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# INPUT SUBSIDIES AND THE DESTRUCTION OF NATURAL CAPITAL: CHINESE DISTANT WATER FISHING

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## ABSTRACT

Input subsidies in natural resource sectors are widely believed to cause depletion of the natural capital on which those sectors rely. But identification and data challenges have stymied attempts to empirically estimate the causal effect of subsidies on resource extraction. China's fishing fleet is the world's largest, and in 2016 the government changed its fuel subsidy policy for distant water vessels to one that increases with predetermined vessel characteristics. The policy features 25 thresholds at which subsidies discontinuously increase. Using a regression discontinuity design, we estimate that a 1% increase in fuel subsidy increases hours of fishing by 2.2%. Reducing Chinese distant water fuel subsidies by 50% could eliminate biological overfishing in several ocean regions.

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# 1 Introduction

Input subsidies distort market efficiency by incentivizing producers to over-produce, leading to a wedge between marginal costs and consumers' marginal valuation of the good. The resulting deadweight loss depends on the elasticity of supply and demand. The economic cost of subsidies can be large: Davis (2014) calculates that in 2012 alone, the global deadweight loss from transportation fuel subsidies was \$44 billion. Subsidies are particularly pervasive in natural resource extraction sectors. For example, in agriculture, input subsidies for water, land, and even fertilizer make up 7% of global revenue (Gautam et al., 2022). But perhaps the most salient example of input subsidies occurs in the world's commercial fisheries: nearly every country subsidizes their fishing fleet, and input subsidies equal 16% of global revenue (FAO, 2020; Schuhbauer et al., 2020; Sumaila et al., 2019).

While deadweight loss resulting from subsidies are reasonably well-understood, much less attention has been given to the fact that in natural resource settings where stock dynamics matter, such as in fisheries, input subsidies may introduce a secondary and possibly long-lasting source of inefficiency by incentivizing the depletion of the resource. This practice is particularly concerning when the subsidized fleet leaves the subsidizing country's waters to fish in other nations' waters or on the high seas. These dynamics have led some researchers to suggest that fuel subsidies in fisheries, which totaled \$8 billion globally in 2018, are a leading cause of fisheries depletion (Cisneros-Montemayor et al., 2022; Costello et al., 2021; Martini & Innes, 2018). The recent WTO fisheries subsidies agreement, which required decades of negotiations and represents the second agreement ever reached at the WTO, exemplifies the centrality of subsidies in fisheries reform efforts (WTO, 2022). Subsidies have been salient in these efforts since at least 1992 (FAO, 1992).

Despite the near consensus on the connection between fuel subsidies and fisheries depletion, there is no causal evidence of the effect of fuel subsidies on fishing. The chief reason for this absence of empirical evidence is that subsidy reforms are typically implemented at the country level, leading to a lack of credible quasi-experimental variation in subsidy levels across producers. Understanding the effect of subsidies on individual producers' actions is essential for designing optimal subsidy reform because producers' actions can result in both a private channel deadweight loss (caused by a difference between the private marginal cost and the buyer's willingness to pay) and an external channel loss (caused by externalities in stock dynamics).

In this paper, we compile new vessel-level panel data on the Chinese distant water fishing (DWF) fleet to estimate the effects of subsidies on production decisions. We leverage vessel-level variation in fuel subsidies that was induced by China's 2016 fuel subsidy reform. The reform created 25 separate thresholds at which fuel subsidies discontinuously increase. These thresholds depend entirely on predetermined vessel characteristics. We measure fishing behavior using real-time data taken from Global Fishing Watch (GFW).

Many features of our data and research design make it a compelling setting to study the impact of input subsidies. First, the fishing effort data come from GFW and they are derived from AIS transponder signals. This means we observe fishing effort in real time at the vessel-level. Second, we leverage vessel-specific quasi-experimental variation in subsidy levels, alleviating concerns about reverse causality (e.g., subsidies being increased when the industry experiences a negative shock) and other sources of omitted variables bias (e.g., subsidizing less profitable individual producers). Third, the reform we analyze was in effect for six years, which allows us to interpret the derived elasticities as long-term elasticities. Long-run elasticities are necessary to measure the economic and ecological costs of subsidies.

The design of China's fuel subsidy program motivates a regression discontinuity approach. This approach compares the fishing effort of vessels that are similar in terms of characteristics such as gross tonnage, engine power, and target species. However, the vessels are eligible for vastly different subsidy levels due to the program's design. The fuel subsidy program applies to China's DWF fleet, which comprises roughly 2,500 large vessels, by far the largest in the world (Bureau of Fisheries et al., 2022).[1] The DWF fleet is distant water in the sense that it fishes inside the Exclusive Economic Zones (EEZs) of countries other than China, as well as on the high seas beyond any nation's jurisdiction. The Chinese government considers distant water fishing to be a strategic industry that contributes to China's "Go Global" industrial restructuring strategy, increases domestic fish supply and food security, and allows

[1] Millage et al. (2021) estimate the Chinese DWF fleet contains five times more vessels than the entire European Union's distant water fleet, the second-largest.

fishers to remain in the industry even as domestic fish stocks become exhausted (Ministry of Agriculture, 2007; Zeng, 2022). Currently, Chinese DWF vessels fish in the EEZs of more than 40 other countries and in the high seas of the Pacific Ocean, Indian Ocean, Atlantic Ocean and Southern Ocean (Bureau of Fisheries, 2021a; Bureau of Fisheries et al., 2022; Ministry of Agriculture and Rural Affairs, 2020; Zeng, 2022), harvesting 2.25 million tons and earning 22.56 billion yuan ($3.5 billion) in revenue in 2021 (Bureau of Fisheries et al., 2022; China Foreign Exchange Trade System, 2021; Ding, 2015).

The regression discontinuity estimates of the effect of fuel subsidies are large: we find that a 1% increase in fuel subsidy increases hours of fishing by 2.2%. Vessels just above a subsidy threshold receive $10,000 more in fuel subsidy each month and they fish 170 more hours per month than vessels just below a subsidy threshold. Similarly, we find that a 1% increase in fuel subsidy increases the distance traveled by vessels (which includes fishing and non-fishing activities) by 1.7%. The fuel subsidy policy we evaluate was in effect for six years. We therefore view these estimates as long-run elasticities, which other research has found to be an order of magnitude larger than short-run elasticities (Buchsbaum, 2022; Feehan, 2018).

We then use our estimated elasticity of fishing with respect to fuel subsidies to simulate how global fish stocks would change if China reduced its distant water fuel subsidies. We use data on fish stock status from Costello et al. (2016) to predict changes in biological overfishing status in 18 major ocean regions. We show mathematically that changes in overfishing status closely correspond to changes in fish biomass. Our estimates indicate that reforming Chinese distant water fuel subsidies would lead to remarkable reductions in fishing effort across most ocean regions where the Chinese distant water fleet is active. In particular, a 50% reduction in distant water fuel subsidies would eliminate overfishing in the Southeast Pacific and the Antarctic Atlantic ocean regions. Overall, the fraction of global fish stocks experiencing overfishing (65%) would drop by 3 percentage points (∼5%) if Chinese fuel subsidies to its distant water fishing fleet were cut in half.

By quantifying the effect of fuel subsidies on global overfishing, our paper contributes to the literature on nature-depleting subsidies, which may be as high as $7 trillion annually (Dasgupta, 2021; Davis, 2014; Ryan & Sudarshan, 2022). At the Conferences of the Parties

(COP) to the Convention on Biological Diversity, countries agreed in 2010 and again in 2022 to reduce and reform these subsidies, and to instead use these funds to promote biodiversity conservation (Convention on Biological Diversity, 2010, 2022). Our analysis illustrates one ecological benefit of implementing those commitments.

The two papers most closely related to ours are Sakai (2017) and Wang et al. (2022). Sakai (2017) estimates the relationship between subsidies and fish stocks, rather than fishing effort. Their identification strategy compares countries with more and less subsidy to each other over time, whereas our paper implements a regression discontinuity design. Wang et al. (2022) studies the effects of fuel subsidies and vessel buyback programs on the capacity of the trawler fleet of Zhejiang Province, China. Our paper differs in its primary outcome variable—hours of fishing, compared to measures of capacity such as the probability of scrapping a vessel—and in its scope—all distant water vessels, compared to vessels registered in Zhejiang that use the trawling fishing method in Chinese national waters.

# 2 Institutional context

Along with 79 other countries, China subsidizes the fuel of its fishing vessels (Schuhbauer et al., 2020). China does so because its fishing industry is economically and strategically important. Six million full-time workers were employed in the fisheries sector in China in 2021 (Bureau of Fisheries et al., 2022). The government particularly encourages distant water fishing, taking places on the high seas or in the EEZs of other countries, because it contributes to China's food security,[2] "Marine Power Strategy", and its "Go Global" and "One Belt One Road" directives (Bureau of Fisheries, 2017; Zeng, 2022).

Chinese fisheries fuel subsidies began in 2006 as a complement to China's economy-wide oil price reform.[3] In order to reduce the cost pressure caused by higher fuel prices, the

[2]The national government exempts import tariff and import value-added tax on self-caught aquatic products (and processed products) that are caught in the EEZs of other countries or on the high seas and shipped back to China by distant water fishing vessels (General Administration of Customs and Ministry of Agriculture, 2000). As a further incentive, some regions provide subsidies that increase with the quantity of aquatic products declared at customs (Government of Fujian Province, 2014, 2021; Tianjin Municipal Committee of Agriculture and Rural Affairs, 2020).

[3]To reduce the price difference between domestic and international oil products, the government introduced a market-oriented reform for oil prices and increased domestic refined oil prices in 2006.

government provided subsidies for vulnerable groups and industries, including fishers and fishing companies (National Development and Reform Commission, 2006). The Chinese government reforms its distant water fuel subsidy policy every five years as part of its Five-Year Plans,[4] and it has separate fuel subsidy policies for distant water fishing vessels and for vessels that fish in its EEZ.[5] Vessels must be "flagged to" (registered in) China to receive fuel subsidies. The distant water fuel subsidy policies between 2006 and 2015 were mainly based on fuel prices and consumption.[6] Instead of achieving its original intent of protecting fishers when oil prices are high, the government came to view this subsidy formula, which awarded subsidies proportionally to fuel consumption, as leading to undesirably high levels of subsidy expenditure, fuel consumption, and fishing (Ministry of Finance, 2016).

China reformed its fuel subsidy policy in 2016 with this concern in mind. We study the effects of the distant water fuel subsidy policy between 2016 and 2020 because that policy features numerous thresholds at which fuel subsidies discontinuously increase with vessel size (Ministry of Agriculture, 2016). Distant water fuel subsidy policies between 2006 and 2015, and from 2021 onward, do not feature discontinuities according to vessel size (Department of Industrial Policy and Regulation, Ministry of Agriculture, 2021; Ministry of Agriculture and Rural Affairs and Ministry of Finance, 2021a).[7] Chinese fuel subsidies are determined ex post in that the amount of subsidy awarded for fishing in year $t$ depends on the policy in year $t+1$. For example, the fuel subsidies vessels receive in 2015 depend on 2015 fishing activities and the parameters of the policy in 2016. We exclude 2015 data from our primary analysis because the policy we evaluate was publicly announced in 2016; some vessels might not have known about the new policy when choosing how much to fish in 2015 (Ministry of

[4] 2006 was the first year of the 11th Five-Year Plan. There have been four iterations of distant water fuel subsidies so far: 2006 to 2010, 2011 to 2015, 2016 to 2020, and 2021 to 2025, corresponding to China's 11th, 12th, 13th, and 14th Five-Year Plan periods.

[5] In 2011, the most recent year in which EEZ fuel subsidies data are available, fuel subsidies to vessels that fish in China's EEZ totaled 20.63 billion yuan ($3.2 billion) (Bureau of Fisheries, 2012; China Foreign Exchange Trade System, 2021). By comparison, total distant water fuel subsidies in 2011 were 2.68 billion yuan ($415 million) (Bureau of Fisheries, 2012; China Foreign Exchange Trade System, 2021).

[6] In 2007, the Ministry of Agriculture published the official formula (Department of Industrial Policy and Regulation, Ministry of Agriculture, 2021). This formula did not change between 2006 and 2015.

[7] China ended explicit fuel subsidies from 2021 and replaced them with a "compliance award" based on the compliance rating scores of distant water fishing companies (Ministry of Agriculture and Rural Affairs and Ministry of Finance, 2021a). These compliance subsidies may also increase fishing because they are linear in "compliance hours" (e.g., hours of fishing in an authorized location).

Agriculture, 2016). We include data from 2020 in our primary analysis because the 2016-2020 formula was used by most provinces to award subsidies that year.[8] We obtain similar results when we repeat our analysis with data between 2015 and 2020, and data between 2016 and 2019 (Section 5.3).

During our period of analysis (2016-2020), the fuel subsidy received by vessel $i$ of gear (fishing method) type $j$ in year $t$ is given by

$$Subsidy_{ijt} = SubsidyStandard_t \times SubsidyFactor_j \times SubsidizedEnginePower_{ij} \times SubsidyDays_{it}$$

The subsidy standard is the same for all vessels but changes each year; we control for this by including year fixed effects some of the specifications below.[9] The subsidy factor is a constant that depends on the vessel's gear.[10] The discontinuities in subsidy amount occur because of the subsidized engine power term, which we explain when we introduce our empirical strategy in Section 4. The particular thresholds at which discontinuities occur derive from the government's goal for firms to scrap their vessels and rebuild them in standardized sizes.[11] We subset the data in our primary analysis to vessels built before 2016 to ensure that our results are driven by vessels who did not choose their characteristics with respect to fuel subsidy thresholds or with respect to other, simultaneously-introduced regulations that could confound our estimates.[12] Finally, subsidy days are the minimum of authorized fishing days and "vessel monitoring system (VMS) days". As we explain below, subsidy

[8] Zhejiang province was an exception (Zhejiang Provincial Department of Finance and Zhejiang Provincial Department of Agriculture and Rural Affairs, 2021). Most provinces used the 2016-2020 formula because they were not required to start applying the 2021-2025 formula until 2021 (Ministry of Agriculture and Rural Affairs and Ministry of Finance, 2021b, 2021c, 2021d).

[9] The subsidy standard was 2,610 in 2015 (Taicang Municipal Government, 2016), 1,808 in 2016 (Wenling Municipal Government, 2017), 1,645 in 2017 (Jiangbei District Government, 2019), 1,331 in 2018 (Jiangbei District Government, 2020), 1,331 in 2019 (Department of Agriculture and Rural Affairs of Liaoning Province, 2020), and 1,065 in 2020 (Department of Agriculture and Rural Affairs of Liaoning Province, 2020). Since the subsidy standard is the same in all regions of China in the same year, our data comes from the public data of specific regions. The downward trend in the subsidy standard is consistent with the national government's desire to reduce the level of subsidy expenditures (Ministry of Finance, 2016).

[10] There are ten gears and four possible values of the subsidy factor, ranging from 0.00246 to 0.00492. Most vessels in our data have a subsidy factor of 0.00369.

[11] The government believes that standardization improves the safety and durability of newly-constructed vessels (Ministry of Agriculture and Rural Affairs, 2021).

[12] These regulations are renovation and reconstruction subsidies and vessel standardization regulations (Sections 5.2.2 and 5.3).

days roughly correspond to the number of days vessels fish, and the fuel subsidy is linear in subsidy days, the fuel subsidy policy could increase fishing because it reduces the marginal cost of fishing.

Each year, vessel owners (firms) request a number of authorized fishing days, as well as the areas in which their vessels will fish, from the Ministry of Agriculture (MOA), which houses the Bureau of Fisheries. Authorized fishing days do not bind subsidy days because the MOA approves requests as long as the firm and its employees are not on the Ministry's blacklist (Bureau of Fisheries, 2020b; FAO, 2022a; Ministry of Agriculture, 2003).[13] VMS days refers to the number of days in which the MOA receives a minimum number of pings (messages) from vessels' VMS transponders.[14] Each ping from a vessel contains its identifying information, location, speed, and direction of travel. Between 2015 and 2019, the minimum ping rate was 6 per day and at least one ping every four hours (Ministry of Agriculture, 2014a). In 2020, the MOA increased the minimum ping rate to 24 per day and at least one ping per hour (Bureau of Fisheries, 2019). VMS days roughly correspond to days of fishing because pings must originate from vessels' authorized fishing areas in order to contribute toward vessels' subsidies (Ministry of Agriculture, 2012).

We do not observe VMS pings because the MOA considers these data to be confidential. Instead, we define a subsidy day as a day in which we observe at least one ping from a vessel's Automatic Identification System (AIS) transponder, which are publicly available (Kroodsma et al., 2018). This measure likely underestimates the number of subsidy days, but by much less than if we applied the MOA's minimum VMS ping rate to the AIS data (Figure A1). AIS transponders transmit similar data to terrestrial receivers and satellites as VMS transponders, but they have worse reception than VMS. We calculate that the fuel subsidy for the median vessel-year is $223,380 (2022 USD) using this measure of subsidy days, but because our measure is an underestimate, the median vessel-year annual fuel subsidy is

[13]China's blacklisting policy began in 2017 (Zhang, 2018). We do not find evidence that this policy induced selection into fuel subsidies. While 26 vessels are blacklisted for at least one year of our data, none of them fall within the optimal bandwidth of our preferred specification (Column 1 of Table 3). The data on blacklisted companies and vessels are from Ministry of Agriculture and Rural Affairs (2018a, 2018b, 2019a, 2019b).

[14]In cases where the countries visited by fishing vessels forbade vessel location surveillance equipment, Chinese distant water fishing vessels are required to install Automatic Identification System (AIS) transponders (Ministry of Agriculture, 2014a).

likely greater. This subsidy amounts to about 10% of annual variable costs for the median vessel-year in our data (Sala et al., 2018). This underestimate of subsidy days affects our elasticity of fishing with respect to fuel subsidy received, but it does not affect our estimate of the effect of the fuel subsidy policy on fishing.

# 3 Data

By combining publicly-available data from international organizations and Chinese agencies, we identify and collect the characteristics of subsidized Chinese distant water fishing vessels. Then we match these characteristics with fishing activity data. The resulting panel data are at the level of vessel-month-year.

We begin by collecting data on mainland Chinese distant water fishing vessels from the seven Regional Fishery Management Organizations (RFMOs) that China belongs to.[15] For each RFMO vessel, we recorded the vessel's registry name and vessel characteristics, including gear, length, gross tonnage, engine power, and the year the vessel was built. Gross tonnage is a non-linear measure of a vessel's internal volume. When vessels have the same name in Chinese pinyin, but the Chinese characters name and other characteristics are different, we regard them as different vessels. In most RFMOs, vessels reported additional identification information such as previous name, Maritime Mobile Service Identity (MMSI), call sign, and International Maritime Organization (IMO) number. We also gathered data from RFMO websites on the species vessels target when they fish, vessels' authorized fishing area, freezer type (if the vessel has a freezing system), the firm the vessel belongs to, and the RFMOs the vessel is registered in. We combine these variables into a single dataset at the vessel-RFMO level.

Not all RFMO databases contain all of the above variables, especially vessel character-

[15] According to the Chinese White Paper on the Compliance of China's Distant Water Fisheries 2020 (Ministry of Agriculture and Rural Affairs, 2020), China is also a member of the Southern Indian Ocean Fisheries Agreement (SIOFA). But because the SIOFA authorized vessels do not contain any fishing vessels from mainland China, we only collect data from the following seven RFMOs: Convention on Conservation of Antarctic Marine Living Resources (CCAMLR), Inter-American Tropical Tuna Commission (IATTC), International Commission for the Conservation of Atlantic Tunas (ICCAT), Indian Ocean Tuna Commission (IOTC), North Pacific Fisheries Commission (NPFC), South Pacific Regional Fisheries Management Organization (SPRFMO), and Western and Central Pacific Fisheries Commission (WCPFC) (CCAMLR, 2021; IATTC, 2021; ICCAT, 2021; IOTC, 2021; NPFC, 2021; SPRFMO, 2021; WCPFC, 2021).

istics, and characteristics sometimes differ across RFMOs for vessels with the same identifiers. To include more vessels and vessel characteristics, we combine our RFMO data with data from Rongcheng, a hub of Chinese distant water fisheries.[16] The municipal dataset of Rongcheng is part of the Shandong Provincial Open Data Platform, which was developed in 2018 and contains 318 distant water fishing vessels registered in Rongcheng (Rongcheng Municipal Government, 2021).[17] We also added 104 vessels that are included in the Rongcheng database but not in the RFMO databases. We fill in missing fishing gear values for eight vessels with information from Chinese news reports and fishing firm websites.[18] We standardize all vessel lengths to meters and all engine powers to kilowatts. After removing duplicate vessels, we obtain data for 2,216 Chinese distant water fishing vessels.[19]

We match these vessel characteristics data to fishing activity data from the organization Global Fishing Watch (GFW).[20] We are able to match about 70% of vessels because most

[16]Rongcheng is both a hub of Chinese distant water fishing vessels and a hub of distant water fishing firms. In 2020, Rongcheng had 307 distant water fishing vessels and 19 distant water fishing firms, compared to China's total of 2,705 distant water fishing vessels and 180 distant water fishing firms that year (Bureau of Fisheries, 2020a; Bureau of Fisheries et al., 2021). Rongcheng is also the only distant water fishing hub in northern China, and it is the county-level city with the largest distant water catch and revenue in China (General Administration of Customs, 2021).

[17]For the 99 vessels missing characteristics in the RFMO data but not in the Rongcheng data, regardless of whether they are registered with only one RFMO or in multiple RFMOs, we use the Rongcheng data to fill in missing characteristics. For the 68 vessels enrolled in multiple RFMOs and with conflicting characteristics across RFMO databases or between RFMO data and Rongcheng data, we use characteristics from the Rongcheng data. We believe that the Rongcheng data are more reliable than the RFMO data because their vessel characteristics data are the same as those used by the MOA to calculate fuel subsidies.

