod quota (expressed in tonnes of expected cod harvest) from regulatory group j included in the bundle. The vector Z_{it} contains vessel characteristics, K_{it} contains quota holdings in other fisheries, and d_t is a set of year fixed effects.

The coefficients β_j capture the baseline semi-elasticity of bundle value with respect to an additional tonne of quota from group j. The model also includes several sets of interaction terms to allow the marginal value of quota to vary along economically and institutionally relevant dimensions.

During the study period, purchases of cod–quota vessels across county borders were restricted, except for buyers in Finnmark and selected municipalities in Troms (see Section 2). To allow marginal quota valuation to differ for these buyers, who had access to a larger potential supply, we will in select specifications interact each quota variable with an indicator g_i that equals one for buyers located in the exempt region. The term $(q_{ijt} \times g_i)$ captures all special-region specific variation in the marginal value of quota.

In 2013, the consolidation caps were increased for all regulatory groups with access to the structural quota scheme. To allow quota valuation to adjust to this regulatory change, we interact each quota variable with the post-2013 indicator b_t. The coefficients β_j^b thus capture how the marginal value of quota from group j differs after the increase in consolidation caps.

To allow for gradual, group-specific changes in quota valuation over time, potentially reflecting changing expectations about consolidation, profitability, stock development, or TAC trajectories, we interact each quota variable with a linear time trend. These terms flexibly approximate group-specific long-run changes in valuation without including a full set of group-by-year fixed effects, which would be infeasible given the limited number of quota transactions, particularly in the largest regulatory groups.

We estimate Equation (13) using ordinary least squares (OLS), the standard approach in the hedonic pricing literature. The log transformation of value_{it} reduces right skewness common in asset-transaction data and improves functional-form fit.[29]

We log-transform continuous vessel characteristics in Z_{it} (e.g. engine power, width), consistent with hedonic studies that treat physical attributes as multiplicative contributors to value (e.g., Buck et al., 2014; Bayer et al., 2009). We include quota holdings in levels, rather than as shares or nonlinear transformations, to preserve their regulatory interpretation and to estimate distinct marginal valuations across groups.[30]

[29] A Box-Cox test confirms that the log specification fits the data well. Following Cropper et al. (1988), most hedonic applications in environmental and resource economics employ OLS log-linear models because they are less sensitive to omitted-variable bias than more flexible alternatives. The issues raised by Kuminoff et al. (2010) relate largely to housing markets, where unobserved spatial amenities induce complex confounding. In our setting, vessels operate in a shared biological environment, and year fixed effects absorb aggregate price movements and regulatory shocks, mitigating these concerns.

[30] This follows the logic in Petrie and Taylor (2007), who argue that level specifications maintain the structural interpretation of rights-based inputs such as irrigation permits.

The primary parameters of interest are the β_j parameters. Under the empirical strategy developed in Section 5, differences across these coefficients quantify how regulatory constraints, particularly the consolidation caps, affect the marginal value of quota. Because the underlying production technology is common across groups and all quota holdings have been converted to standardized tonnes, the β_j can be interpreted as differences in the implicit price of a tonne of cod allowance that are attributable to regulation rather than productivity.

To assess robustness, we estimate parallel specifications using quota holdings measured in tonnes of expected cod harvest and raw quota units. Comparing these specifications allows us to evaluate whether group-specific harvest allowances, captured only in the tonne-based model, change inference about cross-group variation in quota values. We also examine whether including quota holdings from other fisheries alters the estimated value of cod quota.

5.6 Buyer Heterogeneity and Multi–Vessel Transactions

Unobservable characteristics of buyers and differences in transaction structure may influence the estimated marginal value of quota. In this subsection, we discuss how we account for these potential sources of bias and how they inform the robustness checks reported in Section 6.

Repeat Buyers

Individual fishers may differ systematically in expectations, financial constraints, or strategic behavior, and such persistent heterogeneity could bias estimates of quota value. For example, buyers who anticipate future increases in cod prices may be willing to pay more for all bundles, and if such "optimistic" buyers purchase disproportionately many quota-bearing vessels, the resulting estimates of β_j would be biased upwards.

To examine the importance of such heterogeneity, we exploit the presence of repeat buyers in the data. Several fishers appear in multiple transactions over the sample period, allowing us to estimate specifications with buyer fixed effects in the subsample of repeat buyers. This strategy absorbs all time-invariant buyer characteristics and isolates within-buyer variation in transaction values. Buyer fixed effects are commonly used in hedonic studies of differentiated goods to address persistent preference heterogeneity (e.g. Lee, 2014; Gobillon et al., 2017), but, to our knowledge, have not previously been applied to the valuation of production inputs such as quota rights.

Although this approach mitigates concerns about unobserved buyer heterogeneity, it comes at the cost of a substantially reduced sample size, which weakens our ability to identify cross-group differences in quota valuation. For this reason, the fixed-effects specification is used as a robustness check rather than as the primary estimating equation.[31]

Multiple Vessel Transactions

A second set of concerns arises from transactions involving multiple vessels. Because tax data are annual, when a buyer acquires more than one vessel in a year we cannot link transaction values to individual vessels. We therefore treat each such observation as a single fishing bundle and aggregate vessel characteristics linearly. For example, a purchase of two vessels with widths of 5 and 10 meters is recorded as a bundle with total width of 15 meters. This is consistent with the hedonic interpretation of a fishing bundle as a collection of productive attributes.

We partly account for the structure of multi-vessel bundles by including hull-type count variables, which implicitly measure the number of vessels in the bundle. These controls capture scale differences: operating one larger vessel may be cheaper than operating two smaller ones, even when combined physical characteristics are identical.

[31] We also observe repeated sales of vessels, which in principle could allow for vessel fixed effects. Analogous approaches are common in hedonic studies of farmland, where parcel fixed effects are used to control for unobserved, time-invariant land attributes (e.g., Buck et al., 2014). In our setting, however, vessels are mobile, modifiable, and well described in the data, and we see no compelling reason why persistent unobserved vessel traits should systematically affect both transaction value and quota valuation. For this reason, we do not include vessel fixed effects.

Even after aggregation, multi-vessel transactions may differ systematically from single-vessel transactions. As shown in Table 6 in Section 4, single-vessel purchases frequently involve no cod quota, whereas multi-vessel purchases almost always do. If the marginal willingness to pay for quota depends on whether the bundle contains quota at all, pooling all transactions could bias the estimated β_j coefficients.

To evaluate these concerns, we estimate a series of robustness specifications: the full-sample model, a model restricted to single-vessel transactions, a model restricted to multi-vessel transactions, and a fully interacted model in which all regressors are interacted with a multi-vessel dummy. The interaction specification allows direct tests of whether estimated quota values differ systematically across single- and multi-vessel transactions. Together, these checks ensure that our findings are not driven by structural differences in transaction composition.