[18]Eight vessels have "other fishing vessels not specified" listed as their gear in the RFMO data: JINGYUAN616, LUWENYUANYU171, LUWENYUANYU172, LUWENYUANYU175, LUWENYUANYU176, LUWENYUANYU177, LUWENYUANYU178, TIANYUAN. We determined from Chinese news reports that the first seven vessels are squid jiggers and stick-held dip net for Pacific saury fishing vessels, and the last one is a squid jigger (Cong, 2014; Pan, 2015; Zhoushan Property Exchange Co., Zhoushan Jia Lian Auction Co., and Zhoushan Huali Auction Co., 2009). Seven vessels have missing gear in the RFMO data. According to Chinese news reports, FURONGHAI, FUYUANYU9818 and MINGKAI are factory stern trawlers in CCAMLR areas, and PINGTAIRONG131, ZHONGSHUI602, ZHONGSHUI606 and ZHONGSHUI607 are tuna longliners (Wang, 2022; Weng, 2021; Yuan, 2015).

[19]We have slightly fewer vessels in our data compared to the 2,705 legally authorized distant water fishing vessels at the end of 2020 mentioned in the Chinese Fisheries Statistical Yearbook. The reason for this is that our dataset only includes distant water fishing vessels from seven RFMOs and Rongcheng; we are missing distant water fishing vessels not present in these data. For example, vessels authorized to fish in another country's waters, and not in any regions managed by RFMOs, could be authorized by the MOA without being registered in an RFMO database.

[20]We matched our vessel characteristics data to the research version of GFW's fishing data, which is only available to GFW Research Partners, rather than the publicly available version of these data, because the research version contains more vessels. However, in our analysis we subset our data to vessels in the public version of GFW's data so that our results are reproducible.

distant water fishing vessels have Automatic Identification System (AIS) transponders that send their movements to satellite and terrestrial receivers. GFW applies machine learning algorithms to predict fishing activity from AIS vessel movements (Kroodsma et al., 2018). Note that vessels have no differential incentive to disable their AIS transponders with respect to fuel subsidy thresholds because fuel subsidies depend on VMS rather than AIS pings (Section 2).

From the GFW dataset, we extracted information for all vessels flagged to (registered in) China between 2015 and 2020, including the hours of fishing and vessel characteristics. We focused on China-flagged vessels because this is a requirement for a vessel to receive a subsidy from the Ministry of Agriculture. In contrast to the RFMOs, which can obtain detailed vessel data from member countries based on compliance rules, some GFW vessel characteristics are machine-learning-predicted values (Kroodsma et al., 2018). We believe that RFMO vessel characteristics are more reliable than GFW's for this reason. We ignore GFW vessel characteristics data and only match our vessel characteristics data to GFW fishing hours data on the following vessel identifiers: registry name, MMSI (called SSVID by GFW), call sign and IMO.

For vessels that do not match perfectly on these four variables between the two datasets, we develop a matching criterion with two indices: the vessel name as the primary fixed matching index and other indicators as the flexible matching parameter with the priority MMSI > call sign > IMO. This matching criterion means we first match vessels by name and MMSI, then match unmatched vessels by name and call sign, and finally match remaining unmatched vessels by name and IMO. Figure B1 illustrates this process and states the number of vessels in each category.

We first apply this procedure to the 2,202 vessels whose names appear in only one RFMO database. Then we manually match the remaining 14 vessels. In total, we are able to match 1,496 vessels to the GFW fishing data. If a vessel-year has observations in GFW data in some months but not in others, we add rows for those months to our panel data and assign fishing hours = 0.[21] Finally, we subset vessels to those present in the publicly-available version of

[21] Implicit in this procedure is that if a vessel-year does not appear in the GFW data, we do not add rows that vessel-year to our panel data. The issue of when to add zeros only affects our estimates in Section 5.2.1, when the dependent variable is an indicator for positive fishing hours.

Table 1: Summary Statistics on Chinese Distant Water Fishing Vessels

| | Min | 25% | 50% | Mean | 75% | Max | N |
|---|---|---|---|---|---|---|---|
| A. Vessel-level characteristics | | | | | | | |
| Gross tonnage | 97 | 330 | 552 | 720 | 971 | 7,847 | 1,234 |
| Engine power (kW) | 218 | 692 | 882 | 1,036 | 1,400 | 5,920 | 1,234 |
| Length (m) | 21 | 40 | 48 | 49 | 59 | 121 | 1,234 |
| B. Vessel-month-year-level fishing | | | | | | | |
| Fishing hours | 0 | 0 | 186 | 221 | 361 | 751 | 59,124 |
| Fishing hours (positive only) 0 | 1 | 150 | 252 | 297 | 456 | 751 | 44,020 |

GFW's fishing data so that our analysis is reproducible. This filtering reduces the number of matched vessels to 1,340, of which 1,234 have a gear with a gross tonnage discontinuity.[22]

Table 1 reports summary statistics on our estimation sample, which we believe is the largest vessel-level database ever compiled on the Chinese distant water fishing fleet and its attributes. These vessels are typically large, roughly 50 meters long on average, with engine power averaging 1,036 kW. Distant water fishing vessels fish on average 221 hours per month (297 for those fishing positive hours). The range of activity across vessels and months is large, with monthly fishing hours ranging from 1 to 751.

# 4 Empirical strategy

Recall from Section 2 that the annual subsidy in yuan for Chinese distant water fishing vessels is given by the formula: *subsidy standard* × *subsidy factor* × *subsidized engine power* × *subsidy days*. The key variable is subsidized engine power since it contains the discontinuities that our empirical strategy exploits. Subsidized engine power is the minimum of a vessel's engine power and its subsidized engine power *ceiling*. Vessels with higher gross tonnages (GT) have higher ceilings. Table B1 displays how vessels' ceilings of subsidized

[22]Pacific saury vessels have only one ceiling of subsidized engine power: 2,200 kilowatts for vessels with gross tonnage above 1,400 (Table B1). All Pacific saury vessels have gross tonnage above 1,400, and there is no information on what the ceiling of subsidized engine power would be for Pacific saury vessels with gross tonnage below 1,400.

engine power depend on their gross tonnage and gear. Mathematically,

$$
\begin{aligned}
subsidized\ engine\ power = min( & \\
& engine\ power, \\
& subsidized\ engine\ power\ ceiling(gross\ tonnage,\ gear) \\
& )
\end{aligned}
$$

To illustrate the specifics of the program and the discontinuity in subsidy allocation, consider the following example for "squid jiggers", a category of vessels with fishing gear that allows them to target squid. Squid jiggers with GT $\geq$ 300 have a subsidized engine power ceiling of 750 kW, while squid jiggers with $GT < 300$ have a ceiling of 600 kW. The squid jigger in the top right cell of Table 2 has an engine power (EP) of 500 and a GT of 301. This vessel does not receive more subsidy from being above its nearest GT threshold because its ceiling of subsidized engine power would not be binding if its GT was below 300; the vessels in both top cells receive the same subsidized engine power of 500. By contrast, the squid jiggers in the bottom right cells benefit from being above 300 GT because their subsidized engine power ceilings would have been binding if their GT was below 300. These vessels receive subsidized engine powers of 700 and 750, compared to the 600 they would have received if their GT was below 300 (bottom left cells).

Table 2: Example Showing that Subsidized Engine Power Depends Gross Tonnage, and Engine Power

| | | GT: **Below** | GT: **Above** |
|---|---|---|---|
| **EP** | **Non-binding** | (500, 299) $\Rightarrow$ Subsidized EP = 500 | (500, 301) $\Rightarrow$ Subsidized EP = 500 |
| | | (600, 299) $\Rightarrow$ Subsidized EP = 600 | (600, 301) $\Rightarrow$ Subsidized EP = 600 |
| | **Binding** | (700, 299) $\Rightarrow$ Subsidized EP = 600 | (700, 301) $\Rightarrow$ Subsidized EP = 700 |
| | | (800, 299) $\Rightarrow$ Subsidized EP = 600 | (800, 301) $\Rightarrow$ Subsidized EP = 750 |

There are therefore four types of vessels: those above or below their nearest gross tonnage threshold, and those for which their ceiling of subsidized engine power would be binding or would be non-binding if they were below their nearest gross tonnage threshold. We define "binding vessels" as those for which their ceiling of subsidized engine power would be binding and "non-binding" vessels as those for which their ceiling of subsidized engine power would not be binding. Since fuel subsidies are linear in subsidized engine power, "binding" vessels above their nearest gross tonnage thresholds receive discontinuously more subsidy. These vessels form our treatment group, while the other three types of vessels form our control group. Naturally, the regression discontinuity specification will include controls for engine power and gross tonnage, as we explain below.[23]

In the regression analysis, we pool vessels across gears and gross tonnage thresholds because our data are sparse within each gear-gross tonnage threshold discontinuity. First, we identify the nearest gross tonnage threshold of each vessel and calculate its "gross tonnage distance", which equals the gross tonnage of a vessel minus its nearest gross tonnage threshold. In the Table 2 example, vessels in the left-side cells have a gross tonnage distance of -1 and vessels on the right-side cells have a gross tonnage distance of +1. This procedure normalizes gross tonnage thresholds (the cutoff) to 0. Then we calculate "normalized gross tonnage distance" by dividing gross tonnage distance by the width of the vessel's nearest gross tonnage threshold. Threshold width is half the distance to the next threshold.[24]

Normalized gross tonnage distance is the running variable in our primary specification. It is similar to a vessel's percentage distance to its nearest gross tonnage threshold. Figure 1 displays the transformation from (a) gross tonnage in levels to gross tonnage distance; and (b) from gross tonnage distance to normalized gross tonnage distance. Figure 1(c) depicts the gross tonnage thresholds and widths for two gears: tuna purse seiners and squid jiggers, which we use to explain the difference between gross tonnage distance and normalized gross tonnage distance. Consider two vessels: a tuna purse seiner with a gross tonnage of 1,400 and a squid jigger with a gross tonnage of 480. The gross tonnage distance of the tuna purse seiner is -100 and the gross tonnage distance of the squid jigger is -20, while the normalized gross tonnage distance of both vessels is -0.2. When gross tonnage distance

[23]Note that vessels register their characteristics with the government, who inspects vessels and verifies characteristics annually (Bureau of Fisheries, 2003; Chinese Government, 1994; Ministry of Agriculture, 2013a). These inspections mitigate concerns about vessel owners misreporting gross tonnage and engine power in order to receive larger fuel subsidies.

[24]A threshold's width to the left may differ from its width to the right because distance to the below threshold may differ from distance to the above threshold. Relatedly, since a gear's minimum threshold has no threshold below it, we set its left threshold equal to its right threshold. Similarly, we set the right width of a gear's maximum threshold equal to its left width.

is the running variable, the tuna purse seiner will almost always be outside the optimal bandwidth, even though relative to the width of its threshold it is the same distance from its nearest threshold as the squid jigger. Normalizing gross tonnage distance gives large and small vessels a more equal opportunity to fall within the optimal bandwidth and contribute to our estimates because this running variable accounts for the tendency of large vessels to be in large bandwidths. By contrast, when (non-normalized) gross tonnage distance is the running variable, the gross tonnage in levels of most vessels within the optimal bandwidth is small. We prefer normalized gross tonnage distance as the running variable because it does not overweight small vessels.

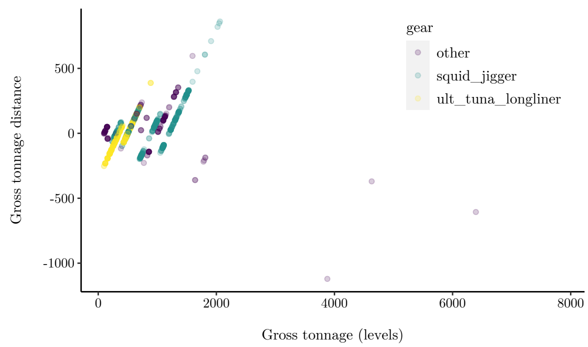
The primary estimating equation is:

$$\begin{aligned} log(fishing\_hours_{ijt}) = {} & \beta_1 \mathbb{1}\{norm\_gt\_dist_{ij} > 0\} + \beta_2 norm\_gt\_dist_{ij} + \\ & \beta_3 norm\_gt\_dist_{ij} \times \mathbb{1}\{norm\_gt\_dist_{ij} > 0\} + \\ & \beta_4 gt_i + \beta_5 engine\_power\_kw_i + \beta_6 length\_m_i + \\ & \beta_7 year\_built_i + \alpha_j + \epsilon_{ijt} \end{aligned} \tag{1}$$

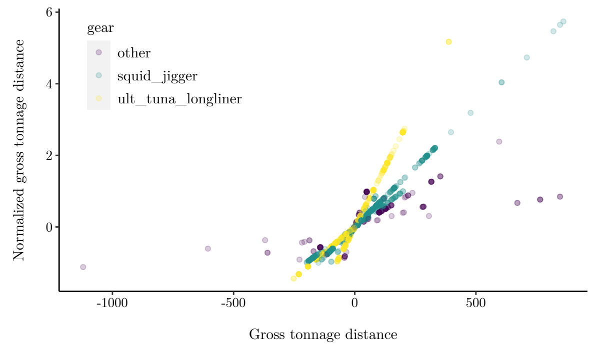
where $i$ = vessel, $j$ = gear, $t$ = month-year, $log(fishing\_hours)$ is log hours of fishing, $norm\_gt\_dist$ is normalized gross tonnage distance, $\mathbb{1}\{norm\_gt\_dist_{ij} > 0\}$ equals 1 if the vessel's gross tonnage is greater than or equal to its nearest gross tonnage threshold and it equals 0 otherwise, $gt$ is the vessel's gross tonnage in levels, $engine\_power\_kw$ is the vessel's engine power in kilowatts, $length\_m$ is the vessel's length in meters, $year\_built$ is the year the vessel was built, $\alpha_j$ are gear fixed effects and $\epsilon_{ijt}$ is the error term. The coefficient of interest is $\beta_1$, which measures the effect of being just above the gross tonnage threshold on fishing and corresponds to the local average treatment effect of receiving more subsidy on fishing behavior. For that interpretation to be valid, the standard regression discontinuity design assumptions must hold. The key assumption is that the conditional expectation function of the potential outcomes (fishing behavior with and without the additional subsidy) are continuous in gross tonnage around the multiple thresholds where the subsidy levels change. Finally, we cluster standard errors at the vessel level because that is the level at which treatment is assigned (Abadie et al., 2023).

Figure 1: Construction of Normalized Gross Tonnage Distance as Running Variable

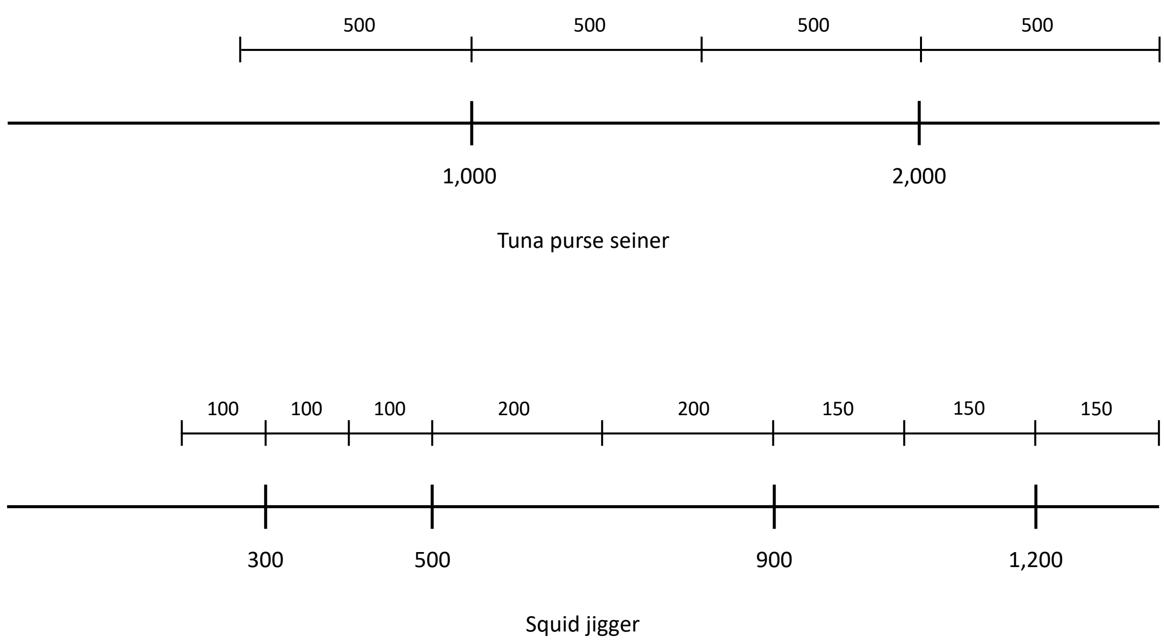
(a) Gross tonnage to gross tonnage distance




(b) Gross tonnage distance to normalized




(c) Gross tonnage thresholds and widths for two gears




Notes: (a) A vessel's gross tonnage distance (y-axis) equals its gross tonnage in levels (x-axis) minus its nearest gross tonnage threshold. (b) A vessel's normalized gross tonnage distance (y-axis) is its gross tonnage distance (x-axis) divided by the width of its nearest gross tonnage threshold. (c) Gross tonnage thresholds (larger font) and widths (smaller font) for two gears.

Unless otherwise noted, we estimate all regressions with the default options of the rdrobust package in R (Calonico et al., 2022). We use the package's default options so as to limit researcher degrees of freedom. The package's default options are: mean squared error-optimal bandwidth selection, a minimum of 10 unique values of the running variable inside the optimal bandwidth,[25] the same bandwidth above and below the gross tonnage threshold, local linear specification for the running variable, triangular kernel function, and local quadratic specification for the bias-correction. The regression tables below report the three estimates that rdrobust reports by default: the conventional point estimate and conventional standard error, the bias-corrected point estimate and conventional standard error, and the bias-corrected point estimate and the robust bias-corrected standard error. Unless otherwise noted, we report 'Conventional RD' estimates in the text because they remain the default estimators in applied microeconomics.

In addition to displaying point estimates and standard errors in table format, we visually reproduce the primary regression results using binned sample means and local linear conditional mean functions to allow the reader to assess the variation of the dependent variable around the gross tonnage threshold. We specify three non-default options so that the difference in the intercepts between the two local linear conditional mean functions corresponds exactly to the conventional regression discontinuity point estimate. Those non-default options are: triangular kernel, local linear specification for the running variable, and the same optimal bandwidth from the corresponding regression table and column. Unless otherwise noted, we use default options in all other instances. The most important of these default options calculates the number of bins and the bin endpoints with the mimicking variance evenly-spaced method using spacings estimators (Calonico et al., 2015).

If the regulator chose subsidy thresholds to award more subsidy to the vessels they expected would fish most, then our estimates of the effect of fuel subsidies on fishing are upward biased. We explore the likelihood of this scenario with pre-period fishing data. Between 2006 and 2014, fuel subsidies for distant water vessels were linear in engine power and independent of gross tonnage (Department of Industrial Policy and Regulation, Ministry of Agriculture, 2021). GFW fishing data begins in 2012. As a placebo test, we estimate Equation 1 on log monthly fishing hours between 2012 and 2014 by "soon-to-be binding" vessels—those with

[25] If the optimal bandwidth results in fewer than 10 unique values of the running variable, then the package enlarges the bandwidth until 10 unique values occur within it.

gear, gross tonnage, and engine power such that their engine power became binding under the 2016-2020 fuel subsidy policy. We exclude 2015 data from this test because some firms may have been aware of the fuel subsidies policy that was applied to calculate 2015 subsidies, even though the policy was not officially announced until 2016 (Ministry of Agriculture, 2016). Pre-period fishing hours by soon-to-be binding vessels are slightly *lower* among vessels who will be just above 2016-2020 fuel subsidy thresholds (Figure A2). This result provides evidence against the hypothesis that more-subsidized vessels would have fished more than less-subsidized vessels even in the absence of fuel subsidies.

# 5 Effects of fuel subsidies on fishing and distance traveled

## 5.1 Intensive margin effects

Table 3 reports our preferred estimates of the impact of the subsidy program on distant water fishing activity. In Column 1, we limit the sample to "binding vessels": vessels for which the engine power ceiling is binding. In this sample, vessels above their gross tonnage threshold receive more subsidy from being above it, and vessels below their gross tonnage threshold would have received more subsidy had they been above it. We find that the fuel subsidy policy increases monthly fishing hours by a statistically significant 1.125 log points (standard error = 0.233). We convert this large coefficient into an elasticity in Section 5.1.1. While this is our preferred estimate of the effect of the policy on fishing, we note that the other regression discontinuity estimates of the subsidy policy impact ("Bias-corrected" and "Robust") are even larger in magnitude and are more precisely estimated.

Limiting the sample in Column 2 to "non-binding vessels"—those for which the engine power ceiling is not binding—provides a placebo test. The fuel subsidy policy should not increase fishing for these vessels because vessels in this sample do not receive more subsidy from being just above their gross tonnage threshold. The estimated impact of the policy on these vessels is slightly negative, statistically insignificant, and much smaller in magnitude than the effect on binding vessels.

Table 3: Estimated Effect of Fuel Subsidies on Fishing Hours and Distance Traveled

| | Dependent variable: | | | |
|---|---|---|---|---|
| | log(fishing hours) | | log(km traveled) | |
| | (1) | (2) | (3) | (4) |
| Conventional | 1.125 | -0.084 | 1.934 | -0.197 |
| | (0.233) | (0.061) | (0.209) | (0.047) |
| Bias-Corrected | 1.565 | -0.040 | 2.208 | -0.170 |
| | (0.233) | (0.061) | (0.209) | (0.047) |
| Robust | 1.565 | -0.040 | 2.208 | -0.170 |
| | (0.276) | (0.067) | (0.345) | (0.060) |
| Bandwidth | 0.199 | 0.310 | 0.199 | 0.310 |
| N | 1,050 | 6,799 | 1,234 | 7,665 |
| Binding vessels | X | | X | |
| Non-binding vessels | | X | | X |

Notes: In each regression, the unit of observation is a vessel-month-year, we cluster standard errors at the vessel-level, we use default options from the rdrobust package, and we control for gear fixed effects, gross tonnage, engine horsepower, length, and year built. In Columns 1 and 2, the dependent variable is log(fishing hours) and in Columns 3 and 4 the dependent variable is log(distance traveled in km). The data used to estimate the regressions in Columns 1 and 3 are Chinese distant water fishing vessels built before 2016 for which the engine power ceiling is binding. In Columns 2 and 4, the data are Chinese distant water fishing vessels built before 2016 for which the engine power ceiling is not binding. In Columns 1 and 2, the bandwidth selection procedure is mean-squared error optimal. In Columns 3 and 4, the bandwidth is from Columns 1 and 2.