6 Results

This section presents the empirical results from estimating the hedonic model developed in Section 5.5. We first report the main findings from the full sample and examine how the estimated marginal value of cod quota varies across regulatory groups. We then evaluate whether geographical restrictions on quota mobility influence marginal quota valuation. Finally, we assess the robustness of these results to alternative sample definitions, repeated buyers, and transactions involving multiple vessels.

6.1 Main Results

Table 7 reports estimates from a sequence of hedonic specifications that progressively incorporate additional controls. Column (1) presents a minimal baseline specification containing cod-quota variables and vessel characteristics. Columns (2) and (3) then add, respectively, quota holdings from other fisheries and year fixed effects. Column (4) extends the model by allowing the marginal effect of quota from each regulatory group to vary with both the structural break associated with the 2013 increase in consolidation caps and with a group-specific time trend. Finally, column (5), our preferred specification, adds geographic controls.

Across all specifications, cod quota variables have a statistically significant and positive association with the value of fishing bundles. This result is consistent with the theoretical framework developed earlier: additional quota increases how much one is able to harvest and raises expected future rents. The coefficient estimates remain positive and precisely estimated throughout the sequence of models, indicating that this result is robust to the inclusion of additional controls.

Adding quota holdings from other fisheries in column (2) has little effect on the cod-quota coefficients. This is expected as cod is the most valuable asset in the vast majority of bundles in our sample. The inclusion of year fixed effects in column (3) absorbs substantial inter-annual variation in profitability, TAC, and other policy conditions, but has little impact on the estimated cod-quota coefficients. The stability of these coefficients reflects that identification comes primarily from cross-sectional differences in regulatory constraints rather than from time-series variation.

Column (4) introduces interactions between quota variables and (i) a post-2013 structural-break indicator capturing the increase of the consolidation caps, and (ii) a group-specific linear time trend. These terms account for potential time-varying components of quota valuation without requiring a full set of group-by-year fixed effects, which would be infeasible given the limited number of transactions in the larger groups.[32] The results show that while some interaction terms are statistically significant, their inclusion leaves the main coefficients on quota holdings largely unchanged. This suggests that cross-group differences in quota valuation cannot be explained solely by year-specific or trend-specific shifts.

The specification in column (5) extends the model by adding geographical market controls that reflect the regulatory structure governing vessel and quota transfers and a special region indicator (cf. section 2.3). As described in Section 2, trade in vessels holding coastal-cod quota was initially restricted to county-based

[32]Estimating a version of the model with a full set of group-by-year fixed effects yields cod-quota coefficients similar in magnitude to those reported in column (4), but substantially higher standard errors, particularly for the largest regulatory groups where there are few quota transactions. As a consequence, several quota coefficients lose statistical significance.

Table 7
Regression Results: Marginal Value of Cod Quota

	Model 1	Model 2	Model 3	Model 4	Model 5
Quota under 11 m	0.011 ***	0.010 ***	0.010 ***	0.008 ***	0.008 ***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Quota 11-14.9 m	0.006 ***	0.006 ***	0.007 ***	0.004 *	0.004 *
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Quota 15-20.9 m	0.004 ***	0.004 ***	0.004 ***	0.004 ***	0.004 ***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Quota 21-27.9 m	0.004 ***	0.004 ***	0.004 ***	0.003 **	0.003 **
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Trend x Quota under 11 m				0.001 *	0.001 *
				(0.001)	(0.001)
Trend x Quota 11-14.9 m				0.001 **	0.001 **
				(0.001)	(0.001)
Trend x Quota 15-20.9 m				0.001 *	0.001 *
				(0.000)	(0.000)
Trend x Quota 21-27.9 m				0.000	0.000
				(0.000)	(0.000)
Cap shift x Quota under 11 m				-0.006 *	-0.006 *
				(0.003)	(0.003)
Cap shift x Quota 11-14.9 m				-0.008 ***	-0.008 ***
				(0.002)	(0.002)
Cap shift x Quota 15-20.9 m				-0.004 **	-0.004 **
				(0.002)	(0.002)
Cap shift x Quota 21-27.9 m				-0.002	-0.001
				(0.002)	(0.002)
Per kilo values of cod quota					
Quota under 11 m	25.176	24.456	25.074	26.899	26.891
	(1.846)	(1.833)	(1.841)	(2.047)	(2.042)
Quota 11-14.9 m	44.458	43.140	45.874	55.327	55.527
	(4.765)	(4.883)	(4.937)	(5.623)	(5.590)
Quota 15-20.9 m	69.667	65.269	69.498	84.959	85.438
	(12.147)	(12.600)	(12.543)	(9.074)	(9.069)
Quota 21-27.9 m	147.239	129.339	143.819	165.224	164.085
	(16.743)	(18.825)	(18.553)	(22.712)	(22.801)
Vessel characteristics	Yes	Yes	Yes	Yes	Yes
Non-cod quotas	No	Yes	Yes	Yes	Yes
Year FE	No	No	Yes	Yes	Yes
Region FE	No	No	No	No	Yes
Adj. R2	0.576	0.582	0.599	0.605	0.606
Observations	2260	2260	2260	2260	2260

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

Note. Robust standard errors in parentheses. Per kilo marginal values of cod quota reported in lower part of the table.

regions (which in some cases comprise multiple neighboring counties, before shifting in 2016 to a two-region north–south division. Our definition of 'South' follows the post-2016 regulatory South. To account for these institutional features, specification (5) includes indicators for three mutually exclusive geographical regions (North, Mid, and South), a structural-break indicator for the 2016 shift in the regulations, and interactions between the regional indicators and the structural-break term. These additions allow the model to absorb level shifts in transaction values associated with changes in market scope, without imposing any direct effect on the marginal value of quota.[33] The estimated coefficients on cod quota remain very stable compared to column (4), indicating that the introduction of geographical controls does not change the key valuation patterns. We therefore take specification (5) as our preferred model.

The results presented in Table 7 show a consistent pattern: the estimated effects of cod-quota holdings are robust to the sequential inclusion of vessel characteristics, quota holdings from other fisheries, year fixed effects, time-varying interactions, and geographical controls. Across all specifications, quota plays a central role in explaining variation in fishing-bundle transaction values, and the key patterns emerge clearly already in the minimal baseline specification. The preferred specification in column (5) confirms that these results are not sensitive to institutional features of the quota-trade market.

With this in place, we turn to the key quantities of interest, the marginal valuation of quota expressed in NOK per kilo of cod. Because the estimated coefficients are semi-elasticities, and because bundles differ systematically in transaction values across regulatory groups, the estimated quota coefficients are not directly comparable. To assess how increasingly restrictive consolidation caps affect quota valuation, we therefore compute group-specific marginal values in NOK per kilo of cod quota. These quantities translate the semi-elasticities into an economically interpretable metric and allow us to quantify the economic consequences of consolidation caps.

6.2 Marginal Valuation of Cod Quota

To translate the estimated semi-elasticities into economically interpretable quantities, we compute the implied marginal value of an additional kilo of cod quota for each regulatory group. For each specification in Table 7, we obtain these marginal values by evaluating the estimated semi-elasticity at the median transaction value across all years for bundles containing quota from the relevant group.[34] Because structural units are converted into lifetime-equivalent base units before estimation (cf. Section 5), differences in marginal values across regulatory groups reflect consolidation caps rather than differences in quota duration.[35]

For specifications that include interactions between quota and other covariates, the semi-elasticity of bundle value with respect to quota depends on the values assigned to those interaction variables. Specifications (1)–(3) contain no such interactions, so their marginal values are implicitly averaged over all observations in the sample. In contrast, specifications (4) and (5) include quota–time interactions.

To ensure comparability across specifications when reporting marginal quota values, we evaluate all quota–interaction terms in models (4) and (5) at representative values. Specifically, we set the time trend to the transaction-value-weighted sample mean over 2009–2017, so that years with larger transactions receive proportionally greater weight, and we set the structural-break indicator to its sample average. This yields a semi-elasticity corresponding to a "typical" year in the dataset. For the regional interactions in appendix Table A2, we evaluate the regional indicators at their empirical mean values, corresponding to each region's share of total transaction value in the sample. This approach produces overall marginal values that summarize the average marginal valuation implied by each specification and makes them directly comparable to the marginal values obtained from specifications (1)–(3).

Across all specifications, the marginal value of quota increases with the group's consolidation potential. The smallest group (under 11 meters), which lacks access to structural consolidation, consistently has the lowest

[33] In appendix Table A2, we report results from a specification that also interacts quota with regional indicators. Although the main valuation patterns remain, precision decreases, particularly for the larger regulatory groups where there are few quota trades.

[34] Appendix A.1 provides details on how we compute these marginal values.

[35] In Appendix Table A1, we show results from a model where we convert units of quota to tonnes after estimation. Both resulting coefficients, and implied marginal values are similar between the specifications.

marginal value. The two intermediate groups fall between the extremes, while the largest regulatory group has the highest values. This pattern is consistent with our main hypothesis: tighter consolidation caps limit the scale at which quota can be profitably employed, thereby reducing buyers' willingness to pay for an additional tonne of quota. Conversely, more permissive caps enable greater expansion on a single vessel, raising the marginal value of quota.

The preferred specification in column (5) shows that moving from the smallest to the next regulatory group almost doubles the marginal value, and values continue to rise monotonically across the larger groups. In the largest group, with the least restrictive consolidation caps, the estimated marginal value of one additional tonne of quota is over five times that of the smallest group. These differences are economically significant; although all groups harvest the same stock with similar technology, their consolidation caps differ, and this difference is capitalized into quota prices.

Statistical inference follows the same pattern. Pairwise comparisons indicate that the marginal values differ significantly at the 5% level between all groups except the two largest. The latter result reflects the limited number of quota transactions in the largest length groups. Nevertheless, the point estimates remain ordered by consolidation potential in all specifications. Figure A1 shows the differences between estimated cod quota coefficients from the preferred specification and 95% confidence bands.

Altogether, the marginal-valuation results provide direct evidence of the equity–efficiency tradeoff embedded in the Norwegian coastal cod quota system. The tight consolidation caps imposed on the smallest groups, intended to support a decentralized fleet, substantially reduce the marginal value of quota. Conversely, the more permissive consolidation caps of the larger groups yield much higher valuations. Although we document some temporal and regional variation in marginal values, these differences are modest relative to the strong cross-group patterns. The differences in marginal values across regulatory groups quantify the economic cost of consolidation constraints and demonstrate how these regulations are capitalized into quota prices.

6.3 Geographic Trade Restrictions and Quota Valuation

We next examine whether regulatory constraints on the geographical transferability of quotas affect their marginal valuation. Ideally, this would involve estimating a three-way interaction between quota holdings, regional market indicators, and the 2016 reform that replaced county-based transfer restrictions with a two-region north–south division. However, once transactions are partitioned by regulatory group, region, and period, the data become sparse, making such a specification difficult to estimate with precision.

To assess the role of regional transfer constraints while preserving statistical power, we therefore estimate a sequence of regional specifications that build on specification (3), which includes vessel characteristics, quota holdings from other fisheries, and year fixed effects. Specification (R1) adds interactions between quota holdings and regional indicators for South, Mid, and North, allowing marginal quota values to differ across regions without imposing time variation. Specification (R2) further interacts these regional quota effects with the 2016 reform. As discussed above, this specification is demanding in terms of data requirements and yields imprecise estimates for most combinations of region, period and regulatory group.

We also estimate two more parsimonious regional specifications, (R3) and (R4). These models interact quota holdings with an indicator for whether buyers are located in the special region, which allows purchases of quota from all other regions. The special region consists of a subset of municipalities within the post-2016 North region (cf. section 2). Specification (R4) additionally allows marginal quota values to differ across the three main regions. These specifications provide a more focused test of whether broader access to quota markets is associated with differences in quota valuation.

Table A2 in Appendix A.2 reports the estimated coefficients for specifications (R1)–(R4), alongside the baseline specification (3). Across all regional specifications, cod quota remains positively and significantly associated with transaction values, and the ordering of marginal quota values across regulatory groups is unchanged. Introducing regional interactions therefore does not qualitatively affect the estimated relationship between consolidation caps and quota valuation.

The marginal quota values implied by specification (R2) exhibit substantial variation across regions and between the pre- and post-2016 periods, but without a stable or economically interpretable pattern. The region with the highest implied valuation varies across regulatory groups and over time, and for several groups marginal values change sharply after 2016 in some regions but not others. These patterns are particularly pronounced for the larger regulatory groups, where the number of quota transactions is limited and estimates are imprecise. We report marginal values for specification (R2)-(R4), computed using the median transaction value across all periods, in Table A3 in Appendix A.2.

Results from the more parsimonious specifications point in a similar direction. In specification (R3), marginal quota values are generally lower for buyers located in the special region, consistent with the intuition that broader access to quota markets lowers quota prices, but this effect is statistically significant only for the smallest regulatory group. When we include additional regional controls in specification (R4), the estimated effects remain negative but become less precise and are no longer statistically significant.

Overall, while the regional specifications suggest that geographic transfer constraints may have contributed to differences in local quota valuation, the absence of a stable pattern across regions and periods makes it difficult to draw strong conclusions about their magnitude. Importantly, accounting for regional heterogeneity does not alter the estimated effects of consolidation caps. Across all specifications, consolidation constraints remain the dominant source of systematic variation in marginal quota values.

6.4 Robustness: Repeat Buyers and Multi–Vessel Transactions

Table 8 reports a series of robustness checks based on the preferred specification in column (1). These exercises evaluate whether our main results are sensitive to (i) restricting the sample to buyers who make repeated purchases, thereby enabling a comparison with and without buyer fixed effects, and (ii) separating the sample into single-vessel and multi-vessel transactions. Across all specifications, we re-estimate the full model using the same controls and interaction structure as in the benchmark regression.