We complement this analysis by also estimating the effect of the policy on the monthly distance traveled by vessels. Distance traveled is the distance between each pair of consecutive transponder pings. Distance traveled may be measured with less error than fishing hours, which is a predicted value (Kroodsma et al., 2018). Thus, we re-estimate the equation in Equation 1 with log(distance traveled in km) as the dependent variable, and present the results in Columns 3 and 4 of Table 3. Column 3 uses the sample of binding vessels, while Column 4 uses the data from non-binding vessels. To allow for a direct comparison between the estimated effects, we use the same bandwidths as in the regressions when the dependent variable was log fishing hours. This ensures that the estimates derive from the same vessels.

For binding vessels, the estimated effects of the subsidy program on distance traveled are larger in magnitude and more precise than the effects of the policy on fishing hours. In Column 3, we find that the fuel subsidy policy increases distance traveled by a vessel in a month by 1.934 log points (standard error = 0.209). As expected, there is no effect of the policy on distance traveled for non-binding vessels (Column 4); the coefficient is much smaller in magnitude and its statistical significance does not survive randomization inference below. The large and precise effect of the policy on distance traveled by binding vessels further demonstrates that fuel subsidies have a sizable impact on vessel behavior. In addition to increasing fishing activities, fuel subsidies could be increasing the amount of time vessels spend searching for fishing grounds.

Figure 2 reproduces the regressions of Table 3 visually.[26] Figure 2(a) corresponds to Column 1 of Table 3; the dependent variable is log fishing hours and the data are binding vessels. Converting the intercepts on either side of the threshold from logs into levels implies that binding vessels just above their nearest gross tonnage threshold fish 170 more hours per month than binding vessels just below their nearest gross tonnage threshold (251 fishing hours compared to 81 fishing hours). But the binned sample means (points) reveal large variation in raw fishing hours near the threshold. This variation suggests the numeric standard errors in Table 3 could overstate the precision of the point estimates. The raw data also raise the question of whether the large positive effect on fishing by binding vessels is an artefact of a small number of influential points or of the particular bandwidth chosen by the mean squared error optimal-bandwidth selector.

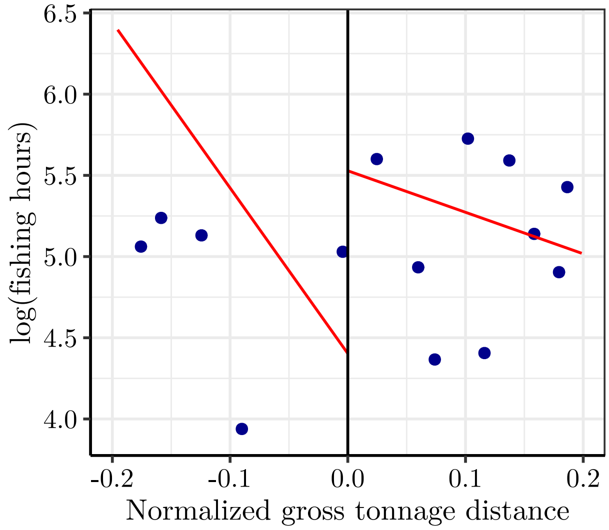
We believe the best way to address these concerns is with randomization inference. Our procedure randomly creates new gross tonnage and ceiling of subsidized engine power thresholds for each gear,[27] calculates the normalized gross tonnage distance of each vessel to these

[26]The downward sloping running variable in Figure 2(a) is consistent with the relationship between gross tonnage and fishing in the period before the 2016 to 2020 fuel subsidy policy. For both vessels who will go on to become binding and vessels who will go on to become non-binding, there is a negative relationship between gross tonnage in levels and pre-period fishing hours (Figure A3).

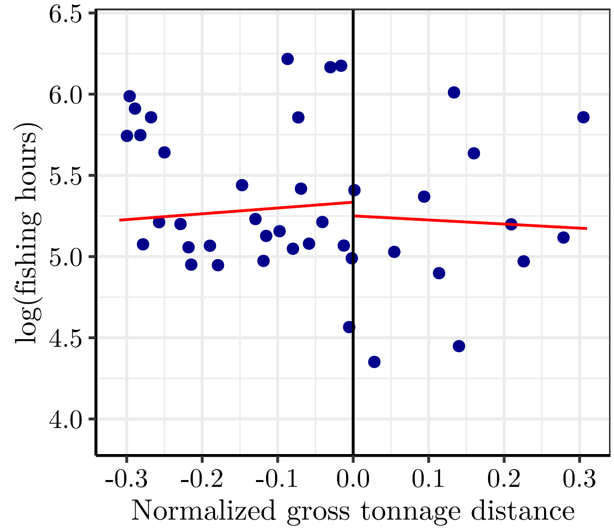
[27]We create placebo gross tonnage and ceiling of subsidized engine power thresholds as follows. For a given gear, identify the minimum over gross tonnage thresholds and vessels' gross tonnages in levels. For example, for squid jiggers the smallest gross tonnage threshold is 300 and the smallest vessel has a gross tonnage of 238, so the minimum gross tonnage threshold is 238. We identify the maximum gross tonnage threshold and the minimum and maximum ceiling of subsidized engine power thresholds in the same way. The maximum (minimum) ceiling of subsidized engine power threshold is the maximum (minimum) over

Figure 2: Effect of Fuel Subsidies on Fishing Hours and Distance Traveled

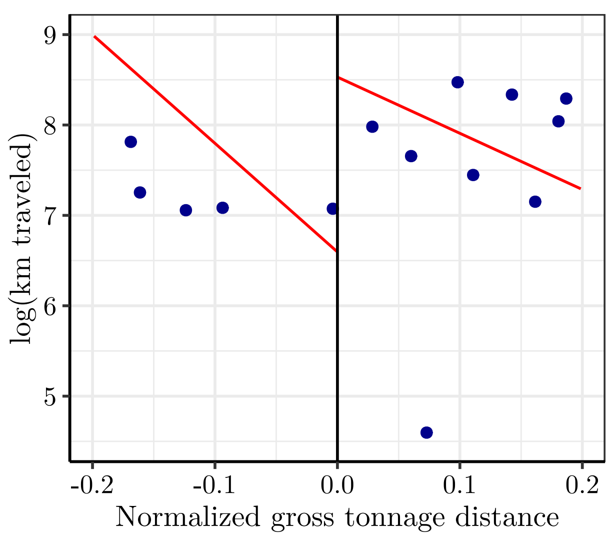
(a) Log fishing hours, binding vessels



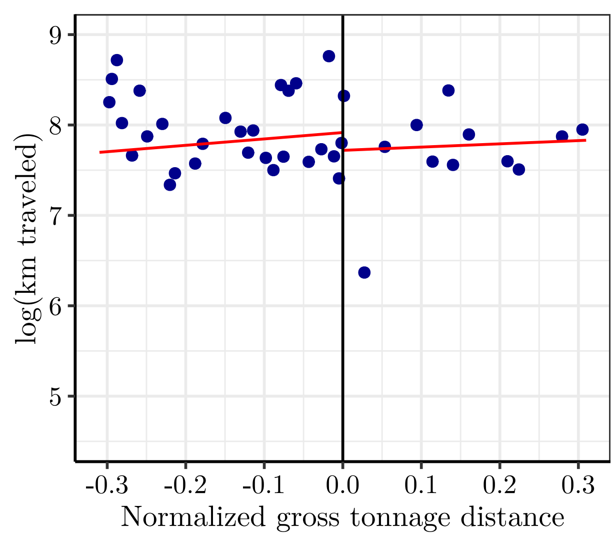

(b) Log fishing hours, non-binding vessels




(c) Log distance traveled, binding vessels




(d) Log distance traveled, non-binding vessels




Notes: Points are binned sample means of the dependent variable (raw data) and lines are local linear conditional mean functions. These plots reproduce regressions from Table 3, with the difference in intercepts between the two regression lines in (a) corresponding to the conventional point estimate in Column 1, (b) corresponding to Column 2, and so on.

ceiling of subsidized engine power thresholds and vessels' engine power. For example, for squid jiggers the largest ceiling of subsidized engine power threshold is 1,800 kW and the largest vessel has an engine power of 2,100 kW, so the maximum ceiling of subsidized engine power threshold is 2,100. Uniformly draw over this interval a number of thresholds equal to the number the gear has in the true fuel subsidy policy.

placebo thresholds, estimates the parameters of Equation 1, and saves the conventional and bias-corrected point estimates. We repeat this procedure 1,000 times and plot the distribution of placebo conventional point estimates against the true conventional point estimate in Figure A4. Based on that, the numeric standard errors in Table 3 seem to overstate precision. The randomization inference p-value for the effect on fishing by binding vessels is 0.062, compared to the p-value of $2\times10^{-6}$ implied by Column 1 of Table 3.[28] The randomization inference p-value for the effect on fishing by non-binding vessels is 0.608.

As in Table 3, the effect of fuel subsidies on distance traveled by binding vessels is more precise than the effect on fishing by binding vessels. The raw data display a more apparent discontinuous increase just above the threshold (Figure 2(c)), and the randomization inference p-value is 0.029 (Figure A4(c)).[29] The randomization inference p-value for the effect on distance traveled by non-binding vessels is 0.776 (Figure A4(d)).

#### 5.1.1 Elasticity of fishing and distance traveled with respect to fuel subsidy

We now convert the reduced form coefficients in Tables 3 into elasticities of fishing hours and distance traveled with respect to fuel subsidies. These elasticities help us interpret the magnitude of the reduced form coefficients, and fuel subsidy elasticity is a key input to our counterfactual analysis presented in Section 6.

First, we calculate the fishing elasticity by dividing the reduced form effect of the policy on log fishing hours by the first stage effect of the policy on log subsidy received. The reduced form is the effect on binding vessels that we report in Column 1 of Table 3. We estimate the first stage effect by replacing the dependent variable in Equation 1 with log subsidy received.

To proceed, we calculate each vessels' monthly subsidy received by allocating their annual subsidy received proportionally to subsidy days. Subsidy days are the number of days in a month in which vessels have positive AIS hours. For example, if half of a vessel's subsidy days in 2017 occurred in January and half occurred in February, we would allocate half of

[28]The randomization inference p-value is the fraction of placebo estimates larger than the true estimate, while the p-value of $2\times10^{-6}$ from Table 3 comes from a two-sided t-test.

[29]In instances like this one where we impose a bandwidth from a different regression, we follow the same procedure in the randomization inference. In this example, for a given run number (panel data created relative to a given random draw of gross tonnage and ceiling of subsidized engine power thresholds), the placebo regression discontinuity on log distance traveled uses the optimal bandwidth from the placebo regression discontinuity of the same run number on log fishing hours.

the vessel's 2017 subsidy to January 2017 and half to February 2017. We convert subsidy amounts from nominal Yuan to 2022 USD.

Table 4 displays the estimates. Column 1 and 4 reproduce the relevant reduced-form estimates from Table 3. The first stage effect of the policy on the amount of subsidy received is 0.517 log points (Column 2). In other words, binding vessels just above their nearest gross tonnage threshold receive 67% more fuel subsidy on average than binding vessels just below their nearest gross tonnage threshold. Figure 3(a) displays this regression visually. Converting the intercepts on either side of the threshold from logs into levels implies that binding vessels just above their nearest gross tonnage threshold receive about $10,000 more in fuel subsidy per month than binding vessels just below their nearest gross tonnage threshold (approximately $24,000 per month compared to $14,000 per month). The elasticity of fishing hours with respect to fuel subsidy received is 2.177 (Column 3). While the conventional first stage and elasticity estimates are large in magnitude, neither are statistically different from zero when we apply our randomization inference procedure. The randomization inference p-values are 0.187 and 0.101 (Figure A5), compared to conventional p-values of $4\times10^{-7}$ and 0.0004. We therefore view these estimates as suggestive evidence that the elasticity of fishing with respect to fuel subsidies may be large, perhaps even larger than 1 (conventional p-value = 0.029). Our estimates could be imprecise because we estimate fuel subsidies with different transponder data than the regulator uses in assigning subsidies (Section 2).[30]

We use a similar procedure to estimate the elasticity of distance traveled with respect to fuel subsidy received. Columns 4 to 6 of Table 4 display the reduced form, first stage, and elasticity estimates. As in Column 3 of Table 3, we apply the optimal bandwidth from when log fishing hours was the dependent variable (to ensure comparability). There are more observations than when we estimate the fishing hours elasticity because of vessel-

[30]Mismeasurement of subsidy days would bias our first stage and elasticity estimates if we differentially mismeasure subsidy days with respect to gross tonnage thresholds. We compare official subsidy days for 273 vessels from Putuo district, Zhoushan in Zhejiang province (see (Figure A1(a)) with our estimate of subsidy days using a t-test. We do not find evidence of differential mismeasurement. Vessels above their nearest gross tonnage threshold have a mean difference between official and estimated subsidy days of -13, while vessels below their nearest gross tonnage threshold have a mean difference of -9 (p-value = 0.625). As a point of comparison for interpreting the magnitude of these differences, the mean official subsidy days is 304. We report results from a t-test because re-estimating Equation 1 with these data results in an error, likely due to the small sample size.

Table 4: Estimated Elasticities of Fishing Hours and Distance Traveled with Respect to Subsidy Received

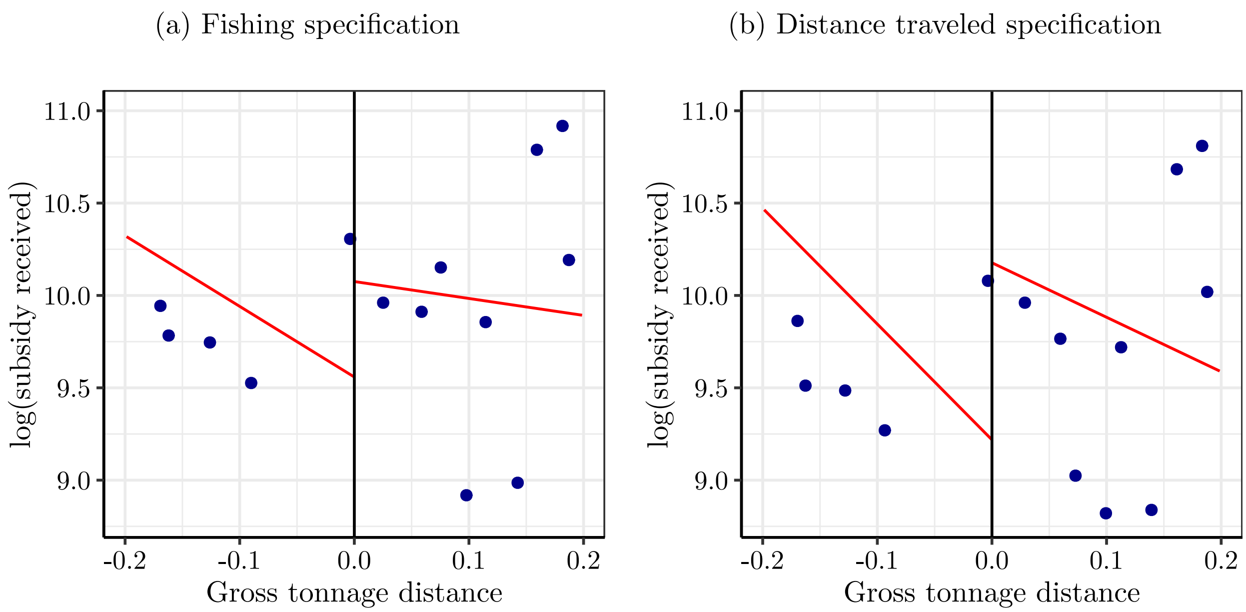
| | Dependent variable: | | | | | |
|---|---|---|---|---|---|---|
| | log(fishing hours) | | | log(km traveled) | | |
| | RF | FS | Elasticity | RF | FS | Elasticity |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Conventional | 1.125 | 0.517 | 2.177 | 1.674 | 0.958 | 1.746 |
| | (0.233) | (0.101) | (0.622) | (0.219) | (0.189) | (0.414) |
| Bias-Corrected | 1.565 | 0.583 | 2.682 | 1.872 | 1.071 | 1.749 |
| | (0.233) | (0.101) | (0.615) | (0.219) | (0.189) | (0.371) |
| Robust | 1.565 | 0.583 | 2.682 | 1.872 | 1.071 | 1.749 |
| | (0.276) | (0.154) | (0.850) | (0.290) | (0.283) | (0.536) |
| Bandwidth | 0.199 | 0.199 | 0.199 | 0.199 | 0.199 | 0.199 |
| N | 1,050 | 1,050 | 1,050 | 1,227 | 1,227 | 1,227 |

Notes: In each regression, the data are binding vessels built before 2016, the unit of observation is a vessel-month-year, we cluster standard errors at the vessel-level, we use default options from the rdrobust package, and we control for gear fixed effects, gross tonnage, engine horsepower, length, and year built. RF (reduced form) is the effect of the policy on log fishing hours (Column 1) or log distance traveled (Column 4), FS (first stage) is the effect of the policy on log fuel subsidy received, and elasticity is the reduced form divided by the first stage. We calculate the elasticity standard errors with the delta method. We use the reduced form optimal bandwidth in estimating the first stage so that the set of vessels used to calculate the instrumental variables elasticity is the same.

months with positive distance traveled and subsidy received but with zero fishing hours. The two first stage estimates differ for this reason.[31] The first stage is more precise in this specification (conventional p-value is $5{\times}10^{-7}$ and randomization inference p-value is 0.057). We find that the elasticity of distance traveled with respect to fuel subsidy received is 1.746. As in Column 3, this estimate is somewhat imprecise (conventional p-value is $3{\times}10^{-5}$ but randomization inference p-value is 0.140). Figure A6 displays the placebo randomization

[31] The reduced form coefficient differs slightly from the estimate in Column 3 of Table 3 for a similar reason. GFW calculates distance traveled from non-public, vessel movement point data. We use the public version of GFW's AIS data when allocating subsidies to the monthly level. Due to the log transformation of the dependent variables, to remain in the data used to estimate Columns 4 to 6 of Table 4, the vessel-month-year must have positive distance traveled in the non-public data and positive AIS hours in the public data. Only the first condition must be true to remain in the data used to estimate Column 3 of Table 3.

Figure 3: Effect of Policy on Fuel Subsidy Received (First Stages)




Notes: Points are binned sample means of log(fuel subsidy). (a) and (b) reproduce the Column 2 and Column 5 regressions of Table 4, with the difference in intercepts between the two regression lines corresponding to the conventional point estimate. Lines are local linear conditional mean functions.

inference coefficients against the true first stage and elasticity coefficients.

The large magnitude of these elasticities may reflect their long-run nature; the fuel subsidy policy we evaluate was in effect for six years. In the context of electricity consumption, Buchsbaum (2022) and Feehan (2018) estimate long-run price elasticities that are an order of magnitude larger than previously estimated short-run price elasticities.

## 5.2 Extensive margin effects

In addition to increasing fishing on the intensive margin, fuel subsidies could increase the likelihood of fishing at all. We estimate the effects of fuel subsidies on the probability of fishing in a month and on measures of entry and exit in Section 5.2.1. Then in Section 5.2.2 we assess the "super extensive" margin by testing whether vessels built after the policy was announced are more likely to be just above a subsidy threshold, compared to vessels built before the policy was announced.

### 5.2.1 Effects on probability of fishing in a month and on measures of entry and exit

We re-estimate Equation 1 with a new dependent variable: an indicator that equals 1 if a vessel has positive fishing hours in a month and equals 0 otherwise and report the results in Table 5. Columns 1 and 2 are based on the sample of subset of binding vessels, while Columns 3 and 4 uses the of non-binding vessels. For comparability, in Columns 1 and 3, we impose the same bandwidths from when log fishing hours was the dependent variable so that the vessels used to estimate the regressions are the same. In Columns 2 and 4 we do not impose bandwidths and instead apply the mean-squared error optimal bandwidth procedure.

We find that fuel subsidies increase the probability of fishing in a given month by 55.4 percentage points (Column 1). This effect is large compared to the 70% average probability of fishing in a month (among vessels within the optimal bandwidth). It is also precisely estimated (t-statistic is 5.5 and randomization inference p-value is 0.028). The Column 2 coefficient is implausibly large—twice as large as the mean of the dependent variable—perhaps because the optimal bandwidth is small. We find no effect of the policy on non-binding vessels (Columns 3 and 4). The coefficients are precisely estimated zeros, and they are two orders of magnitude smaller than the coefficients for binding vessels. Figure 4 displays the Column 1 and 3 regressions visually. These results suggest that fuel subsidies significantly increase fishing activity on the extensive margin.