The first column of Table 8 reproduces the full-sample estimates for convenience. Columns (2) and (3) of Table 8 present results from restricting the sample to buyers with at least two observed transactions. This restriction yields a substantially smaller estimation sample, but allows us to assess the role of persistent buyer heterogeneity.

Column (2) reports estimates for the repeat-buyer sample without buyer fixed effects. All cod-quota coefficients remain positive, and for every regulatory group either the cod-quota coefficient itself or the trend-by-quota interaction term is statistically significant at conventional levels. Relative to the full-sample benchmark, the coefficient for the smallest regulatory group declines from 0.008 to 0.003, whereas the estimates for the two middle groups fall only modestly, and increases slightly for the largest. Given the smaller sample and resulting loss of precision, these differences are well within what would be expected from sampling variation. Indeed, the coefficients for the three largest groups in column (2) remain very close to the benchmark estimates.

Column (3) adds buyer fixed effects. When comparing these estimates to those in column (2), we find that both the quota coefficients and the trend-by-quota interaction terms remain remarkably stable. For all regulatory groups, the baseline quota coefficients in column (3) are either identical to those in column (2) or only marginally smaller, and the time–trend interactions display a similar pattern. The main difference between columns (2) and (3) is therefore not the point estimates but the substantial increase in standard errors that follows from conditioning on buyer fixed effects, particularly for the larger regulatory groups. The close alignment of both the quota and trend-by-quota estimates across the two specifications confirms that persistent buyer heterogeneity does not drive our valuation results. The ordering of marginal quota values, reported in the lower part of the table, is also preserved when controlling for buyer fixed effects. Quota valuations are therefore robust to conditioning on buyer-level heterogeneity.

Columns (4) and (5) report results from estimating the preferred specification separately for single-vessel and multi-vessel transactions. Because multi-vessel bundles aggregate characteristics across several vessels, these samples differ systematically in the amount of variation available for identification. Disaggregating the sample provides a test of whether heterogeneous transaction structures distort inference.

Column (4) shows that in single-vessel transactions, the quota coefficients are slightly larger and remain significant at conventional levels. For example, the estimate for the smallest regulatory group increases to

Table 8
Regression Results: Repeat Buyers and Multi–Vessel Transactions

	Baseline	Rep. Buyer Samp.	Rep. Buyer FE	Single Vessel	Mult. Vessels
Quota under 11 m	0.008 ***	0.003	0.003	0.012 ***	0.001
	(0.002)	(0.003)	(0.004)	(0.002)	(0.003)
Quota 11-14.9 m	0.004 *	0.003	0.003	0.006 **	0.002
	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)
Quota 15-20.9 m	0.004 ***	0.004 **	0.003 *	0.005 **	0.002 *
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Quota 21-27.9 m	0.003 **	0.004 *	0.002	0.005 *	0.003
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Trend x Quota under 11 m	0.001 *	0.002 *	0.002 *	0.001 *	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Trend x Quota 11-14.9 m	0.001 **	0.002 **	0.001	0.002 **	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Trend x Quota 15-20.9 m	0.001 *	0.001	0.001	0.001	0.000
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
Trend x Quota 21-27.9 m	0.000	0.000	0.000	0.001	-0.000
	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)
Cap shift x Quota under 11 m	-0.006 *	-0.008 *	-0.010 *	-0.006	-0.005
	(0.003)	(0.004)	(0.004)	(0.003)	(0.004)
Cap shift x Quota 11-14.9 m	-0.008 ***	-0.007 **	-0.007 *	-0.008 **	-0.006 *
	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)
Cap shift x Quota 15-20.9 m	-0.004 **	-0.004 *	-0.004	-0.005 *	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Cap shift x Quota 21-27.9 m	-0.001	-0.002	-0.000	-0.002	0.001
	(0.002)	(0.003)	(0.003)	(0.003)	(0.002)
Per kilo values of cod quota					
Quota under 11 m	26.891	23.420	19.076	32.042	13.868
	(2.042)	(3.145)	(4.071)	(1.845)	(5.270)
Quota 11-14.9 m	55.527	62.864	57.010	55.318	49.686
	(5.590)	(7.627)	(9.650)	(5.489)	(11.307)
Quota 15-20.9 m	85.438	82.671	74.049	96.589	62.631
	(9.069)	(10.921)	(14.485)	(8.882)	(15.578)
Quota 21-27.9 m	164.085	148.021	104.134	265.559	70.026
	(22.801)	(25.701)	(30.667)	(38.127)	(21.740)
Vessel characteristics	Yes	Yes	Yes	Yes	Yes
Non-cod quotas	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes
Adj. R2		0.556		0.604	0.576
No. of buyer groups			471		
Observations	2260	1241	1241	1806	454

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

Note. Robust standard errors in parentheses. Per kilo marginal values of cod quota reported in lower part of the table.

0.012, close to the full-sample estimate, while the coefficients for the larger groups remain between 0.005 and 0.006. This alignment with the benchmark underscores that the main results are not driven by combining single- and multi-vessel observations.

Column (5) reports results based solely on multi-vessel transactions, reducing the sample from 2,260 observations in the full sample to 454. These estimates display reduced precision and somewhat smaller quota coefficients, consistent with a mechanical reduction in variation from aggregated bundles and a substantially smaller sample. Multi-vessel purchases naturally compress variation in vessel characteristics, since the transaction price reflects an internally averaged bundle composition. This compression reduces identifying variation and inflates standard errors. Although the absolute marginal quota valuations are smaller in this subsample, all quota coefficients remain positive, and the coefficient for the second largest groups is statistically significant. The qualitative ranking across regulatory groups persists, indicating that the structure of quota valuations is robust even when transaction bundles are more complex. These findings suggest that the hedonic model robustly recovers the relationship between quota holdings and transaction values across the full range of observed transaction types.

To summarize, the robustness checks in Table 8 demonstrate that the estimated marginal value of cod quota is stable across alternative samples and identification strategies. Whether we restrict attention to repeat buyers (with or without accounting for buyer fixed effects) or separate the sample by transaction structure, the quota coefficients remain positive, economically meaningful, and consistent with the valuation ordering documented in the main results. This supports the conclusion that regulatory constraints, reflected in the different quota groups, play a key role in shaping quota values, and that our core findings are not driven by sample composition or modeling choices.

6.5 Additional Results

Beyond the quota parameters, the estimated coefficients on vessel and bundle characteristics (reported in Table A4) are generally stable across specifications and align with economic intuition. Vessel width consistently exhibits a positive and statistically significant association with transaction value, reflecting its role as a key determinant of harvesting capacity and operational flexibility. Engine power shows a similar, though less robust, pattern: its coefficient is positive in most specifications but often loses statistical significance in reduced samples, such as the repeat-buyer and multi-vessel subsamples, where standard errors increase. Vessel age enters negatively across nearly all models, consistent with depreciation and higher expected maintenance costs. The coefficient on the age-squared term is small in all specifications and generally statistically insignificant, indicating limited curvature in the relationship between age and bundle value and supporting the interpretation of a predominantly linear depreciation profile.

The coefficients on hull-material indicators show little systematic variation across models, and most are statistically insignificant, suggesting that hull composition plays a minor role in explaining cross-sectional price differences once other characteristics are controlled for. Quota holdings from other fisheries typically carry small positive coefficients, though rarely statistically significant. This is consistent with diversified fishing opportunities having modest additional value relative to cod, which remains the dominant revenue source in these bundles. One exception is the coefficient on southern saithe quota, which appears negative in several specifications. While the mechanism is unclear, the magnitude of this effect is small. Also, including quota holdings from other fisheries has little impact on the estimated cod-quota coefficients.

These additional coefficients reinforce the central empirical conclusion: variation in transaction values is driven primarily by regulatory constraints on cod-quota consolidation rather than by vessel characteristics or secondary quota holdings. The hedonic structure performs as intended, absorbing technological, physical, and compositional factors, while leaving the regulatory environment as the main source of systematic differences in quota valuation.

The results in this section provide a coherent and consistent empirical picture of how consolidation caps shape the market value of cod quota. Across all specifications, samples, and robustness checks, quota from groups with more permissive consolidation caps commands a substantially higher marginal value, while tighter caps depress willingness to pay. These patterns persist after accounting for vessel characteristics, other quota holdings, year effects, time-varying policy shocks, regional trade regimes, repeated buyer behavior, and transaction structure. Although some coefficients become less precisely estimated in restricted samples, particularly for the largest regulatory groups where quota trades are sparse, the qualitative ordering of marginal valuations is remarkably stable. The additional results on vessel and bundle characteristics also behave as expected, reinforcing the validity of the hedonic framework. The empirical findings demonstrate that consolidation caps impose economically meaningful costs that are fully capitalized into quota prices, providing clear evidence of the equity–efficiency tradeoff embedded in the regulatory architecture of the Norwegian coastal cod fishery.

7 Conclusion

Catch share programs that allow the transfer of harvest rights are common across the world, yet there is relatively little empirical work on what determines the value of these rights or how regulatory constraints affect that valuation. We address this gap using a comprehensive dataset that links the universe of vessels, quota holdings, and ownership transfers in the Norwegian coastal cod fishery from 2009–2017. We develop and estimate a hedonic model in which fishing bundles are composite goods combining vessel attributes and quota from multiple regulatory groups. The institutional structure of the fishery—where regulatory groups face different consolidation caps but otherwise can use the same technologies under the same ecological conditions—provides the cross-sectional variation needed to isolate the effect of consolidation caps on marginal quota valuation. This framework allows us to quantify how these caps are capitalized into the marginal value of cod quota. The resulting valuation patterns are highly robust to alternative specifications and sample selections.

Our results show a clear and monotonic relationship between consolidation caps and the marginal value of cod quota. Estimated marginal valuations rise sharply as regulatory constraints are relaxed: the group with no access to structural consolidation exhibits the lowest marginal value, while the group with the most permissive consolidation caps displays the highest. Across the four groups, marginal values range from roughly NOK 27 to NOK 160 per kilogram, compared to a cod price of roughly 17 NOK in 2017, demonstrating substantial economic differences attributable to regulation. These patterns are consistent with the economic mechanism implied by the consolidation policy. Tighter caps limit the amount of quota that can be used on a single vessel and therefore reduce the return to an additional tonne of quota. Less restrictive caps expand the possible scale of operation and increase expected profitability, and these gains are capitalized into higher marginal valuations. The ordering of valuations across groups therefore directly reflects their relative consolidation potential.

Our framework also allows us to explore how geographic trading restrictions shape quota valuation. Although we find some indications of regional differences, particularly in the period before the 2016 reform that replaced county-based markets by a north–south division, these effects are modest and imprecisely estimated due to sparse data. The patterns are consistent with the intuition that broader trading opportunities lower local prices, but regional transfer constraints play a secondary role relative to consolidation limits.

Our contribution complements (Kroetz, Sanchirico, et al., 2015), who study a policy experiment with restricted vs. unrestricted permits in the Alaskan halibut and sablefish fisheries using observed permit prices, and (Newell et al., 2005), who analyze ITQ price formation in markets with transparent trading. In contrast, our setting features unobserved quota prices, so we recover implicit valuations from vessel-quota bundle transactions in tax records via a hedonic framework. The institutional details also differ, as our case study has group-specific consolidation caps, structural quotas with sunset provisions and a quota deduction on consolidation, and geographic trading restrictions. Vessels in our sample harvest the same stock with similar technology, allowing us to isolate regulatory design as the source of valuation differences. Under these conditions, the estimated spread in marginal quota valuations across groups quantifies the efficiency cost of equity-motivated consolidation caps, providing evidence that complements prior studies.

Our findings have several implications for the design of tradable-permit systems. They show that regulatory constraints embedded in consolidation caps can generate large and persistent differences in the value of otherwise identical harvest rights. In the coastal cod fishery, these differences arise despite a common stock, shared technologies, and uniform biological conditions. This illustrates how transferability restrictions segment quota markets and limit the efficiency of quota allocation, implying lower marginal valuations, and thus lower potential resource rent, than would arise under a less constrained regulatory regime. By introducing restrictions motivated by non-efficiency objectives, such as social or distributional goals, policymakers implicitly accept a lower level of resource rent from the fishery. The effectiveness of these objectives is often uncertain. For example, Sutherland and Edwards (2022) find that quota allocation and market transfer rules in the Alaskan halibut and sablefish IFQ program did not prevent population or revenue declines in remote communities.

While we cannot observe the counterfactual marginal value of quota in the absence of consolidation caps, our estimates quantify the magnitude of valuation differences attributable to these constraints. This insight is relevant for many catch-share systems worldwide that incorporate similar restrictions. The substantial gaps in marginal quota values across regulatory groups therefore provide quantitative evidence on the economic cost of consolidation limits and highlight the tradeoff between maintaining a decentralized fleet structure and allowing efficient consolidation.

Our research also contributes to the ongoing debates about the distribution of resource rents in catch share programs. In Norway, discussions surrounding the coastal cod fishery have centered on how the benefits from a publicly owned fish stock should be allocated across vessel groups and coastal communities, reflecting a broader debate common to many catch-share systems globally. The estimated spread in marginal valuations from NOK 25 to 160 per kg between the most- and least-restricted groups, provides a measure of the efficiency cost of equity-motivated consolidation caps. Because vessels harvest the same stock with similar technology, these differences are attributable to regulation. The regulations influence both the efficiency of quota allocation and who ultimately captures the economic returns from the fishery. These findings therefore provide an empirical basis for policy to balance the distributional objectives against foregone rents.