Next we examine whether the fuel subsidy program affected entry into and exit from the fishery. We estimate regressions of the following form:

$$\begin{aligned} Y_{ij} = {} & \beta_1 \mathbb{1}\{norm\_gt\_dist_{ij} > 0\} + \beta_2 norm\_gt\_dist_{ij} + \\ & \beta_3 norm\_gt\_dist_{ij} \times \mathbb{1}\{norm\_gt\_dist_{ij} > 0\} + \\ & \beta_4 gt_i + \beta_5 engine\_power\_kw_i + \beta_6 length\_m_i + \alpha_j + \epsilon_{ij} \end{aligned} \tag{2}$$

where $Y_{ij}$ is a measure of entry or exit for vessel $i$ of gear type $j$ and all other variables

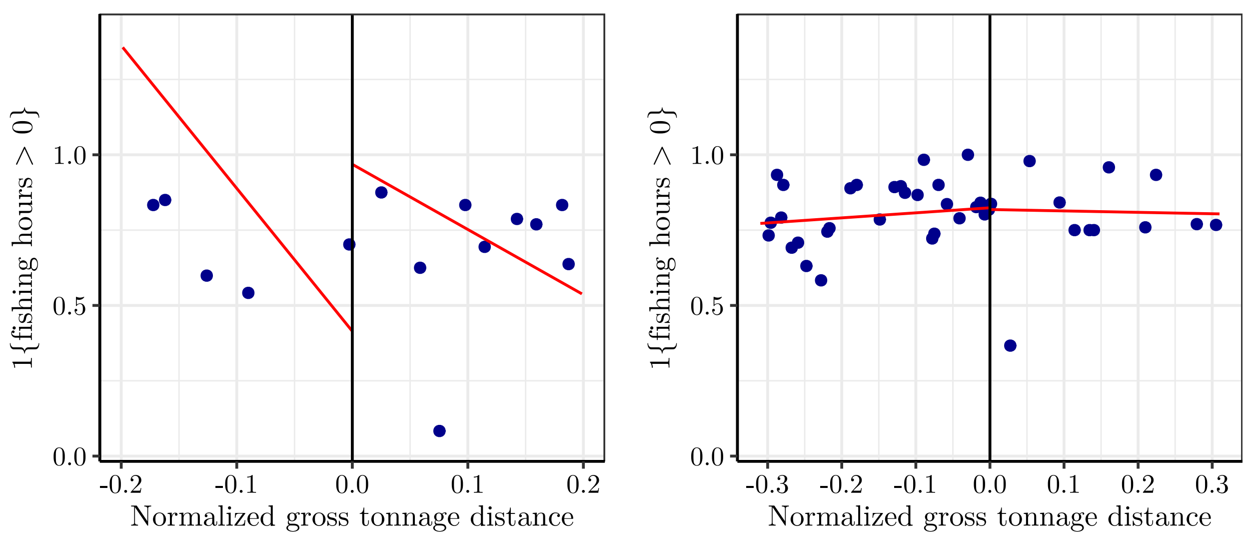
Table 5: Estimated Effect of Fuel Subsidies on Extensive Margin Measures of Fishing Activity

| | Dependent variable: | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1{Fishing hours > 0} | | | | 1{Entered} | | 1{Exited} |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Conventional | 0.554 | 291.095 | -0.006 | -0.015 | 0.104 | 0.431 | 0.071 |
| | (0.100) | (0.117) | (0.017) | (0.018) | (0.043) | (0.231) | (0.133) |
| Bias-Corrected | 0.696 | 429.920 | 0.001 | -0.021 | 0.188 | 0.531 | 0.117 |
| | (0.100) | (0.117) | (0.017) | (0.018) | (0.043) | (0.231) | (0.133) |
| Robust | 0.696 | 429.920 | 0.001 | -0.021 | 0.188 | 0.531 | 0.117 |
| | (0.137) | (0.135) | (0.021) | (0.021) | (0.121) | (0.281) | (0.163) |
| Bandwidth | 0.199 | 0.148 | 0.310 | 0.270 | 0.199 | 0.271 | 0.259 |
| N | 1,500 | 1,020 | 8,472 | 6,912 | 79 | 89 | 87 |
| Binding vessels | X | X | | | X | X | X |
| Non-binding vessels | | | X | X | | | |
| Impose bandwidth | X | | X | | X | | |
| Mean dep. var. | 0.700 | 0.686 | 0.803 | 0.809 | 0.316 | 0.562 | 0.165 |

Notes: All regressions use default options from the rdrobust package and control for gear fixed effects, gross tonnage, length in meters, and engine horsepower. Mean dep. var. is the mean dependent variable within the bandwidth. In Columns 1 to 4, the unit of observation is a vessel-month-year, we exclude vessels built on or after 2016, the dependent variable is an indicator for positive fishing hours, and we cluster standard errors at the vessel-level. In Columns 5 to 7, the unit of observation is a vessel and standard errors are heteroskedasticity-robust nearest neighbor. The dependent variables in Column 5 to 7 are indicators that equal 1 for vessels built on or after 2016, if the first year we observe a vessel in the GFW data is not 2016, and if the last year we observe a vessel in the GFW data is not 2020. In Columns 1, 3, and 5, the bandwidth is from Columns 1, 2, and 1 (again) of Table 3, respectively. In Columns 2, 4, 6, and 7, the bandwidth selection procedure is mean-squared error optimal.

Figure 4: Effect of Fuel Subsidies on Indicator for Fishing in a Month

(a) Binding vessels (b) Non-binding vessels




Notes: Points are binned sample means of an indicator for a vessel having positive fishing hours in a month and lines are local linear conditional mean functions. These plots reproduce Columns 1 and 3 of Table 5, with the difference in intercepts between the two regression lines in (a) corresponding to the conventional point estimate in Column 1, and (b) corresponding to Column 3.

are as defined in Equation 1. Note that Equation 2 is identical to Equation 1 except for the different dependent variable and the absence of $t$ subscripts: We collapse our data to a vessel-level cross-section for this analysis because we want to estimate whether a vessel ever enters or exits the industry during the sample period, regardless of how often they fish. These regressions use binding vessels only, but they no longer require vessels to have been built before 2016 (because being built on or after 2016 is one of our measures of entry). We no longer cluster standard errors at the vessel-level since there is only one observation per vessel. We instead estimate standard errors with the heteroskedasticity-robust nearest neighbor variance estimator because that is the default method in the rdrobust package (Calonico et al., 2022).

Our first measure of entry is an indicator that equals 1 if the vessel was built on or after

2016 and equals 0 otherwise (Column 5 of Table 5).[32] The coefficient is positive, which is consistent with entry, but it is imprecise (t-statistic is 2.4 and randomization inference p-value is 0.239). The visual reproduction of this regression, Figure A7(a), does provide some suggestive evidence in the form of the leftmost point just above the threshold. Binding vessels just above their nearest threshold are more likely to have been built after the policy was announced than nearby vessels (other points), but the difference is not statistically significant. We explore the potential for constructing vessels just above subsidy thresholds in greater detail in Section 5.2.2.

Column 6 of Table 5 uses a different measure of entry as the dependent variable: an indicator that equals 1 if the first year we observe a vessel in the GFW data is *not* 2016. The indicator equals 0 if 2016 is the first year we observe a vessel in the GFW data. This measure of entry differs from the previous one in that it allows already-existing vessels that were not previously observed fishing to re-enter the fishery without rebuilding their vessel. We again estimate a positive but statistically insignificant effect of fuel subsidies on entry.

Finally, we measure exit with an indicator that equals 1 if the last year we observe a vessel in the GFW data is not 2020. The indicator equals 0 if 2020 is the last year we observe a vessel in the GFW data. We find no evidence that the subsidy policy increased the exit rate from the industry: while the coefficient is slightly positive it is not statistically different from zero (Column 7 of Table 5).

### 5.2.2 Comparing vessel characteristics before and after policy

23% of vessels in our data were built during or after 2016. Though the regulator banned the entry of new distant water fishing vessels in 2013, firms may scrap their vessels, rebuild them, and remain eligible for fuel subsidies (Ministry of Agriculture, 2013b). We compare the distance to the nearest gross tonnage threshold of vessels built before 2016 and of vessels built on or after 2016. The regulator began two other policies in 2014 and 2015 that partially overlap with the fuel subsidy thresholds: a one-time renovation and reconstruction subsidy,

[32] The mean-squared error optimal bandwidth is so small that the regression results in an error. We therefore impose the optimal bandwidth from Column 1 of Table 3 to estimate this regression. We also exclude year built as a control variable in this regression since the dependent variable is a function of year built.

and a vessel standardization regulation.[33] These regulations do not invalidate our estimates of the effect of fuel subsidies on fishing because our results are robust to excluding vessels built after these regulations would have affected vessel construction decisions (Section 5.3). But they do prevent us from interpreting differences in gross tonnage distances as due entirely to the 2016-2020 fuel subsidy policy. Among vessels built on or after 2015, the median one-time renovation and reconstruction subsidy received is $703,166, compared to the median annual fuel subsidy of $223,380 (both 2022 USD). Examining these distributions is nonetheless informative for assessing our focus on vessels built before 2016 in Sections 5.1 and 5.2.1.

Figure 5 plots the normalized gross tonnage distance distribution for all vessels, regardless of whether their engine power ceiling is binding, because the fuel subsidy policy may affect the characteristics of all vessels.[34] Vessels built before 2016 are discontinuously more likely to have gross tonnage just *below* their gross tonnage threshold (Figure 5a). By contrast, there is no discontinuous difference at the threshold in the density of vessels built on or after 2016 (Figure 5b). The t-statistic on the difference in these two discontinuities is 2.2. Firms seem to have responded to the regulator's suite of regulations by reconstructing larger vessels, including vessels that will be eligible to receive larger fuel subsidies. Note that there is no discontinuous difference in the density of binding vessels built before 2016 (Figure A8).

## 5.3 Robustness checks

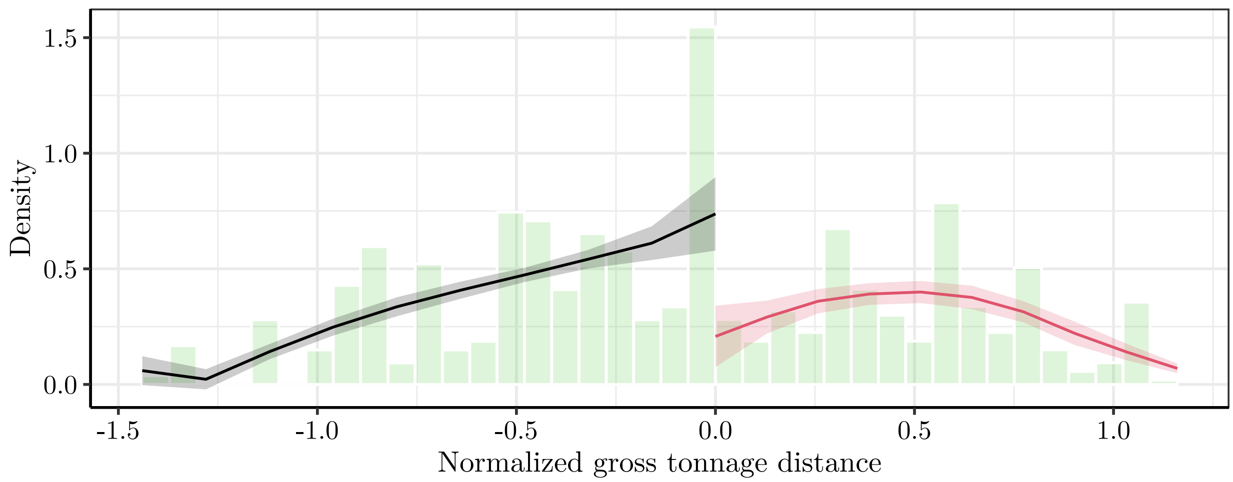
If less-subsidized vessels fish less because of the 2016 to 2020 fuel subsidy policy, then the Stable Unit Treatment Value Assumption (SUTVA) would be violated. One way this SUTVA violation could occur is if more-subsidized vessels decreased the fish biomass available for less-subsidized vessels to catch. We consider this scenario by plotting log monthly fishing hours between 2012 and 2020 for binding and non-binding vessels above and below their

[33] Vessels built on or after 2015 are eligible for the renovation and reconstruction subsidy, which depends on gear, gross tonnage, and vessel length (Ministry of Agriculture, 2016). The vessel standardization regulations began in 2014 and they specify gear-specific standards for vessel characteristics like width (Ministry of Agriculture, 2014b, 2015). The regulator updated these standards in 2017, 2018, and 2021 (Bureau of Fisheries, 2018, 2021b; Ministry of Agriculture, 2017).

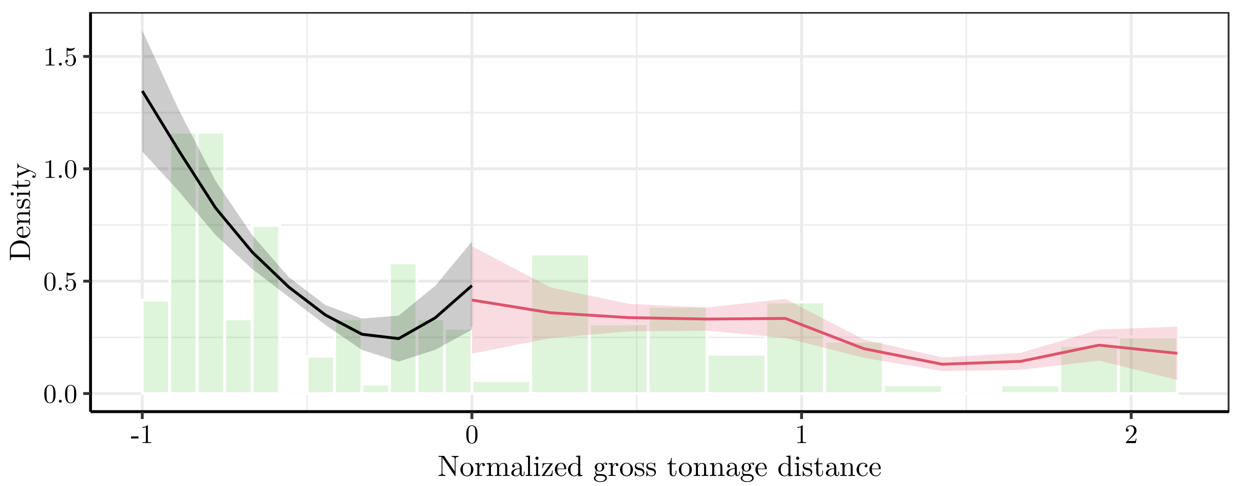
[34] We created these figures with the rdplotdensity command from the rddensity package (Cattaneo et al., 2021). We used all default options with one exception: we set the local polynomial order used to construct the bias-corrected density estimators as 2 (default = 3). This change causes the confidence intervals to be conventional rather than bias-corrected.

Figure 5: Distribution of Vessels' Normalized Gross Tonnage Distances by Year of Construction

(a) Vessels built before 2016




(b) Vessels built on or after 2016




Notes: Bars are binned vessel densities (one observation per vessel), lines are local quadratic estimators of density, and shaded regions are 95% confidence intervals for the density of (a) all vessels built before 2016 and (b) all vessels built on or after 2016. Figure A8 shows there is no discontinuous difference in the density of binding vessels built before 2016.

nearest gross tonnage thresholds (four groups). If the SUTVA assumption fails, we would expect to see fishing hours by the two groups of non-binding vessels and fishing by binding vessels below their nearest gross tonnage threshold to decrease between 2016 and 2020. We

Table 6: Effect of Fuel Subsidies on Log Hours of Fishing, Alternative Specifications

| | Dependent variable: log(fishing hours) | | | | | | |
|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Conventional | 2.084 | 1.254 | 293.648 | 1.135 | 1.186 | 0.227 | 1.743 |
| | (0.259) | (0.202) | (0.271) | (0.240) | (0.223) | (0.207) | (0.280) |
| Bias-Corrected | 3.139 | 1.732 | 54.018 | 1.402 | 1.631 | 0.356 | 1.740 |
| | (0.259) | (0.202) | (0.271) | (0.240) | (0.223) | (0.207) | (0.280) |
| Robust | 3.139 | 1.732 | 54.018 | 1.402 | 1.631 | 0.356 | 1.740 |
| | (0.319) | (0.229) | (0.330) | (0.322) | (0.264) | (0.278) | (0.339) |
| Bandwidth | 0.168 | 0.178 | 0.144 | 0.199 | 0.197 | 52.153 | 0.148 |
| N | 820 | 583 | 737 | 1,143 | 1,050 | 3,541 | 700 |
| Impose bandwidth | | | | X | | | |

Notes: In each regression, the data are Chinese distant water fishing vessels for which the engine power ceiling is binding, the unit of observation is a vessel-month-year, the dependent variable is log fishing hours, we cluster standard errors at the vessel-level, we use default options from the rdrobust package, and we control for gear fixed effects, gross tonnage, and engine horsepower. All columns except for 7 also control for vessel length and year built. Column 4 imposes the bandwidth (BW) from Column 1 of Table 3. Column 1 only includes vessels built on or before 2014, Column 2 excludes 2020 data, Columns 3 and 4 include 2015 data, and Column 5 includes year fixed effects. The running variable in Column 6 is (non-normalized) gross tonnage distance.

show that fishing hour by all three groups is constant during this period, providing support that SUTVA holds in our setting (Figure A9).

We assess the robustness of the estimates in our preferred specification in Table 6. All of the regressions estimate a variant of Equation 1 on the subset of binding vessels. Our results are similar to our preferred specification in Column 1 of Table 3 in that the coefficients are all large and positive.

In Column 1 of Table 6, we find that the effect of the policy remains large and positive when we require vessels to have been built on or before 2014, when the first vessel standardization regulation was published, and before the fuel subsidy policy we evaluate went into effect. In Column 2, we obtain a similar result when we subset the data to between 2016 and 2019, instead of 2016 to 2020, since 2020 was a transitional year between policy regimes (Section 2). In Columns 3 and 4, we subset the data to between 2015 and 2020, since the fuel subsidy policy we evaluate was applied ex post to 2015 fishing. The Column 3 coefficient is implausibly large, perhaps because the mean-squared error optimal bandwidth is small. When we re-estimate the regression with the optimal bandwidth from Column 1 of Table 3, we obtain a coefficient that is nearly identical to the coefficient from our preferred specification.

Next, in Column 5 we include year fixed effects. Year is a potentially relevant control because fuel subsidies depend on a time constant that changes each year. Our coefficient is nearly identical compared to our preferred specification. The regression in Column 6 replaces the running variable with non-normalized gross tonnage distance. The coefficient remains positive, but it is smaller than in our preferred specification. In Column 7 we exclude vessel length and the year a vessel was built as control variables. Excluding any of the other control variables—gear fixed effects, gross tonnage, and engine horsepower—would violate our identifying assumption because these variables determine treatment status. The Column 7 coefficient is slightly larger than in our preferred specification.

# 6 Fuel subsidies and overfishing

We now use our empirical estimate of the subsidy-fishing elasticity to assess whether global fisheries sustainability would improve if China were to reform its distant water fuel subsidies. For example, if China were to halve its subsidy allocations, how would overfishing status change in the 18 Food and Agriculture Organization (FAO) Regions that span the world's oceans? We will follow the fisheries science literature, where biological overfishing occurs when fishing pressure ($F$) is higher than the fishing pressure that would produce the maximum sustainable yield ($F_{msy}$). Then, the relevant metric is the ratio $F/F_{msy}$, where $F/F_{msy} > 1$ indicates overfishing, $F/F_{msy} = 1$ indicates biologically sustainable fishing, and $F/F_{msy} < 1$ indicates fishing pressure could increase without threatening the long-term biological size of the stock. We refer to this ratio as overfishing status.

## 6.1 Calculating changes in overfishing status

We calculate the change in overfishing status that would result from a reduction in Chinese distant water fuel subsidies. Specifically, we consider three policy changes that would reduce the subsidy by 10%, 30%, and 50%. We follow the same approach as McDermott et al. (2019), who calculated the changes in overfishing status that result from changes in fishing effort[35] using catch-weighted mean $F/F_{msy}$ values by FAO Region. Our values of overfishing status are for 4,713 fish stocks and they come from Costello et al. (2016).[36] We take fishing hours observed during 2020, the most recent publicly available year of data, as the baseline level of fishing activity currently occurring in the world's oceans. We then aggregate fishing hours by Chinese and all other vessels to the level of FAO Region and calculate the fraction attributable to Chinese distant water vessels (Figure A10). Since we only analyze the subsidies granted to China's distant water fishing fleet, we assume that only Chinese fishing outside Chinese waters responds to changes in subsidies.[37]

For each policy scenario, we use our estimate of the elasticity of fishing by Chinese distant water vessels with respect to fuel subsidies (Column 3 of Table 4) to calculate the predicted change in fishing by Chinese vessels in each FAO Region, and the corresponding change in overfishing status.[38] We then calculate the percent change in overfishing status by FAO Region by comparing the predicted overfishing status in each scenario to the current overfishing status.

Consider the following example of a 50% reduction in subsidies and FAO Region 87 (Southeast Pacific), where Chinese vessels accounted for 70.3% (1.02 million hours) of fishing in 2020 (Figure A10). The current overfishing status in FAO Region 87 is $F/F_{msy} = 1.28$ (so overall fishing in that region of ocean is about 28% larger than the biologically sustainable benchmark). By how much would this value decrease if China was to reform its distant

[35] McDermott et al. (2019) study the preemptive fishing effort that occurs following the announcement of a soon-to-be-established marine reserve.

[36] These stocks represent 78% of global reported fish catch. Table A1 reports the number of stocks in each FAO Region.

[37] Chinese waters here refer to China's internationally-recognized Exclusive Economic Zone and its claims in the South China Sea. Though the latter claims are contested by other countries, Chinese vessels fishing in the South China Sea are unlikely to receive distant water fuel subsidies (since China considers those waters domestic).

[38] This portion of the analysis uses fishing hours by all Chinese-flagged fishing vessels, as identified by publicly available data from GFW.

water fuel subsidy program? With an elasticity of 2.177 and a 50% reduction in Chinese fuel subsidies, we calculate the reduction in fishing by Chinese vessels as $((1 - 0.5)^{2.177} - 1) \times 100 = -77.9\%$. Since Chinese vessels account for 70.3% of fishing hours in the area, the total reduction in fishing in this FAO area would be $77.9\% \times 70.3\% = 54.8\%$. Affecting only the numerator in the $F/F_{msy}$ ratio, this change in fishing hours implies that $F/F_{msy}$ would decrease from 1.28 to 0.58 (because $1.28 \times (1 - 0.548) = 0.58$). Thus, we estimate that reducing Chinese distant water fuel subsidies by 50% would be sufficient to eliminate biological overfishing in the Southeast Pacific. Of course, each region has a different fraction of Chinese fishing hours and different baseline levels of overfishing status, so the calculations need to be repeated worldwide.