While our analysis focuses on the coastal cod fishery, the Norwegian fisheries management system is data-rich and well suited for further empirical work. Extending the framework to additional fisheries would allow for examining how quota valuation responds to regulatory constraints in multi-species settings, where vessels operate across several fisheries and consolidation policies interact. Such extensions could provide new insights into how transferability constraints, consolidation rules, and market structure jointly shape asset values. More generally, our empirical framework can be applied to other regulated markets where transferability constraints and scale limits influence asset values. An important direction for future research is to identify regulatory designs that deliver on social and distributional objectives while minimizing the associated efficiency losses that our analysis have quantified.

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A Appendix

A.1 Marginal Valuation of Cod Quota

This appendix provides additional detail on how we compute marginal values of cod quota and their standard errors from the estimated hedonic model. The procedure depends on the specification reported in Table 7. For models without interaction terms (e.g., columns 1–3), the marginal effect equals the single quota coefficient β_j. For specifications with time interactions (columns 4 and 5), the marginal effect combines multiple coefficients, and for regional models in Appendix Table A2, additional interaction terms enter the calculation.

Computing Marginal Values

For the preferred specification (column 5), the estimated semi–elasticity of transaction value with respect to one additional tonne of cod quota for group j in year t is:

$$\eta_{ijt} = \beta_j + \beta_j^b \, b_t + \beta_j^t \, t,$$

where b_t is the post-2013 structural-break indicator that shifts consolidation caps, and t is the linear time trend.

Because

$$\frac{\partial \ln(\text{value}_{it})}{\partial q_{ijt}} = \frac{1}{\text{value}_{it}} \frac{\partial \text{value}_{it}}{\partial q_{ijt}},$$

the implied marginal value of an additional tonne of cod quota from group j, expressed in NOK per tonne and evaluated at a representative transaction value $V_{jt}^{\star}$, is

$$MV_{jt} = \eta_{ijt} \times V_{jt}^{\star}.$$

In the main text, Table 7 presents marginal values evaluated at the median transaction value across all years for each group. For ease of exposition, we express the value in NOK per kilo. For specifications that include interactions with time controls (columns 4 and 5 of Table 7), the marginal values reported in the main text further assumes average value of the time-interaction variables over the 2009–2017 period, yielding a "typical" marginal value implied by the full model.

Standard Errors

When η_{ijt} combines multiple coefficients, its sampling variance must account for covariances among them. We compute standard errors using the delta method:

$$\text{Var}(\eta_{ijt}) = w' \Sigma w,$$

where $w = [1, t, b_t]$ is the weight vector and Σ is the 3×3 variance–covariance submatrix for $(\beta_j, \beta_j^t, \beta_j^b)$. For regional models, w and Σ expand to include the relevant interaction terms. The standard error of the combined semi-elasticity is:

$$\text{SE}(\eta_{ijt}) = \sqrt{\text{Var}(\eta_{ijt})}.$$

For marginal values expressed in NOK per kilo, we scale the combined semi-elasticity by $V_{jt}^{\star}$ as above.

A.2 Robustness Checks and Regional Interactions

This appendix presents results from additional robustness checks and models where the quota variables are interacted with regional indicators. Table A1 shows results from a model where we convert units of quota to tonnes after estimation. The first column reports the results from our preferred specification (5) from Table 7, (2) is identical to (5) but uses quota measured in units, while (3) presents results from (3) after adjusting quota coefficients for the average conversion key over the study period for each regulatory group.

Results show that coefficients for quota holdings in each regulatory group are statistically significant across all specifications. Resulting marginal values from specification (3), where units are converted to tonnes after estimating preserves the ordering between groups, but magnitudes are slightly lower for the three largest regulatory groups.

Table A2 reports results from regional specifications that build on specification (3) from Table 7. Specification (R1) adds interactions between quota holdings and regional indicators for South, Mid, and North, (R2) interacts these regional quota effects with the 2016 reform. Specification (R3) interact quota holdings with an indicator for whether buyers are located in the special region, while (R4) also allows marginal quota values to differ across the three main regions. Table A3 Reports marginal values for specifications (R2)-(R4).

Marginal quota values from specification (R2) vary substantially across regions and between pre- and post-2016 periods, but without a consistent or economically interpretable pattern; the region with the highest valuation shifts across regulatory groups and over time, and sharp changes after 2016 occur in some regions but not others. These irregularities are most pronounced for larger regulatory groups, where limited transactions yield imprecise estimates. More parsimonious specifications (R3–R4) suggest lower valuations for buyers in the special region, consistent with broader market access, but this effect is statistically significant only for the smallest group and becomes less precise when additional controls are included. Overall, regional heterogeneity may reflect transfer constraints, yet the absence of stable patterns limits inference on their magnitude. Importantly, consolidation caps remain the dominant source of systematic variation across all specifications.

Table A1
Regressions Results: Baseline Quota Tonnes and Quota Units

	Tonnes	Units	Units Converted
Quota under 11 m	0.008 ***	0.230 ***	0.010 ***
	(0.002)	(0.045)	(0.002)
Quota 11-14.9 m	0.004 *	0.109 ***	0.005 ***
	(0.002)	(0.031)	(0.002)
Quota 15-20.9 m	0.004 ***	0.086 ***	0.004 ***
	(0.001)	(0.018)	(0.001)
Quota 21-27.9 m	0.003 **	0.055 **	0.003 **
	(0.001)	(0.020)	(0.001)
Trend x Quota under 11 m	0.001 *	0.005	0.000
	(0.001)	(0.013)	(0.001)
Trend x Quota 11-14.9 m	0.001 **	0.010	0.000
	(0.001)	(0.010)	(0.000)
Trend x Quota 15-20.9 m	0.001 *	0.003	0.000
	(0.000)	(0.005)	(0.000)
Trend x Quota 21-27.9 m	0.000	0.004	0.000
	(0.000)	(0.006)	(0.000)
Cap shift x Quota under 11 m	-0.006 *	-0.019	-0.001
	(0.003)	(0.074)	(0.003)
Cap shift x Quota 11-14.9 m	-0.008 ***	-0.070	-0.003
	(0.002)	(0.040)	(0.002)
Cap shift x Quota 15-20.9 m	-0.004 **	-0.041	-0.002
	(0.002)	(0.028)	(0.001)
Cap shift x Quota 21-27.9 m	-0.001	-0.006	-0.000
	(0.002)	(0.029)	(0.001)
Per-kilo values of cod quota			
Quota under 11 m	26.891		26.198
	(2.042)		(2.081)
Quota 11-14.9 m	55.527		40.268
	(5.590)		(5.027)
Quota 15-20.9 m	85.438		61.310
	(9.069)		(7.229)
Quota 21-27.9 m	164.085		125.733
	(22.801)		(18.308)
Vessel characteristics	Yes	Yes	Yes
Non-cod quotas	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Region FE	Yes	Yes	Yes
Adj. R2	0.606	0.601	0.601
Observations	2260	2260	2260

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

Note. Robust standard errors in parentheses. Per kilo marginal values of cod quota reported in lower part of the table. Model (3) shows results from a model where coefficient estimates have been adjusted by the average conversion key for quota units over the study period.