Our scenarios hold fishing by non-Chinese vessels constant. If other countries do not simultaneously reduce fuel subsidies or otherwise limit fishing (e.g., through fisheries management), then our our calculations could be viewed as upper bounds on the changes in overfishing because it is possible that non-Chinese vessels would increase their fishing in response to the reduction in fishing by Chinese vessels. But viewed from the perspective of WTO negotiations, in which countries simultaneously reduce fisheries subsidies, then our calculations could be viewed as lower bounds in the sense that reductions in Chinese fuel subsidies would likely co-occur with reductions in subsidies by other countries. Our *ceteris paribus* scenarios are intermediate to these two cases.

## 6.2 Predicted changes in overfishing status

Today, 16 of the 18 FAO Regions experience overfishing (Figure A11). We find that a 10% reduction in Chinese distant water fuel subsidies would not eliminate overfishing in any FAO Region in the sense of reducing $F/F_{msy}$ from above 1 to 1 or below (Figures 6 and 7). At best, our 10% reform scenario could reduce overfishing by up to 14% in some regions (e.g., the Southeast Pacific [FAO Region 87]). In contrast, consider our high reform scenario where Chinese distant water fuel subsidies are reduced by 50%. This would move two FAO Regions (the Southeast Pacific [87] and the Antarctic Atlantic [48]) below the overfishing threshold of $F/F_{msy} = 1$ and result in a further reduction in overfishing status in other regions by up to 20% (East Central Pacific [77] and West Central Pacific [71]).

Figure 6 shows the changes in overfishing status by FAO Region for the three scenarios of subsidy reduction. We predict the largest decreases in overfishing in FAO Regions in the Pacific Ocean, where Chinese vessels account for large shares of fishing (Figure A10 and Table A2). Using the stock-level data, we can also calculate the proportion of stocks that would be subject to overfishing under each scenario. Currently, 64.5% of stocks (N = 3,042 stocks) are estimated to experience overfishing (Costello et al., 2016). A 10% reduction in fuel subsidies to China's distant water fishing fleet would see this fraction decrease to 63.8%, while a more ambitious 50% reduction in subsidies to China's distant water fishing fleet would result in 61.6% of stocks experiencing overfishing. While few stocks would no longer experience overfishing (N = 29 to 132 stocks [0.65% - 2.8% of total], depending on the level of the subsidy reduction), these stocks account for much of the reported catch from stocks currently experiencing overfishing,[39] and thus translate into large reductions in FAO Region-level overfishing status.

While overfishing status is an important measure of sustainability, it may also be useful to understand the implications of these reductions on fish stocks themselves. To get a back-of-the-envelope estimate of the effect on fish stocks, we derive a new elasticity. A common model used to assess fishery sustainability is the Pella-Tomlinson model, for which the steady state can be defined as follows:

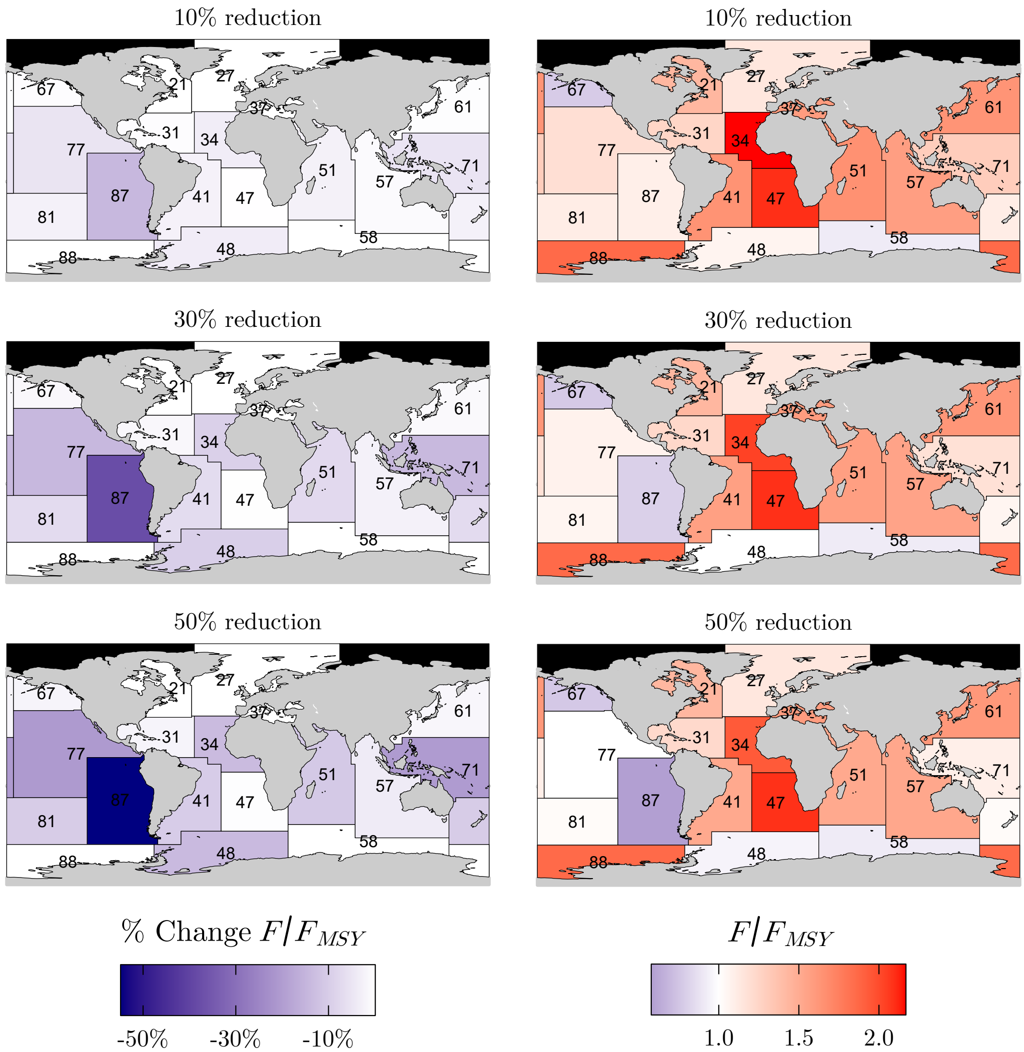
$$F/F_{MSY} = \frac{\phi + 1 - (B/B_{MSY})^{\phi}}{\phi} \tag{3}$$

where $F/F_{MSY}$ is the measure of biological overfishing defined above, $B/B_{MSY}$ is a measure of the fish biomass in steady state for that level of $F/F_{MSY}$, and $\phi$ is a parameter. For example, if $\phi = 1$ this model returns the familiar steady state from a logistic growth model. For any value of $\phi$ it is straightforward to calculate the elasticity of steady state biomass with respect to fishing pressure, as follows:

$$\frac{\%\Delta B/B_{MSY}}{\%\Delta F/F_{MSY}} = \frac{B/B_{MSY} - \phi - 1}{\phi(B/B_{MSY})^{\phi}} \tag{4}$$

[39] In the 50% fuel subsidy reduction scenario, the 132 stocks that cease experiencing overfishing account for 7.97% of total biomass and 6.56% of total catch derived from stocks currently experiencing overfishing.

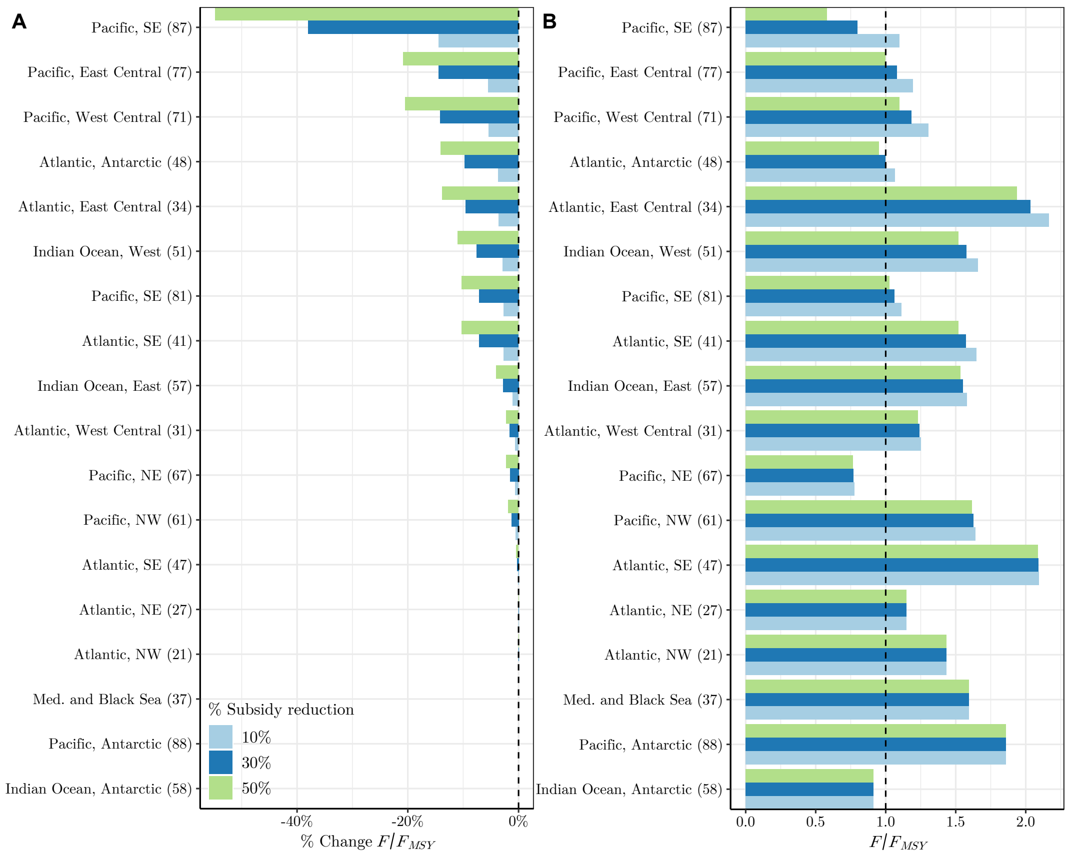
Figure 6: Percentage Change in Overfishing Status (Left) and Resulting Level of Overfishing Status (Right) Under Three Subsidy Reduction Scenarios




Notes: The numbers on the maps correspond to FAO Regions.

Inserting $B/B_{MSY} = 1$ as a typical value delivers an elasticity of exactly -1 for any value of $\phi$. In other words, for the purposes of back-of-the-envelope calculations, we can interpret an x% reduction in overfishing status ($F/F_{MSY}$) as giving rise to an equal x% increase in steady state fish stocks ($B/B_{MSY}$). In our simulations, reductions in overfishing status of 10%-30% are common, suggesting that commensurate biomass gains of a similar percentage magnitude are possible.

Figure 7: Changes in Overfishing Status for 18 FAO Regions Under Three Scenarios of Chinese Distant Water Fuel Subsidies Reduction




Notes: Colors of bars indicate the subsidy reduction scenairos. Panel A shows the percentage change in $F/F_{msy}$, and the dashed line shows indicates no change. Panel B shows the resulting $F/F_{msy}$, and the dashed line indicates the management reference point of $F/F_{msy} = 1$. FAO regions are ordered by the fraction of fishing effort in the FAO Region that Chinese vessels account for in 2020.

# 7 Discussion and Conclusion

The overexploitation of many of the world's fish stocks has depleted an important source of natural capital (FAO, 2022b). Nearly two centuries of research has identified institutional, economic, and ecological drivers that potentially contribute to this depletion (Kroetz et al., 2022; Smith, 2012; Smith, 1994). Fuel subsidies have attracted particular attention because they can reduce marginal production costs, incentivizing greater quantities of fishing effort. Concerns about the ecologically damaging impact of fuel subsidies are magnified in weakly regulated countries and in the high seas beyond any nation's jurisdiction. The lack of empirical evidence on the effect of fuel subsidies on fishing has possibly inhibited policy responses that can address this problem.

This paper seeks to assess how fuel subsidies to the Chinese distant water fleet, by far the largest in the world, have contributed to the steady depletion of global fish stocks. To this end we use real-time tracking data on the fishing activity of more than 1,000 individual Chinese distant water fishing vessels over the period 2016 to 2020. We identify the effect of fuel subsidies on fishing behavior by exploiting China's 2016 distant water fuel subsidy reform. This reform created 25 separate thresholds at which fuel subsidies discontinuously change for otherwise similar-sized vessels. The resulting regression discontinuity estimates are large: we find that a 1% increase in fuel subsidies increases hours of fishing by 2.2% and distance traveled by 1.7%. The local average treatment effect indicates that a $10,000 increase in fuel subsidy around discontinuity thresholds leads to 170 additional hours of fishing per month.

We then use these empirical estimates in a counterfactual analysis that isolates the contribution of Chinese distant water fuel subsidies to the overfishing status of global stocks. We derive a new elasticity to show that changes in overfishing status closely correspond to changes in biomass. We find that reforming fuel subsidies to China's distant water fishing fleet could reduce—but not entirely eliminate—overfishing in most FAO Ocean Regions.

The results of this paper have key implications for ongoing debates about how to reform subsidies in fisheries. For example, in June 2022, the WTO adopted the "Agreement on Fisheries Subsidies", which prohibits signatory countries from subsidizing vessels that fish for depleted stocks or engage in Illegal, Unauthorized, and Unregulated (IUU) fishing (WTO, 2022). This agreement is the second ever reached, on any subject, at the WTO. China has already updated its distant water fuel subsidy to comply with the WTO agreement (Ministry of Agriculture and Rural Affairs and Ministry of Finance, 2021a).

While historic, the WTO agreement is narrow in the types of subsidies it limits. Data do not usually exist to demonstrate that stocks in low- and middle-income countries are depleted, and IUU fishing is only one contributor to fisheries depletion. Depletion depends on the total quantity of fishing, not the fraction of fishing that is legal. By demonstrating the large effect of fuel subsidies on the total quantity of fishing, our findings suggest that further, more ambitious subsidy reform could result in large ecological gains.

# References


Abadie, A., Athey, S., Imbens, G. W., & Wooldridge, J. M. (2023). When Should You Adjust Standard Errors for Clustering? *The Quarterly Journal of Economics*, *138*(1), 1–35.

Buchsbaum, J. (2022). Long-run Price Elasticities and Mechanisms: Empirical Evidence from Residential Electricity Consumers.

Bureau of Fisheries. (2003). Regulations of the People's Republic of China on the Inspection of Fishing Vessels (English translation). http://www.moa.gov.cn/govpublic/YYJ/201006/t20100606_1538258.htm

Bureau of Fisheries. (2012). *China Fisheries Yearbook 2012*. Beijing: China Agriculture Press.

Bureau of Fisheries. (2017). National Distant Water Fishery Development Plan during the 13th Five-Year Plan Period (English translation). http://www.moa.gov.cn/gk/ghjh_1/201712/t20171227_6128624.htm

Bureau of Fisheries. (2018). Notice of the General Office of the Ministry of Agriculture and Rural Affairs on the Issuance of the Standardized Vessel Type Parameter Table for Distant Water Vessels (2018 Edition) (English translation). http://www.moa.gov.cn/nybgb/2018/201811/201901/t20190102_6165927.htm

Bureau of Fisheries. (2019). Notice of the Bureau of Fisheries of the Ministry of Agriculture and Rural Affairs on the Issuance of Measures for Monitoring the Position of Distant Water Fishing Vessels (English translation). www.moa.gov.cn/nybgb/2019/201909/202001/t20200109_6334654.htm

Bureau of Fisheries. (2020a). Compliance Rating Scores for Distant-water Fishing Companies of China in 2020 (English translation). https://www.sohu.com/a/456096182_120214181

Bureau of Fisheries. (2020b). Regulations on Distant Water Fishery (English translation). http://www.gov.cn/gongbao/content/2020/content_5503553.htm

Bureau of Fisheries. (2021a). Compliance Rating Scores for Distant-water Fishing Companies of China in 2021 (English translation). https://www.sohu.com/a/529991476_672426

Bureau of Fisheries. (2021b). Notice of the General Office of the Ministry of Agriculture and Rural Affairs on the Issuance of the Standardized Vessel Type Parameter Table for Distant Water Vessels (2021 Edition) (English translation). http://www.moa.gov.cn/nybgb/2021/202110/202112/t20211207_6384150.htm

Bureau of Fisheries, National Fisheries Technology Extension Center, & China Society of Fisheries. (2021). *China Fishery Statistical Yearbook 2021*. Beijing: China Agriculture Press.

Bureau of Fisheries, National Fisheries Technology Extension Center, & China Society of Fisheries. (2022). *China Fishery Statistical Yearbook 2022*. Beijing: China Agriculture Press.

Calonico, S., Cattaneo, M. D., Farrell, M. H., & Titiunik, R. (2022). *rdrobust: Robust Data-Driven Statistical Inference in Regression-Discontinuity Designs* [R package version 2.0.2]. https://CRAN.R-project.org/package=rdrobust

Calonico, S., Cattaneo, M. D., & Titiunik, R. (2015). Optimal Data-Driven Regression Discontinuity Plots. *Journal of the American Statistical Association*, *110*(512), 1753–1769.

Cattaneo, M. D., Jansson, M., & Ma, X. (2021). *rdrobust: Manipulation Testing Based on Density Discontinuity* [R package version 2.2]. https://cran.r-project.org/web/packages/rddensity/rddensity.pdf

CCAMLR. (2021). CCAMLR List of Authorised Vessels. https://www.ccamlr.org/en/compliance/authorised-vessels-0 (accessed November 13, 2021)

China Foreign Exchange Trade System. (2021). Central Parity Rate of RMB (Annual Average exchange rate). https://www.chinamoney.com.cn/chinese/bkccpr/?tab=2 (accessed December 21, 2022)

Chinese Government. (1994). Regulations of the People's Republic of China on Vessel Registration (English translation). http://www.gov.cn/gongbao/content/2016/content_5139454.htm

Cisneros-Montemayor, A. M., Sinan, H., Nguyen, T., Da Rocha, J. M., Sumaila, U. R., Skerritt, D. J., Schuhbauer, A., Sanjurjo, E., & Bailey, M. (2022). A constructive critique of the world trade organization draft agreement on harmful fisheries subsidies. *Marine Policy*, *135*, 104872.

Cong, Y. (2014). Wendeng Adds Another Distant Water Fishing Vessel, with an Annual Fishing Capacity of 2,300 Tons of Aquatic Products (English translation). http://weihai.iqilu.com/whyaowen/2014/0314/1908400.shtml

Convention on Biological Diversity. (2010). Aichi Biodiversity Targets. https://www.cbd.int/sp/targets/

Convention on Biological Diversity. (2022). By 2030: Protect 30% of Earth's Lands, Oceans, Coastal Areas, Inland Waters; Reduce by $500 Billion Annual Harmful Government Subsidies; Cut Food Waste in Half. https://www.cbd.int/article/cop15-cbd-press-release-final-19dec2022

Costello, C., Millage, K., Eisenbarth, S., Galarza, E., Ishimura, G., Rubino, L. L., Saccomanno, V., Sumaila, U. R., & Strauss, K. (2021). Ambitious Subsidy Reform by the WTO Presents Opportunities for Ocean Health Restoration. *Sustainability Science*, *16*(4), 1391–1396.

Costello, C., Ovando, D., Clavelle, T., Strauss, C. K., Hilborn, R., Melnychuk, M. C., Branch, T. A., Gaines, S. D., Szuwalski, C. S., Cabral, R. B., et al. (2016). Global fishery prospects under contrasting management regimes. *Proceedings of the national academy of sciences*, *113*(18), 5125–5129.

Dasgupta, P. (2021). *The Economics of Biodiversity: The Dasgupta Review*. London: HM Treasury.

Davis, L. W. (2014). The economic cost of global fuel subsidies. *American Economic Review*, *104*(5), 581–585.

Department of Agriculture and Rural Affairs of Liaoning Province. (2020). Announcement of Subsidies for Fishery Development and Vessel Scrapping and Dismantling (Distant Water Fisheries) in 2020 (English translation). http://shuichan.jinnong.cn/n/2020/08/05/3413994115.shtml

Department of Industrial Policy and Regulation, Ministry of Agriculture. (2021). *Encyclopedia of Agricultural Regulations*. Beijing: Law Press.

Ding, D. (2015). The Annual Output of China's Distant Water Fisheries has Increased Nearly 800 Times in 30 Years (English translation). https://www.chinanews.com/cj/2015/03-30/7170787.shtml

FAO. (1992). *Marine fisheries and the Law of the Sea: a decade of change* (FAO Fisheries Circular No. 853). Food and Agriculture Organization (FAO). Rome.

FAO. (2020). *The State of World Fisheries and Aquaculture 2020: Sustainability in Action.* Food and Agriculture Organization (FAO). Rome. https://doi.org/10.4060/ca9229en.

FAO. (2022a). *Mapping Distant-Water Fisheries Access Arrangements*. Food, Agriculture Organization (FAO) Fisheries, and Aquaculture Circular No. 1252. Rome. https://doi.org/10.4060/cc

FAO. (2022b). *The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation.* Food and Agriculture Organization (FAO). Rome. https://doi.org/10.4060/cc0461en.

Feehan, J. P. (2018). The Long-run Price Elasticity of Residential Demand for Electricity: Results from a Natural Experiment. *Utilities Policy*, *51*, 12–17.

Gautam, M., Laborde, D., Mamun, A., Martin, W., Pineiro, V., & Vos, R. (2022). *Repurposing Agricultural Policies and Support*. World Bank, Washington, DC.