Table A2
Regression Results: Regional Interactions

	Model 3		Model R1		Model R2		Model R3		Model R4	
Quota under 11 m	0.010 ***	(0.001)	0.012 ***	(0.001)	0.011 ***	(0.001)	0.011 ***	(0.001)	0.013 ***	(0.001)
Quota 11-14.9 m	0.007 ***	(0.001)	0.008 ***	(0.001)	0.008 ***	(0.001)	0.007 ***	(0.001)	0.008 ***	(0.001)
Quota 15-20.9 m	0.004 ***	(0.001)	0.004 ***	(0.001)	0.003 **	(0.001)	0.004 ***	(0.001)	0.004 ***	(0.001)
Quota 21-27.9 m	0.004 ***	(0.001)	0.005 ***	(0.001)	0.005 ***	(0.001)	0.005 ***	(0.001)	0.005 ***	(0.001)
North x Quota under 11 m			-0.003 *	(0.002)	-0.002	(0.002)			-0.002	(0.002)
South x Quota under 11 m			-0.003	(0.002)	-0.001	(0.002)			-0.003	(0.002)
North x Quota 11-14.9 m			-0.001	(0.001)	-0.003 *	(0.001)			0.000	(0.002)
South x Quota 11-14.9 m			-0.002	(0.001)	-0.003 *	(0.001)			-0.002	(0.001)
North x Quota 15-20.9 m			0.002	(0.001)	0.002	(0.001)			0.002	(0.001)
South x Quota 15-20.9 m			0.000	(0.001)	0.000	(0.002)			0.000	(0.001)
North x Quota 21-27.9 m			-0.000	(0.001)	-0.000	(0.001)			0.000	(0.002)
South x Quota 21-27.9 m			-0.000	(0.001)	-0.000	(0.001)			-0.000	(0.001)
Region Shift x North					-0.241	(0.159)				
Region Shift x South					0.115	(0.172)				
Region Shift x Quota under 11 m					0.006 *	(0.003)				
Region Shift x Quota 11-14.9 m					0.000	(0.002)				
Region Shift x Quota 15-20.9 m					0.002	(0.001)				
Region Shift x Quota 21-27.9 m					0.002	(0.003)				
Region Shift x North x Quota under 11 m					-0.003	(0.004)				
Region Shift x South x Quota under 11 m					-0.006	(0.005)				
Region Shift x North x Quota 11-14.9 m					0.007	(0.004)				
Region Shift x South x Quota 11-14.9 m					0.002	(0.003)				
Region Shift x North x Quota 15-20.9 m					0.001	(0.002)				
Region Shift x South x Quota 15-20.9 m					-0.001	(0.002)				
Region Shift x South x Quota 21-27.9 m					-0.002	(0.004)				
Special Region x Quota under 11 m							-0.004 *	(0.001)	-0.003	(0.002)
Special Region x Quota 11-14.9 m							-0.002	(0.001)	-0.003	(0.002)
Special Region x Quota 15-20.9 m							0.001	(0.001)	-0.000	(0.002)
Special Region x Quota 21-27.9 m							-0.000	(0.001)	-0.001	(0.002)
Per kilo values of cod quota										
Quota under 11 m	25.074	(1.841)	26.285	(1.966)	27.896	(2.199)	25.874	(1.921)	26.371	(1.988)
Quota 11-14.9 m	45.874	(4.937)	47.837	(4.978)	52.455	(5.964)	47.149	(5.082)	48.395	(5.100)
Quota 15-20.9 m	69.498	(12.543)	71.875	(12.147)	80.027	(11.083)	71.588	(12.925)	73.168	(12.454)
Quota 21-27.9 m	143.819	(18.553)	144.943	(19.108)	156.030	(26.443)	146.574	(19.363)	145.737	(19.620)
Vessel characteristics	Yes		Yes		Yes		Yes		Yes	
Non-cod quotas	Yes		Yes		Yes		Yes		Yes	
Year FE	Yes		Yes		Yes		Yes		Yes	
Region FE	No		Yes		Yes		Yes		Yes	
Adj. R2	0.599		0.600		0.604		0.600		0.600	
Observations	2260		2260		2260		2260		2260	

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

Note. Robust standard errors in parentheses. Per kilo marginal values of cod quota reported in lower part of the table. There were no observations of transactions of quota from the largest group in the region "North" after the region shift. Therefore there is no interaction term for this case reported in the table.

TABLE A3
Regional Interactions: Marginal Values by Region

	R2			**R3**		**R4**			
	Mid	North	South	Spec.	Non-spec.	Spec.	North*	Mid	South
Quota under 11 m - Before Shift	26.03	20.63	23.81	19.09	27.49	19.02	26.16	29.98	23.20
Quota under 11 m - After Shift	39.32	26.90	22.34						
Quota 11-14.9 m - Before Shift	56.08	35.08	36.17	36.78	48.94	37.02	56.23	54.25	38.15
Quota 11-14.9 m - After Shift	56.28	80.99	47.62						
Quota 15-20.9 m - Before Shift	59.05	85.75	62.50	90.16	68.85	91.07	98.19	62.63	65.55
Quota 15-20.9 m - After Shift	89.88	128.47	80.04						
Quota 21-27.9 m - Before Shift	149.59	140.27	144.62	134.08	149.10	136.64	156.65	155.19	139.82
Quota 21-27.9 m - After Shift	208.91		146.24						

Note. Per kilo marginal values of cod quota from regional models in Table A2. Only model R4 contains interactions between regional shift and quota variables. "Special Region" is a subset of "North". There were no transactions in the largest regulatory after the regional shift, therefore there is no marginal value reported for this group under R2.
*Excludes areas covered by the special region.

A.3 Pairwise Differences Between Cod Quota Estimates

Figure A1 reports pairwise tests of whether cod quota coefficient estimates from the preferred specification differ across regulatory groups. The specification includes interactions between quota variables, a cap shift indicator, and a trend variable. Tests rely on combined standard errors and differences are evaluated at transaction value weighted averages of the trend indicator, and sample average for the cap shift indicator. Error bars represent 95% confidence intervals.

Results show that differences between all groups, except the two largest, are statistically significant at the 5% level. When differences are expressed in terms of implied per-kilogram prices—obtained by scaling coefficients by group-specific median transaction volumes—all contrasts are statistically significant.