General Administration of Customs. (2021). Towards the Deep Blue: Rongcheng's Distant Water Fisheries Set Sail. http://www.customs.gov.cn/customs/ztzl86/302414/302415/gmfc40/2813466/3796069/index.html (accessed December 4, 2021)

General Administration of Customs and Ministry of Agriculture. (2000). Notice of the General Administration of Customs and the Ministry of Agriculture on the Issuance of the Interim Administrative Measures on the Exemption from Taxation of Self-caught Aquatic Products Shipped Back by Distant Water Fishing Companies (English translation). http://www.customs.gov.cn/publish/portal0/tab20149/module51150/info111011.htm

Government of Fujian Province. (2014). Notice of the Government of Fujian Province on Six Measures to Accelerate the Development of Distant Water Fisheries (English translation). http://www.quanzhou.gov.cn/zfb/xxgk/zfxxgkzl/fgwj/yhfczc/201409/t20140926_150725.htm

Government of Fujian Province. (2021). Notice of the General Office of the People's Government of Fujian Province on Eight Measures to Promote the High-quality Development of Distant Water Fisheries (English translation). http://www.quanzhou.gov.cn/zfb/xxgk/zfxxgkzl/fgwj/yhfczc/201409/t20140926_150725.htm

IATTC. (2021). IATTC Vessel Registry. https://www.iattc.org/VesselRegister/VesselList.aspx?Lang=en (accessed November 13, 2021)

ICCAT. (2021). ICCAT Record of Vessels. https://www.iccat.int/en/VesselsRecord.asp (accessed November 13, 2021)

IOTC. (2021). IOTC Record of Authorised Vessels. https://www.iotc.org/vessels (accessed November 13, 2021)

Jiangbei District Government. (2019). Announcement of the Distribution of Subsidies for the Development and Utilization of International Fishery Resources in Jiangbei District, Ningbo, Zhejiang Province in 2017 (English translation). http://www.nbjb.gov.cn/art/2019/4/15/art_1229058946_420160.html

Jiangbei District Government. (2020). Announcement of the Distribution of Subsidies for the Development and Utilization of International Fishery Resources in Jiangbei District, Ningbo, Zhejiang Province in 2018 (English translation). http://www.nbjb.gov.cn/art/2020/1/16/art_1229172881_1708.html

Kroetz, K., Nøstbakken, L., & Quaas, M. (2022). The Future of Wild-Caught Fisheries: Expanding the Scope of Management. *Review of Environmental Economics and Policy*, *16*(2), 241–261.

Kroodsma, D. A., Mayorga, J., Hochberg, T., Miller, N. A., Boerder, K., Ferretti, F., Wilson, A., Bergman, B., White, T. D., Block, B. A., et al. (2018). Tracking the global footprint of fisheries. *Science*, *359*(6378), 904–908.

Martini, R., & Innes, J. (2018). *Relative effects of fisheries support policies*. OECD.

McDermott, G. R., Meng, K. C., McDonald, G. G., & Costello, C. J. (2019). The blue paradox: Preemptive overfishing in marine reserves. *Proceedings of the National Academy of Sciences*, *116*(12), 5319–5325.

Millage, K. D., Warham, M., Rubino, L. L., & Costello, C. (2021). *Distant Water Fishing Subsidy Atlas*. http://www.dwfsubsidyatlas.org/

Ministry of Agriculture. (2003). Regulations on Distant Water Fishery (English translation). http://www.yyj.moa.gov.cn/bjwj/201904/t20190419_6197124.htm

Ministry of Agriculture. (2007). National Fishery Development Plan during the 11th Five-Year Plan Period (English translation). http://www.mofcom.gov.cn/article/bh/200702/20070204363537.shtml

Ministry of Agriculture. (2012). Notice of the General Office of the Ministry of Agriculture on the Issuance of Interim Measures for Monitoring the Position of Distant Water Fishing Vessels (English translation). www.moa.gov.cn/nybgb/2012/deq/201805/t20180512_6141964.htm

Ministry of Agriculture. (2013a). Regulations of the People's Republic of China on Vessel Registration (revised by Decree No. 5 of the Ministry of Agriculture in 2013) (English translation). http://www.moa.gov.cn/gk/zcfg/gfxwj/201401/t20140120_3743553.htm

Ministry of Agriculture. (2013b). The Ministry of Agriculture Further Strengthens the Management of the Renovation and Transformation of Distant Water Fishing Vessels (English translation). http://www.gov.cn/govweb/gzdt/2013-09/03/content_2480463.htm

Ministry of Agriculture. (2014a). Notice of the General Office of the Ministry of Agriculture on the Issuance of Measures for Monitoring the Position of Distant Water Fishing Vessels (English translation). www.moa.gov.cn/nybgb/2014/shiyi/201712/t20171219_6111611.htm

Ministry of Agriculture. (2014b). Notice of the General Office of the Ministry of Agriculture on the Standardization of Vessel Types of Distant Water Fishing Vessels (English translation). http://www.yyj.moa.gov.cn/bjwj/201904/t20190419_6197386.htm

Ministry of Agriculture. (2015). Notice of the General Office of the Ministry of Agriculture on the Issuance of the Parameter Table of Standardized Vessel Types for Distant Water Fishing Vessels (the first batch) (English translation). http://www.moa.gov.cn/govpublic/YYJ/201507/t20150722_4758184.htm

Ministry of Agriculture. (2016). *Notice of the General Office of the Ministry of Agriculture on the Issuance of the Implementation Plan for the Adjustment of the Fuel Subsidy Policy for Distant Water Fisheries (No. Nongbanyu [2016] 43) (English translation)*. Ministry of Agriculture.

Ministry of Agriculture. (2017). Notice of the General Office of the Ministry of Agriculture on the Issuance of the Parameter Table of Standardized Vessel Types for Distant Water Fishing Vessels (the second batch) (English translation). http://www.moa.gov.cn/nybgb/2018/201811/201901/t20190102_6165927.htm

Ministry of Agriculture and Rural Affairs. (2018a). Notice of the General Office of the Ministry of Agriculture and Rural Affairs on the Investigation and Punishment of Suspected Violations of Laws and Regulations by Some Distant Water Fishing Companies and Fishing Vessels (English translation). *Gazette of the Ministry of Agriculture and Rural Affairs of the People's Republic of China*, (6).

Ministry of Agriculture and Rural Affairs. (2018b). Notice of the General Office of the Ministry of Agriculture and Rural Affairs on the Punishment of Some Distant Water Fishing Companies and Fishing Vessels for Violations of Laws and Regulations (English translation). *Gazette of the Ministry of Agriculture and Rural Affairs of the People's Republic of China*, (3).

Ministry of Agriculture and Rural Affairs. (2019a). Notice of the General Office of the Ministry of Agriculture and Rural Affairs on the Investigation and Punishment of Suspected Violations of Laws and Regulations by Some Distant Water Fishing Companies and Fishing Vessels (English translation). *Gazette of the Ministry of Agriculture and Rural Affairs of the People's Republic of China*, (9).

Ministry of Agriculture and Rural Affairs. (2019b). Notice on the Investigation and Punishment of Suspected Violations of Laws and Regulations by Some Distant Water Fishing Companies and Fishing Vessels (English translation). http://www.moa.gov.cn/xw/bmdt/201909/t20190923_6328680.htm

Ministry of Agriculture and Rural Affairs. (2020). Chinese White Paper on the Compliance of China's Distant Water Fisheries 2020 (English translation). http://www.moa.gov.cn/xw/bmdt/202011/t20201120_6356632.htm

Ministry of Agriculture and Rural Affairs. (2021). Reply to Recommendation No. 4651 of the Fourth Session of the Thirteenth National People's Congress (English translation). http://www.moa.gov.cn/govpublic/YYJ/202107/t20210722_6372551.htm

Ministry of Agriculture and Rural Affairs and Ministry of Finance. (2021a). Notice of the General Office of the Ministry of Agriculture and Rural Affairs and the General Office of the Ministry of Finance on Implementing the Fishery Development Subsidy Policy in 2021 (English translation). http://www.moa.gov.cn/nybgb/2021/202108/202111/t20211104_6381398.htm

Ministry of Agriculture and Rural Affairs and Ministry of Finance. (2021b). Notice of the General Office of the Ministry of Agriculture and Rural Affairs and the General Office of the Ministry of Finance on the Implementation of the Fishery Development Subsidy Policy in 2021 (English translation). http://www.moa.gov.cn/nybgb/2021/202108/202111/t20211104_6381398.htm

Ministry of Agriculture and Rural Affairs and Ministry of Finance. (2021c). Notice on the Implementation of Fishery Development Support Policies to Promote the High-quality Development of Fisheries (English translation). http://www.mof.gov.cn/gp/xxgkml/jjjss/201605/t20160511_2512196.htm

Ministry of Agriculture and Rural Affairs and Ministry of Finance. (2021d). Notice on the Issuance of the Administrative Measures for Fishery Development Subsidy Funds

(English translation). http://nys.mof.gov.cn/czpjZhengCeFaBu_2_2/202104/t20210425_3691999.htm

Ministry of Finance. (2016). Notice of the Ministry of Finance, the Ministry of Transport, the Ministry of Agriculture and the State Forestry Administration on the Adjustment of Fuel Subsidy Policies for Rural Passenger Transport and Other Industries (English translation). http://www.mof.gov.cn/gp/xxgkml/jjjss/201605/t20160511_2512196.htm

National Development and Reform Commission. (2006). Notice of the National Development and Reform Commission on Adjusting the Price of Refined Oil (English translation). http://www.gov.cn/govweb/gzdt/2006-03/26/content_236868.htm

NPFC. (2021). Member/CNCP Flagged Vessels Register. https://www.npfc.int/compliance/vessels (accessed November 13, 2021)

Pan, F. (2015). New Squid Jiggers Go Fishing in the High Seas (English translation). https://www.sohu.com/a/23514395_11540

Rongcheng Municipal Government. (2021). Information on Distant Water Fishing Vessels in Rongcheng. http://data.weihai.gov.cn/weihai/catalog/c9218964eb00436ebf8988bc317d73af (accessed December 4, 2021)

Ryan, N., & Sudarshan, A. (2022). Rationing the Commons. *Journal of Political Economy*, *130*(1), 210–257.

Sakai, Y. (2017). Subsidies, Fisheries Management, and Stock Depletion. *Land Economics*, *93*(1), 165–178.

Sala, E., Mayorga, J., Costello, C., Kroodsma, D., Palomares, M. L., Pauly, D., Sumaila, U. R., & Zeller, D. (2018). The economics of fishing the high seas. *Science Advances*, *4*(6), eaat2504.

Schuhbauer, A., Skerritt, D. J., Ebrahim, N., Le Manach, F., & Sumaila, U. R. (2020). The Global Fisheries Subsidies Divide Between Small- and Large-Scale Fisheries. *Frontiers in Marine Science*, 792.

Smith, M. D. (2012). The New Fisheries Economics: Incentives Across Many Margins. *Annu. Rev. Resour. Econ.*, *4*(1), 379–402.

Smith, T. D. (1994). *Scaling Fisheries: The Science of Measuring the Effects of Fishing, 1855-1955*. Cambridge University Press.

SPRFMO. (2021). SPRFMO Vessel Records. https://www.sprfmo.org/web/public/vessel (accessed November 13, 2021)

Sumaila, U. R., Ebrahim, N., Schuhbauer, A., Skerritt, D., Li, Y., Kim, H. S., Mallory, T. G., Lam, V. W., & Pauly, D. (2019). Updated estimates and analysis of global fisheries subsidies. *Marine Policy*, *109*, 103695.

Taicang Municipal Government. (2016). Announcement of the Distribution of Subsidies for the Development and Utilization of International Fishery Resources in Taicang in 2015 (English translation). http://www.taicang.gov.cn/taicang/sngg/201612/7efc136eca6946bdb2b41abd37729e6e.shtml

Tianjin Municipal Committee of Agriculture and Rural Affairs. (2020). Notice of the Municipal Committee of Agriculture and Rural Affairs on the Issuance of the Implementation Plan for the 2020 Project of Tianjin Distant Water Fishery Companies Transporting Back Self-Caught Aquatic Products (English translation). https://nync.tj.gov.cn/ZWGK0/ZCFG152022/202110/t20211011_5643503.html

Wang, C. (2022). Dejun, Yang: the Captain of "FURONGHAI" in the Distant Water Fishing Journey (English translation). https://baijiahao.baidu.com/s?id=1731355939779614633&wfr=spider&for=pc

Wang, K., Reimer, M. N., & Wilen, J. E. (2022). Fisheries Subsidies Reform in China. Working paper. https://www.researchgate.net/publication/366897685_Fisheries_Subsidies_Reform_in_China

WCPFC. (2021). WCPFC Record of Fishing Vessels. https://www.wcpfc.int/record-fishing-vessel-database (accessed November 13, 2021)

Weng, Y. (2021). March to the Sea (English translation). http://paper.cztvcloud.com/jrpt/pc/content/202112/17/content_184777.html

Wenling Municipal Government. (2017). Announcement of the Distribution of Subsidies for the Development and Utilization of International Fishery Resources for Distant Water Fishing Vessels in Wenling, Zhejiang province in 2016 (English translation). http://www.wl.gov.cn/art/2017/12/6/art_1402221_14083124.html

WTO. (2022). The WTO Agreement on Fisheries Subsidies Factsheet. World Trade Organization (WTO). https://www.wto.org/english/tratop_e/rulesneg_e/fish_e/fish_factsheet_e.pdf

Yuan, Y. (2015). The Qingdao MINGKAI, Asia's Largest Distant Water Fishing Vessel, Made its Maiden Voyage to the Antarctic (English translation). https://www.dailyqd.com/2015-02/27/content_217617.htm

Zeng, S. (2022). Blue Answer Sheet: Remarkable Results have been Achieved in the Development of Distant Water Fishery in the First Year of the 14th Five-Year Plan (English translation). http://journal.crnews.net/ncpsczk/2022n/d5q/gz/946851_20220414021929.html

Zhang, C. (2018). China Cracks Down on Illegal Distant Water Fishing. https://chinadialogueocean.net/en/fisheries/4239-china-cracks-down-on-illegal-distant-water-fishing/

Zhejiang Provincial Department of Finance and Zhejiang Provincial Department of Agriculture and Rural Affairs. (2021). Notice of Zhejiang Provincial Department of Finance and Zhejiang Provincial Department of Agriculture and Rural Affairs on the Allocation of Central Fishery Development Subsidy Funds in 2021 (English translation). http://czt.zj.gov.cn/art/2021/5/26/art_1164164_58922829.html

Zhoushan Property Exchange Co., Zhoushan Jia Lian Auction Co., and Zhoushan Huali Auction Co. (2009). Auction Announcement for the Squid Jigger Tianyuan (English translation). http://zjrb.zjol.com.cn/html/2009-06/13/content_4882544.htm

# Online Appendix

Input Subsidies and the Destruction of Natural Capital: Chinese Distant Water Fishing

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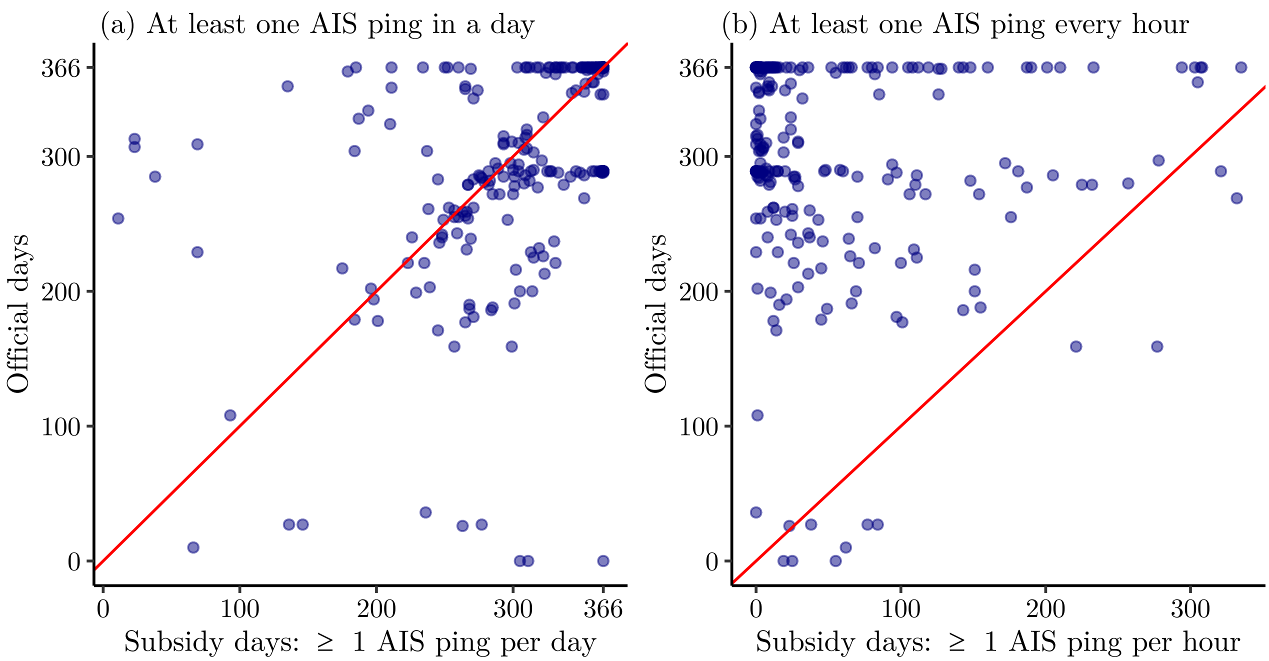
Qutu Jiang, Mingzhao Hu, Olivier Deschenes, and Christopher Costello

March 2, 2023

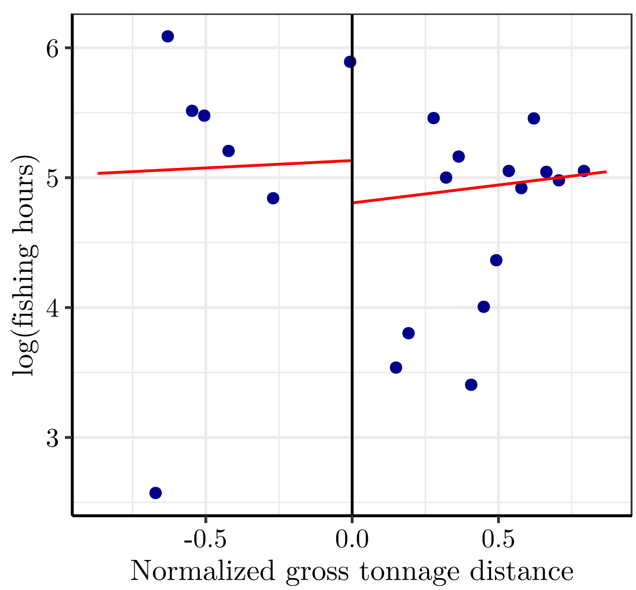
# A Appendix figures and tables

Figure A1: Comparison of Two Definitions of Subsidy Days



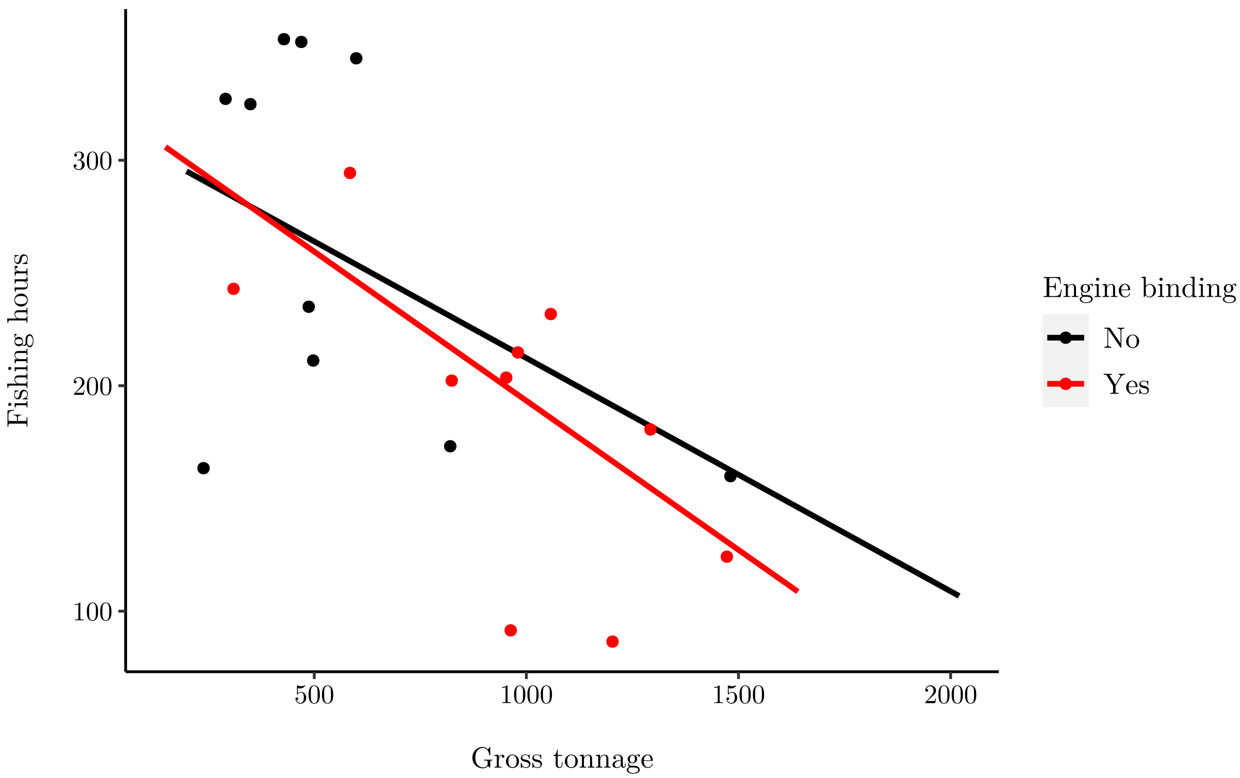

Notes: We obtained subsidy days for 273 vessels in 2020 from the regulator in Putuo district, Zhoushan, in Zhejiang province (y-axis). We compare these official subsidy days, which are based on VMS data we do not observe, to two definitions of subsidy days based on AIS data that we do observe. A subsidy day is one in which we observe (a) at least one AIS ping from the vessel that day or (b) at least one AIS ping from the vessel every hour that day. The former measure has a closer correspondence to official subsidy days, so we use it as our measure of subsidy days when calculating the annual fuel subsidy received by each vessel.