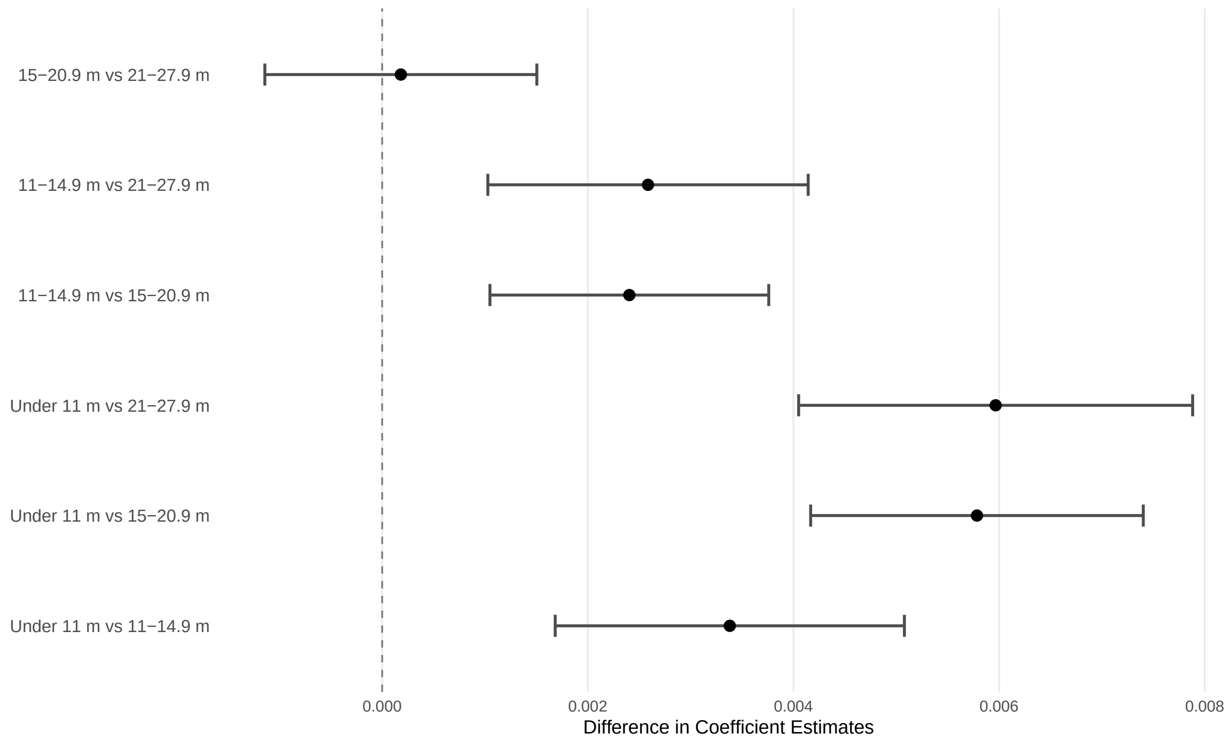

Figure A1: Pairwise Tests of Cod Quota Coefficients
Note. Coefficients from preferred specification, with 95% confidence intervals.

A.4 Additional Results

Table A4 presents additional coefficient results for vessel and bundle characteristics from same specifications as the quota coefficients reported in Table 7 in Section 6.

Table A4
Regression Results: Additional Bundle Characteristics

	Model 1	Model 2	Model 3	Model 4	Model 5
Width	2.228 ***	2.159 ***	2.168 ***	2.072 ***	2.048 ***
	(0.177)	(0.172)	(0.170)	(0.160)	(0.160)
Engine power	0.318 ***	0.317 ***	0.303 ***	0.294 ***	0.299 ***
	(0.056)	(0.056)	(0.055)	(0.055)	(0.054)
Age	-0.008 **	-0.008 **	-0.010 ***	-0.011 ***	-0.011 ***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Age Sq.	0.000	0.000	0.000	0.000 *	0.000 *
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Wood hull	0.076	0.063	0.092	0.041	0.044
	(0.097)	(0.095)	(0.093)	(0.085)	(0.084)
Alloy hull	0.381 *	0.370 *	0.328	0.247	0.254
	(0.181)	(0.181)	(0.189)	(0.185)	(0.185)
Aluminium hull	0.207 *	0.193	0.166	0.085	0.081
	(0.103)	(0.102)	(0.101)	(0.093)	(0.094)
Plastic hull	0.225 *	0.205 *	0.190 *	0.129	0.135
	(0.093)	(0.092)	(0.090)	(0.085)	(0.085)
SUK quota		0.002	0.002	0.002	0.002
		(0.001)	(0.001)	(0.001)	(0.001)
NSSH quota		-0.005	-0.007	-0.006	-0.006
		(0.009)	(0.008)	(0.007)	(0.008)
NSH quota		0.030	0.023	0.031	0.026
		(0.030)	(0.029)	(0.030)	(0.030)
Saithe north quota		0.135 *	0.137 *	0.108	0.110
		(0.069)	(0.066)	(0.059)	(0.059)
Saithe south quota		-0.479 *	-0.515 *	-0.561 *	-0.559 *
		(0.220)	(0.228)	(0.243)	(0.246)
Mackerel Net		0.127 **	0.115 **	0.078	0.066
		(0.042)	(0.042)	(0.043)	(0.044)
Mackerel Seine <13m		0.372 ***	0.315 ***	0.269 **	0.229 *
		(0.089)	(0.090)	(0.093)	(0.095)
Mackerel Seine >13m		0.025	0.024	0.013	0.013
		(0.026)	(0.026)	(0.028)	(0.028)
Special region					-0.031
					(0.050)
Buyer Region North x Region Shift					-0.207 *
					(0.098)
Buyer Region South x Region Shift					0.086
					(0.105)
Vessel characteristics	Yes	Yes	Yes	Yes	Yes
Non-cod quotas	No	Yes	Yes	Yes	Yes
Year FE	No	No	Yes	Yes	Yes
Region FE	No	No	No	No	Yes
Adj. R2	0.576	0.582	0.599	0.605	0.606
Observations	2260	2260	2260	2260	2260

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

Property rights-based management is widely used to improve efficiency in natural resource sectors such as fisheries. In catch share programs, harvesting rights are allocated to individuals or firms and traded in markets, with prices reflecting both economic outlooks and regulatory constraints. To address equity and social concerns, many programs impose restrictions on transferability, such as limits on consolidation, geographic trade, or harvesting technology, which reduce efficiency. Although such tradeoffs between efficiency and social objectives are common, there is limited empirical evidence on how these constraints affect quota valuation, which are often not publicly observable. We analyze how transferability restrictions affect quota values in a large Norwegian catch-share fishery. Using a novel dataset linking all vessel and quota transactions from 2009 to 2017, we estimate a hedonic pricing model that recovers the capitalized value of quota rights embedded in fishing-bundle transactions. This allows us to quantify the equity–efficiency tradeoff associated with Norway's coastal cod quota policy. In particular, we find large and systematic differences in marginal quota values across regulatory groups, where quotas associated with tighter consolidation caps have substantially lower marginal valuations. Geographic restrictions also affect markets, though their effects are modest relative to the impact of consolidation caps.

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