Figure A2: Pre-Period Placebo Test



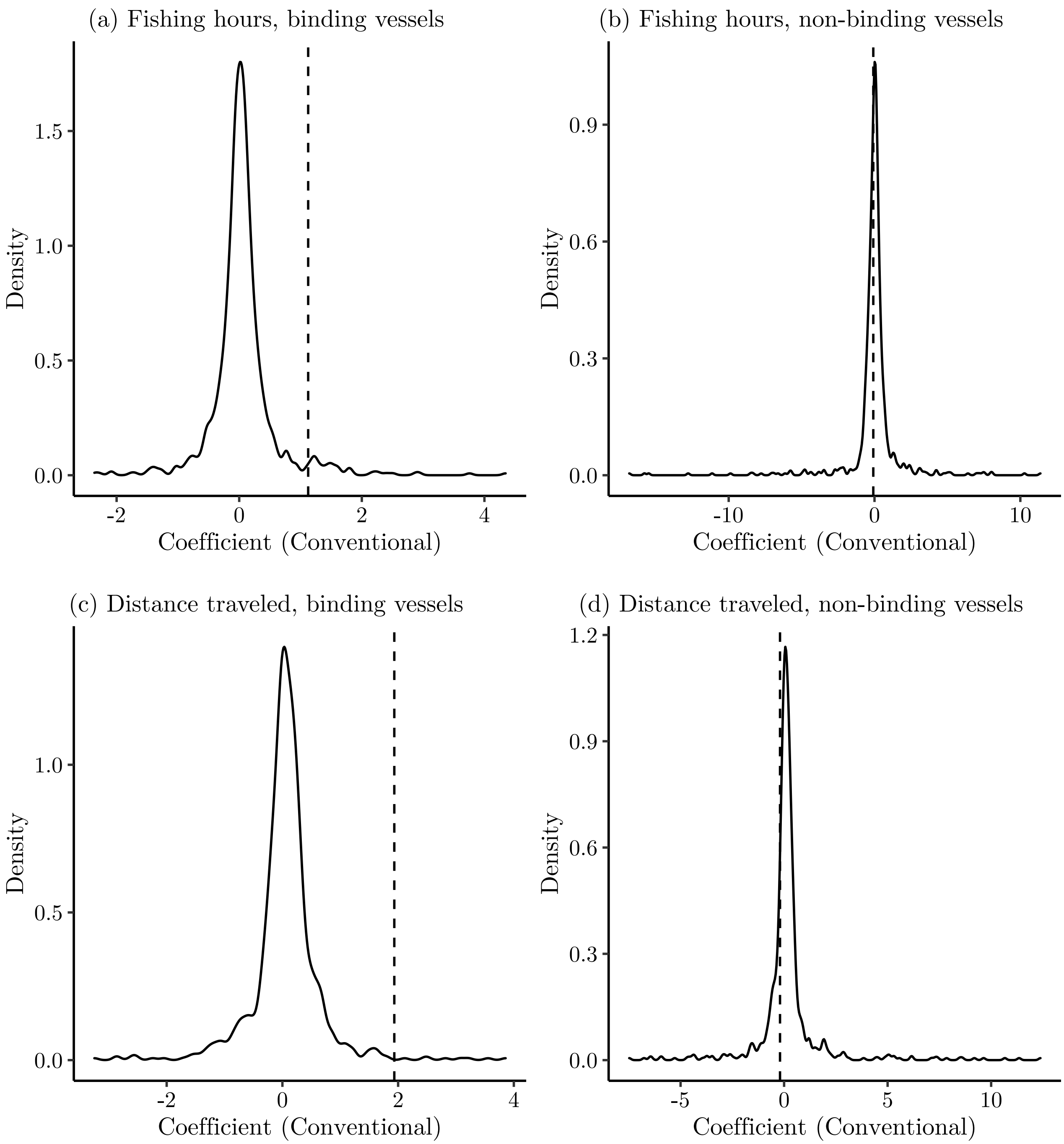

Notes: Points are binned sample means of log(fishing hours) and lines are local linear conditional mean functions. The regression initially resulted in an error because the mean-squared error optimal bandwidth is too small. We therefore specified a bandwidth that would result in a similar number of observations within the bandwidth as in the Table 3, Column 1 regression. Specifically, we set the bandwidth equal to the optimal bandwidth from the Table 3 Column 1 regression, multiplied by the number of observations in our panel data between 2016 and 2020, divided by the number of observations in our panel data between 2012 and 2014.

Figure A3: Relationship Between Pre-Period Monthly Fishing Hours and Gross Tonnage



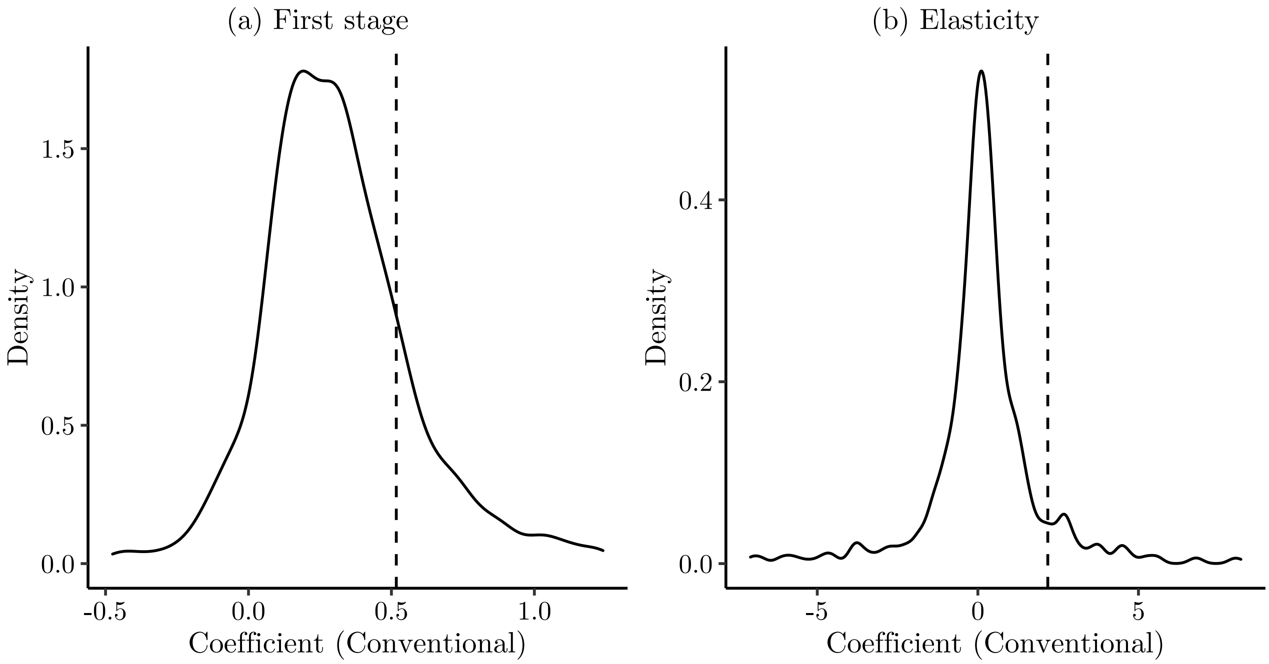

Notes: Linear monthly fishing hours between 2012 and 2014 (y-axis) and gross tonnage in levels (x-axis). Points are decile bins, but lines are drawn through the entire data. We exclude 2015 fishing data since vessels choosing how much to fish in this year might have been aware of the 2016-2020 policy. Engine binding calculated with respect to 2016-2020 policy. Of the 1,234 Chinese distant water fishing vessels that we matched to GFW data and that are of a gear with a gross tonnage discontinuity, only 405 have positive fishing hours between 2012 and 2014. We exclude from this plot's data 9 vessels with gross tonnage greater than 4,000 tons to improve legibility and because these vessels are not near a gross tonnage discontinuity.

Figure A4: Randomization Inference Effect of Fuel Subsidies on Log Hours of Fishing or Log Distance Traveled in km for Different Subsets of Vessels



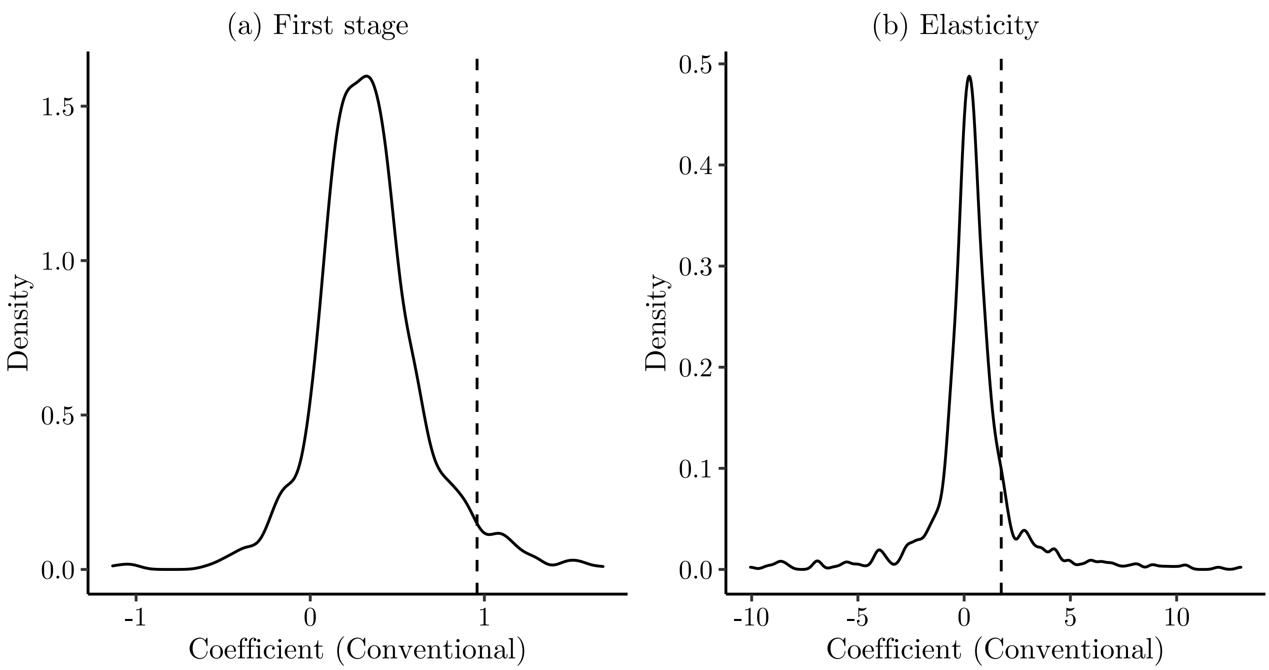

Notes: Placebo conventional point estimates (solid lines) against true conventional point estimates (vertical dashed lines). We trim the top and bottom 2% of placebo conventional point estimates for legibility, but retain all placebo estimates when calculating p-values. The randomization inference p-values are (a) 0.062, (b) 0.608, (c) 0.029 and (d) 0.776.

Figure A5: Randomization Inference Elasticity of Fishing Hours with Respect to Fuel Subsidies




Notes: Each subfigure displays the distribution of placebo conventional point estimates (solid line) against the true conventional point estimate (vertical dashed line). We trim the top and bottom 2% of placebo conventional point estimates for legibility, but we retain all placebo estimates when calculating p-values. The dependent variable in (a) is log monthly fuel subsidy received and in (b) it is the placebo reduced form coefficient (effect of policy on log fishing hours) divided by the placebo first stage coefficient from the same random thresholds run. The randomization inference p-values are (a) 0.187 and (b) 0.101.

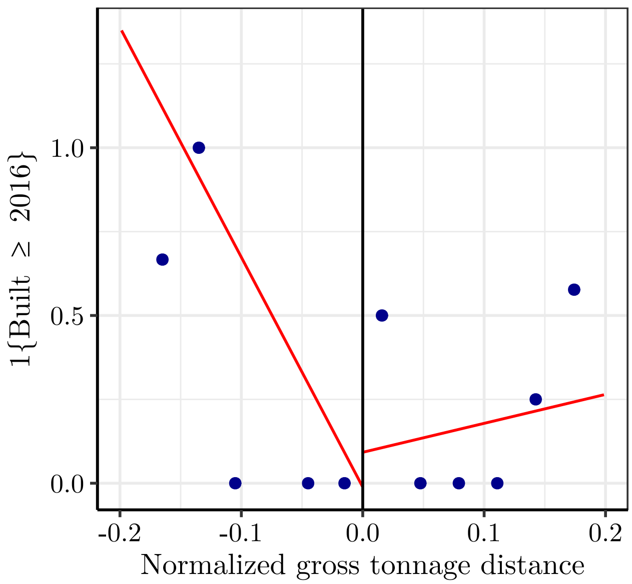
Figure A6: Randomization Inference Elasticity of Distance Traveled with Respect to Fuel Subsidies



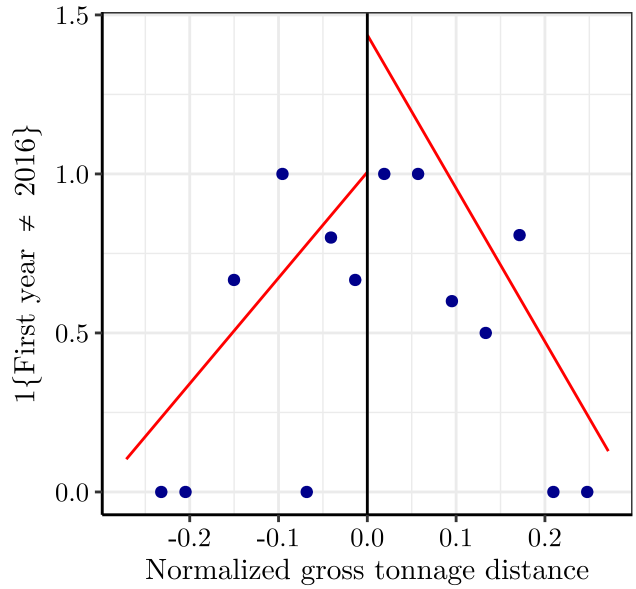

Notes: Each subfigure displays the distribution of placebo conventional point estimates (solid line) against the true conventional point estimate (vertical dashed line). We trim the top and bottom 2% of placebo conventional point estimates for legibility, but we retain all placebo estimates when calculating p-values. The dependent variable in (a) is log monthly fuel subsidy received and in (b) it is the placebo reduced form coefficient (effect of policy on log distance traveled) divided by the placebo first stage coefficient from the same random thresholds run. The randomization inference p-values are (a) 0.057 and (b) 0.140.

Figure A7: Effect of Fuel Subsidies on Entry and Exit

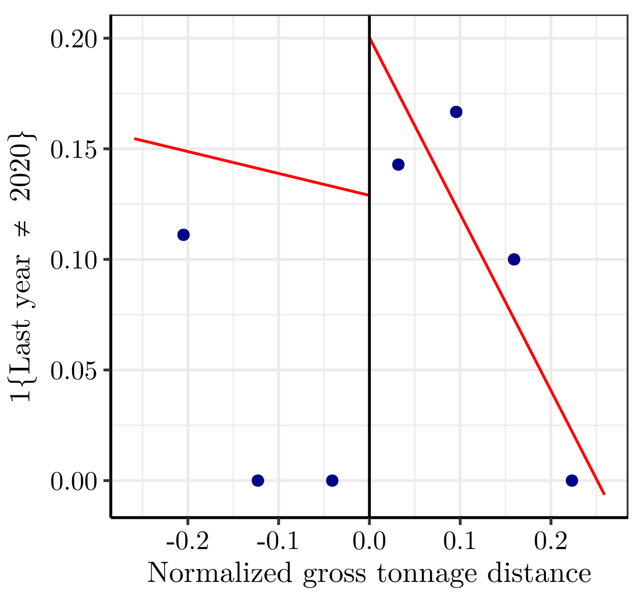
(a) 1{Built ≥ 2016}




(b) 1{First year ≠ 2016}



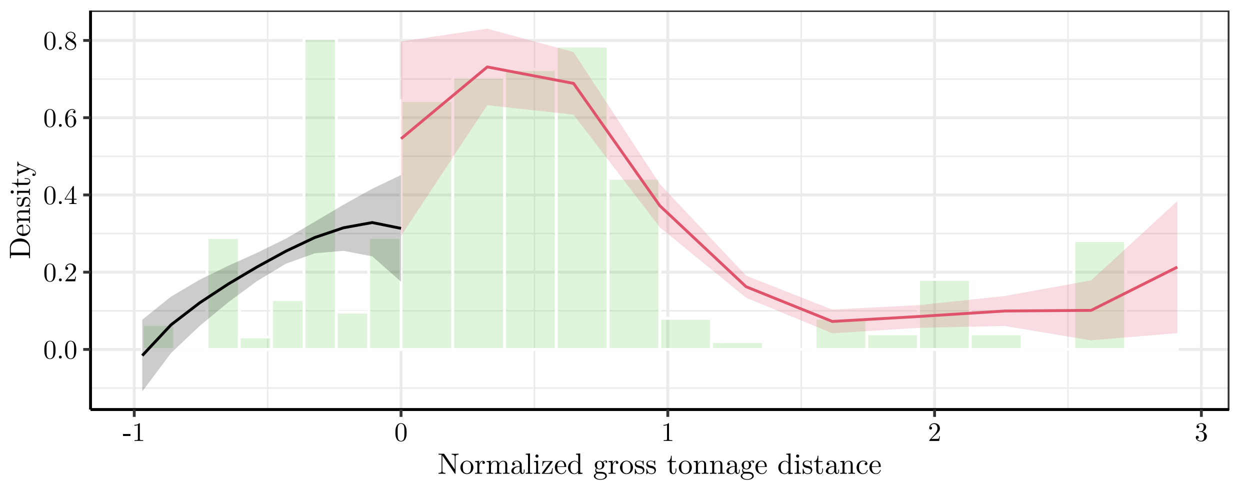

(c) 1{Last year ≠ 2020}



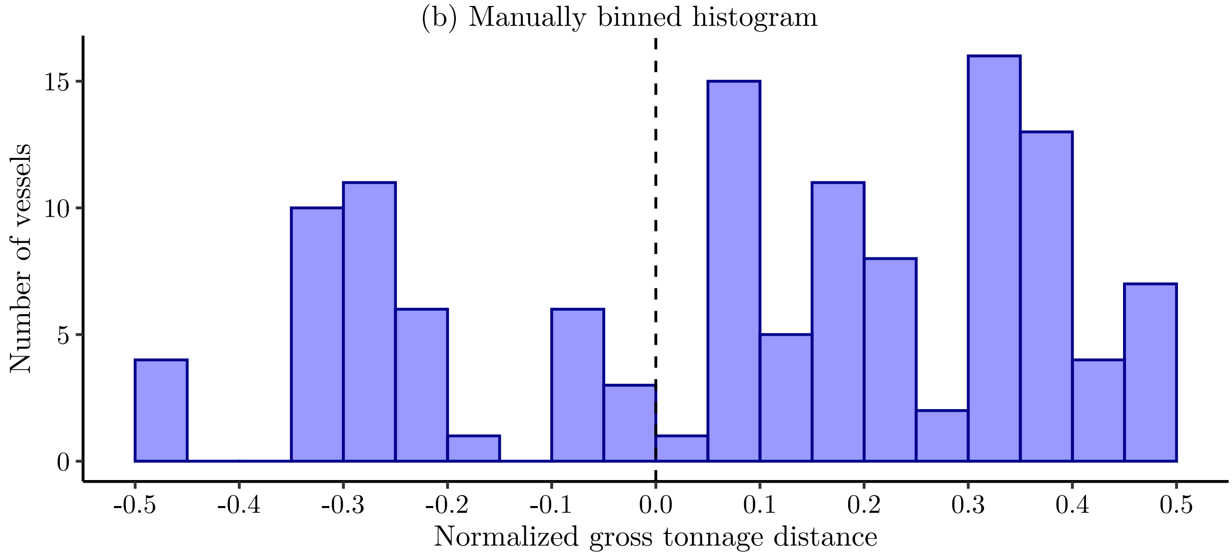

Notes: Points are binned sample means of the dependent variable (subfigure title) and lines are local linear conditional mean functions. These plots reproduce the regressions in Columns 5 to 7 of Table 5, with the difference in intercepts between the two regression lines in (a) corresponding to the conventional point estimate in Column 5, and so on.

Figure A8: Normalized Gross Tonnage Distance Distribution for Binding Vessels Built Before 2016

(a) Density test



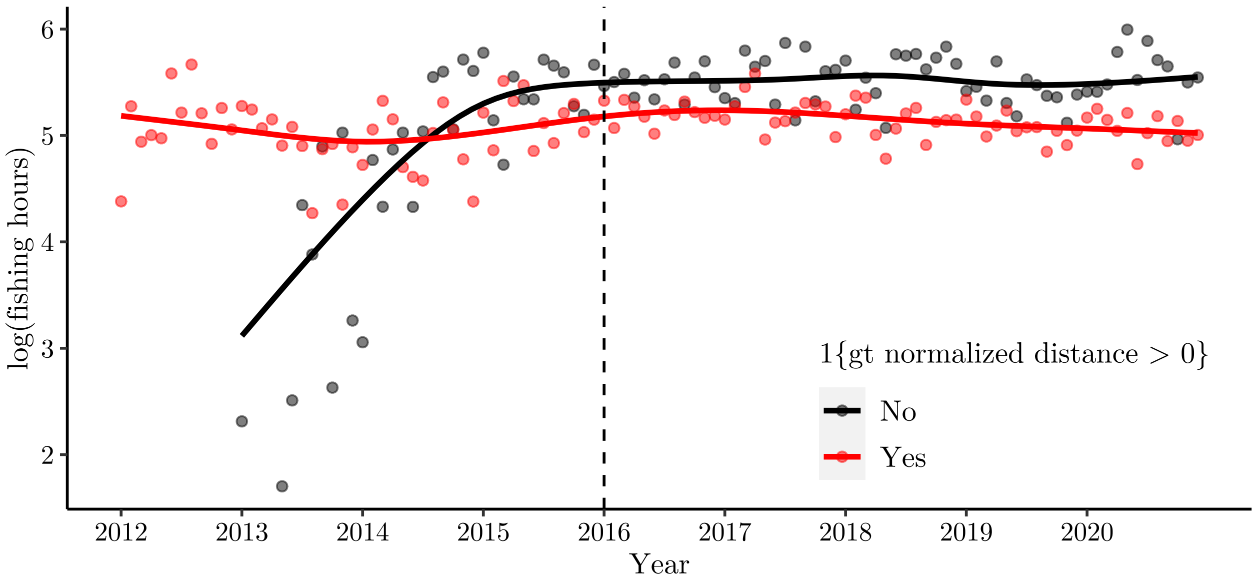

(b) Manually binned histogram



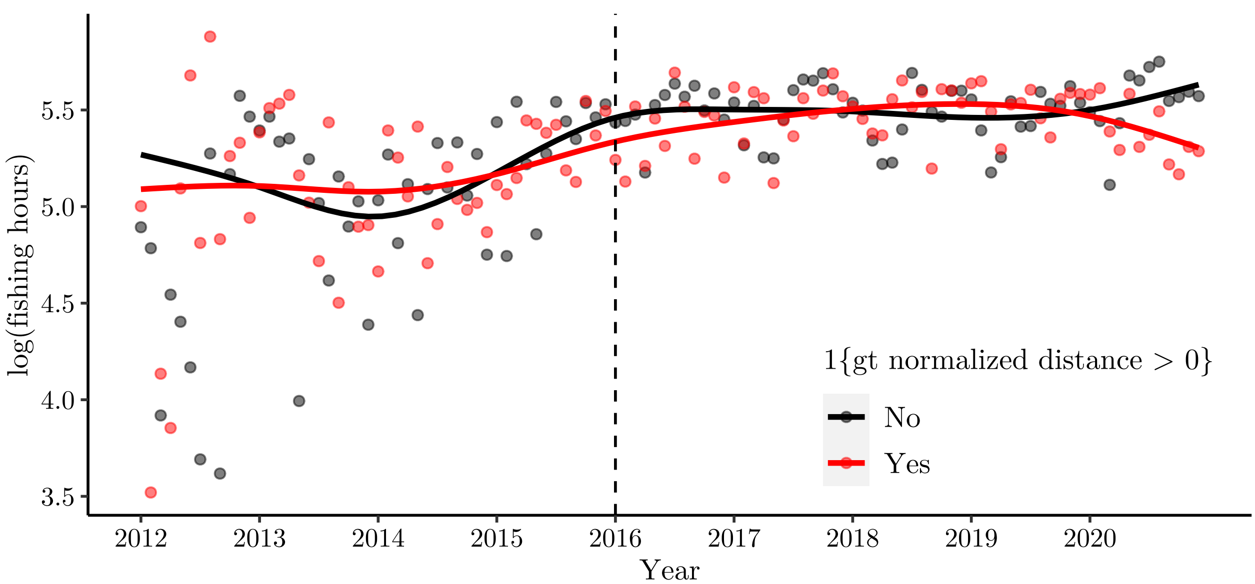

Notes: Data for both plots are the normalized gross tonnage distance of binding vessels built before 2016. In (a) bars are binned vessel densities (one observation per vessel), lines are local quadratic estimators of density, and shaded regions are 95% confidence intervals for the density. We created (a) with the rddensity package (Cattaneo et al., 2021). (b) is a histogram in which we have manually chosen the bin width to be 5 for all bins and the range of data to be between -0.5 and 0.5.

Figure A9: Log Monthly Fishing Hours Over Time

(a) Binding vessels




(b) Non-binding vessels




Notes: Points are average log monthly fishing hours for (a) binding and (b) non-binding vessels below (black) and above (red) their nearest gross tonnage threshold. We subset the data to vessels built before 2016 to facilitate comparison with our primary regressions. Lines are generalized additive model fits through vessel-level (non-averaged) log monthly fishing hours. Fishing hours are sometimes low or missing before 2015 because satellite coverage was poor before 2015.

Figure A10: Chinese Fishing Hours in 2020 by FAO Region as a Percentage of Total Fishing Effort

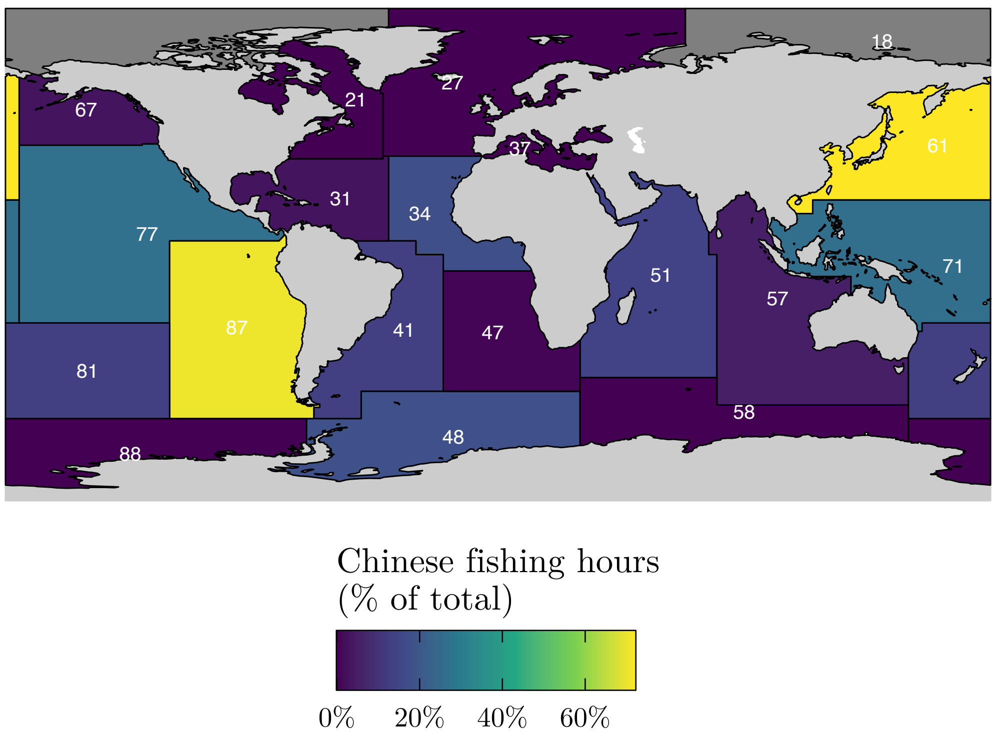
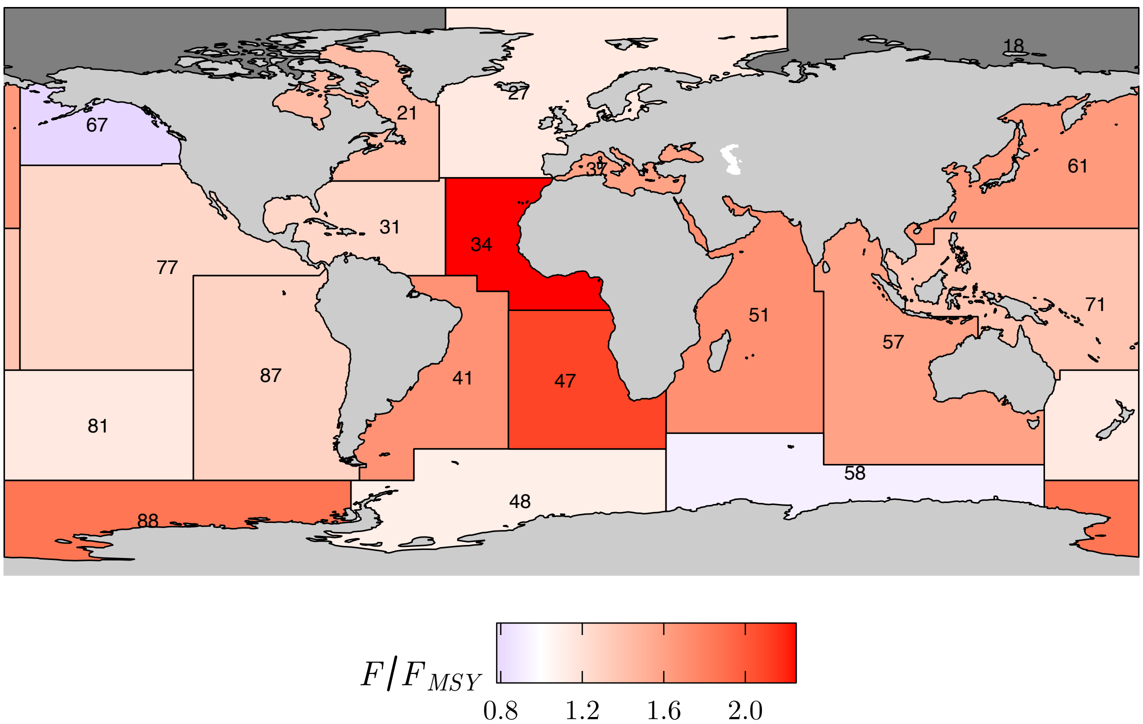


Figure A11: Catch-weighed mean overfishing ($F/F_{msy}$) status by FAO Region




Notes: Values greater than 1 indicate biological overfishing and are shown in red (16 FAO regions). Values less than 1 are shown in blue (2 FAO regions). Data are from Costello et al. (2016).

Table A1: Summary of stocks included in our analysis.

| FAO region (code) | N | % | Cumulative N | Cumulative % |
|---|---|---|---|---|
| Atlantic, NE (27) | 772 | 16.380% | 772 | 16.38% |
| Med. and Black Sea (37) | 578 | 12.264% | 1350 | 28.64% |
| Atlantic, East Central (34) | 538 | 11.415% | 1888 | 40.06% |
| Indian Ocean, West (51) | 436 | 9.251% | 2324 | 49.31% |
| Atlantic, West Central (31) | 365 | 7.745% | 2689 | 57.05% |
| Pacific, West Central (71) | 329 | 6.981% | 3018 | 64.04% |
| Pacific, NW (61) | 265 | 5.623% | 3283 | 69.66% |
| Indian Ocean, East (57) | 235 | 4.986% | 3518 | 74.64% |
| Atlantic, SE (41) | 192 | 4.074% | 3710 | 78.72% |
| Pacific, East Central (77) | 189 | 4.010% | 3899 | 82.73% |
| Atlantic, NW (21) | 179 | 3.798% | 4078 | 86.53% |
| Pacific, SE (81) | 169 | 3.586% | 4247 | 90.11% |
| Pacific, SE (87) | 159 | 3.374% | 4406 | 93.49% |
| Pacific, NE (67) | 114 | 2.419% | 4520 | 95.90% |
| Atlantic, SE (47) | 94 | 1.994% | 4614 | 97.90% |
| Indian Ocean, Antarctic (58) | 11 | 0.233% | 4625 | 98.13% |
| Atlantic, Antarctic (48) | 7 | 0.149% | 4632 | 98.28% |
| Pacific, Antarctic (88) | 5 | 0.106% | 4637 | 98.39% |
| Multi-zone stocks | 76 | 1.613% | 4713 | 100.00% |

Table A2: Chinese fishing hours in 2020 by FAO region as percentage of total fishing hours

| Ocean Group | FAO region (code) | % of fishing by Chinese vessels |
|---|---|---|
| Atlantic | Arctic Sea (18) | 0.00% |
| | Med. and Black Sea (37) | 0.00% |
| | Atlantic, NW (21) | 0.00% |
| | Atlantic, NE (27) | 0.01% |
| | Atlantic, SE (47) | 0.52% |
| | Atlantic, West Central (31) | 2.89% |
| | Atlantic, SE (41) | 13.14% |
| | Atlantic, East Central (34) | 17.67% |
| Indian | Indian Ocean, East (57) | 5.19% |
| | Indian Ocean, West (51) | 14.06% |
| Pacific | Pacific, NE (67) | 2.85% |
| | Pacific, SE (81) | 13.23% |
| | Pacific, West Central (71) | 26.29% |
| | Pacific, East Central (77) | 26.76% |
| | Pacific, SE (87) | 70.32% |
| | Pacific, NW (61) | 72.13% |
| Southern | Indian Ocean, Antarctic (58) | 0.00% |
| | Pacific, Antarctic (88) | 0.00% |
| | Atlantic, Antarctic (48) | 18.01% |

# B Data appendix

In order to calculate vessels' subsidies, we need to determine their gear. We do so as follows:

1. "Tuna purse seiner" and other "purse seiner": if the gear is tuna purse seiner, or if the gear is purse seiner and the target species of the vessel contains tuna, we classify the vessel as a tuna purse seiner. If the gear is purse seiner or light purse seiner, we classify it as other purse seiner.

2. "Large factory trawler (including Antarctic krill fishing and processing vessels)", "double-deck trawler and trawler fishing on high seas" and "other trawler": because all CCAMLR vessels are stern factory trawlers, if the gear is "stern factory trawler ", then we classify the vessel's gear as such. Since both double-deck trawlers and high sea trawlers can be assigned to the category "double-deck trawler and high sea trawler", we only need to find if a trawler is a double-deck trawler or a high sea trawler. If the gear is trawler or single trawler, and the authorized area contains "high seas", then we classify the vessel as a high seas trawler. For non-high sea trawlers, we use Chinese media to determine which vessels are double-deck trawlers. If no news reports are available for a vessel, we classify it as an "other trawler". the vessel is assumed as a non double-deck trawler and high sea trawler. If at the end of this process a trawler belongs to neither "large factor trawler" nor "double-deck trawler and trawler fishing on high seas", we classify it as "other trawler".

3. Pacific saury (Cololabis saira) fishing vessel: we classify vessels as such if their target species contains the word "SAP" (Pacific saury).[40]

4. Squid jigger: if vessels' gear contains "squid jigger", we classify them as such.

5. "Ultra-low temperature tuna longliner (ULT)" and other "tuna longliner". In order to distinguish the two categories, we first need to identify all tuna longliners. Vessels with

[40] In the acronym SAP, SA refers to saury and P refers to Pacific.

the gear “tuna longliner” are tuna longliners, as are vessels with the gear “longliner” or “drifting longliner” and the target species containing “albacore” or “tuna”. For vessels with the gear “longliner” or “drifting longliner”, but missing values in the “target species” column, we infer tuna longliners based on RFMO membership. ICCAT, IATTC and IOTC longline vessels are all tuna longliners. We identified other tuna longliners from Chinese media.[41]

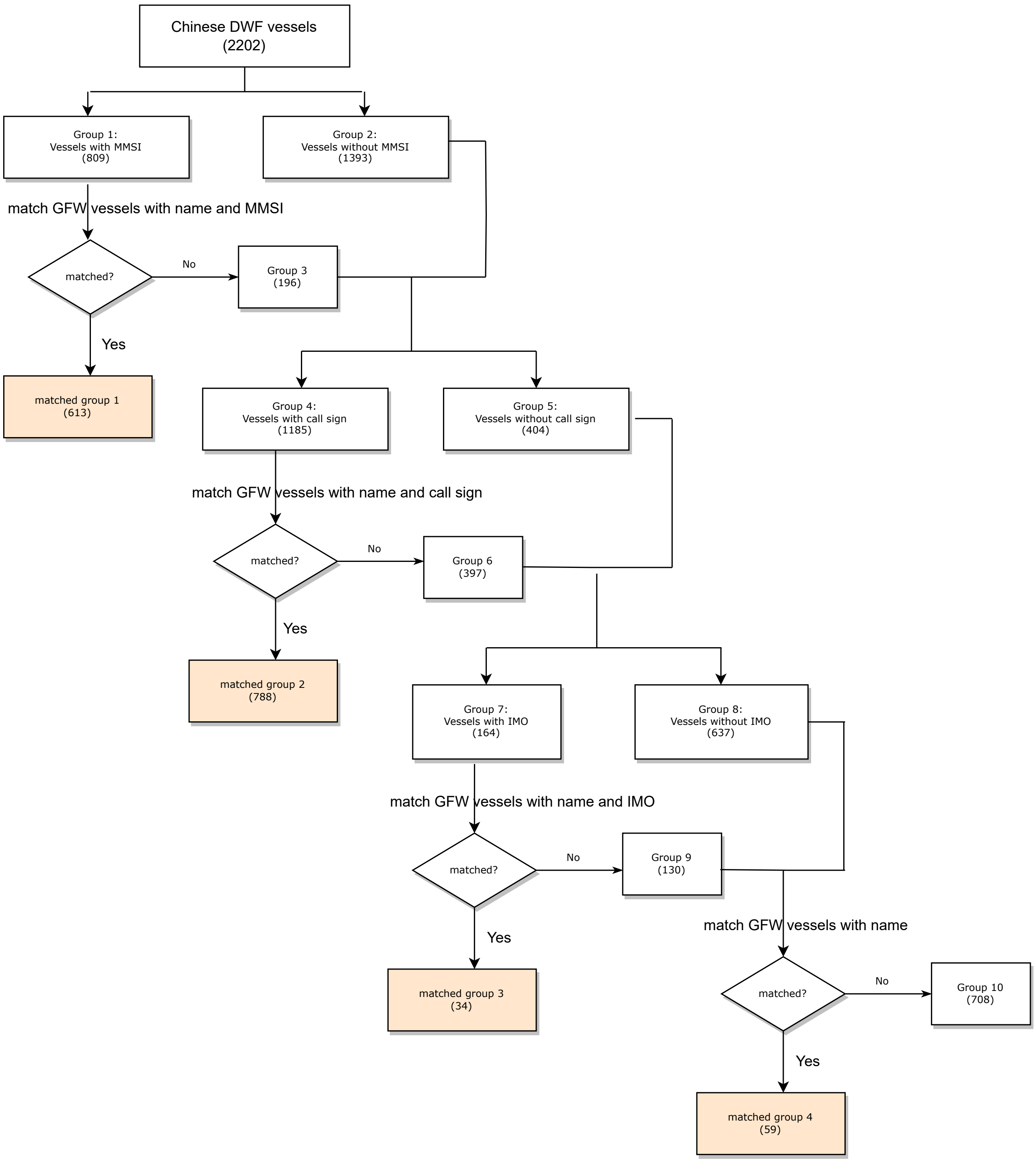
Then, we use three data sources to determine if a tuna longliner is a ULT tuna longliner: Chinese media reports, reports and announcements from publicly-listed Chinese fishing firms, and the websites of unlisted Chinese fishing firms.[42] We also identified tuna longliners as ULT based on their freezer types: “blast” or “blast and ice” or “plate”. We classify the remaining tuna longliners as (non-ULT) “tuna longliner” because we could not find any evidence that they are ULT.

6. Other vessels (set net, gillnet, fishing, baskets and pots, etc): we classify vessels as such if their gear is “pot vessel”.

[41] For example, the WCPFC vessel “YUEXIAYU90093” from the website http://www.shuichan.cc/news_view-189092.html.

[42] The annual reports and announcements of publicly-listed Chinese fishing firms, such as CNFC Overseas Fisheries Co., contain the identities of firms’ ULT tuna vessels. We checked the websites of non-listed fishing firms, such as Penglai Jinglu Fisheries Co., Ltd., Zhejiang Ocean Family Co., Ltd., Dalian Ocean Fishing Co., Ltd., and Shandong Zhonglu Oceanic Fisheries Co., Ltd., to determine which of these firms’ tuna longliners are ULT.

Figure B1: Flow Chart of the Matching Process Between Vessel Characteristics Data and GFW Data




Notes: The 2,202 Chinese DWF vessels are the vessels whose names appear only once in the vessel characteristics dataset, including 2,098 vessels in RFMO data and 104 vessels in Rongcheng data. The number in parentheses below each group is the corresponding number of vessels. The matched subsidized vessels include all vessels from Matched Group 1 to Matched Group 4.

Table B1: Ceiling of Subsidized Engine Power

| Gear | Gross tonnage | Ceiling of subsidized engine power (kW) |
|---|---|---|
| Tuna purse seiner | $\geq 2000$ | 3650 |
| | 1000-1999 | 2800 |
| | $\leq 999$ | 1800 |
| Ultra-low temperature (ULT) tuna longliner | $\geq 500$ | 1200 |
| | 350-499 | 1000 |
| | $\leq 349$ | 800 |
| Tuna longliner | $\geq 400$ | 1000 |
| | 200-399 | 750 |
| | 100-199 | 550 |
| | $\leq 99$ | 300 |
| Squid jigger | $\geq 1200$ | 1800 |
| | 900-1199 | 1500 |
| | 500-899 | 1000 |
| | 300-499 | 750 |
| | $\leq 299$ | 600 |
| Pacific saury | $\geq 1400$ | 2200 |
| Large factory trawler | $\geq 7000$ | 8000 |
| | 5000-6999 | 6500 |
| | 3000-4999 | 5500 |
| Double-deck trawler and trawler fishing on high seas | $\geq 1500$ | 3500 |
| | 1000-1499 | 3000 |
| | 700-999 | 2500 |
| | 500-699 | 1800 |
| | 300-499 | 1500 |
| Trawler | $\geq 500$ | 1200 |
| | 300-499 | 1000 |
| | 200-299 | 900 |
| | 100-199 | 600 |
| | $\leq 99$ | 300 |
| Purse seiner | $\geq 1000$ | 1500 |
| | 500-999 | 1200 |
| | 200-499 | 900 |
| | $\leq 199$ | 550 |
| Other vessels | 200-500 | 750 |
| | $\leq 199$ | 550 |

Notes: Large factory trawler includes Antarctic krill fishing and processing vessels. "Other vessels" includes set net, gillnet, baskets, and pots.

# References

Cattaneo, M. D., Jansson, M., & Ma, X. (2021). *rdrobust: Manipulation Testing Based on Density Discontinuity* [R package version 2.2]. https://cran.r-project.org/web/packages/rddensity/rddensity.pdf

Costello, C., Ovando, D., Clavelle, T., Strauss, C. K., Hilborn, R., Melnychuk, M. C., Branch, T. A., Gaines, S. D., Szuwalski, C. S., Cabral, R. B., et al. (2016). Global fishery prospects under contrasting management regimes. *Proceedings of the national academy of sciences*, *113*(18), 5125–5129.