Fueling the Tensions: Examining the Effects of Fuel Subsidy on Chinese Fleets Compliance

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Abstract

In recent years, there has been significant discussion regarding the impacts of input subsidies on the sustainability of marine ecosystems, particularly in terms of promoting overexploitation through the marginal reduction of costs; moreover, Illegal, Unauthorized, and Unreported (IUU) fishing has significant implications for the sustainability of many fisheries worldwide. Using a newly released dataset, I examine the impact of the fuel subsidies provision on fishing activity and unauthorized fishing following a fuel subsidy program reform introduced in 2016 by the Chinese government. The Chinese government has been known for providing a wide variety of subsidies within its economy to bolster its economic position relative to other world economies. In 2016, China introduced a reform to its fuel subsidy program for fishing fleets due to high levels of subsidy expenditure, fuel consumption, and overfishing. By leveraging the discontinuities introduced by the reform, I find that after the reform, the hours of unauthorized fishing increased, particularly in Taiwan and in disputed areas. Vessels that receive a greater amount of subsidies reduce their activity within national waters and increase their operations in foreign waters, potentially leading to overexploitation of fish stocks in international waters and conflicts with neighboring countries over disputed fishing grounds. The results suggest that subsidies decrease the level of compliance among fishermen and encourage IUU fishing.

Key words: Fuel Subsidies, Fisheries Management, Commercial Fishing, Unauthorized Fishing.
JEL Classification: H23,O13,Q22,Q28

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1 Introduction

Input subsidies have been widely used as an instrument for capacity-enhancement across various sectors of the economy (Sumaila et al., 2019). In the fisheries sector, in particular, there has been considerable debate about the implications of subsidies in contributing to the overexploitation of marine resources and the depletion of natural products (Sumaila et al., 2019, 2021, Shen and Chen, 2022). In 2018, approximately 35.4 billion dollars were distributed in subsidies to global fisheries, of which capacity-enhancing subsidies are USD 22.2 billion (Sumaila et al., 2019). This has generated overcapacity leading to overexploitation problems (Sumaila et al., 2010), especially, in scenarios with low controls (Wang et al., 2023).

According to Englander et al. (2023), 16 out of 18 FAO regions are experiencing overfishing, putting the sustainability of marine natural resources at risk. Thus, the World Trade Organization (WTO) has been promoting negotiations to eliminate input subsidies in fisheries to ensure the reduction of overfishing levels, in order to achieve Sustainable Development Goal (SDG) 14.6 (Shen and Chen, 2022). The provision of subsidies is particularly concerning because it enables vessels to fish outside their own countries, venturing into the high seas or the waters of other nations (Englander et al., 2023), generating rents that would not have been possible without the subsidies (Sumaila et al., 2019, Shen and Chen, 2022). Moreover, this creates distortions in national budgets, complicating the management of other fiscal objectives and increasing the opportunity cost for governments and society (Davis, 2014).

This paper examines an additional component in the discussion regarding the implications of subsidies on the sustainability of marine ecosystems, specifically focusing on Illegal, Unreported, and Unregulated (IUU) fishing. IUU fishing not only impacts fish stock levels (Khan et al., 2024) but also affects international relations between countries (Spijkers et al., 2019, Chen et al., 2023). This study addresses this issue by evaluating the impact of fuel subsidies provided to Chinese fishing fleets on fishing activities in the East China Sea, which includes operations in the waters of Taiwan and Japan. China leads the group of countries providing the highest amount of subsidies. In 2018, it allocated USD 7.2 billion, representing 21% of global subsidies, 81% of which are categorized as capacity-enhancing subsidies (Sumaila et al., 2019). Chinese fishing activity has become a global concern due to its immense fishing capacity, which poses a threat to the sustainability of global ecosystems (Englander et al., 2023). Additionally, China's significant involvement in IUU fishing contributes to generating tensions among nations (Tseng and Ou, 2010, Zhang, 2016, Kim, 2019, Watson and Woodill, 2022).

Although recent literature has presented causal evidence on the implications of subsidy provision on fishing capacity (Wang et al., 2023, Shen and Chen, 2022) and overfishing (Englander et al., 2023), there is a lack of causal empirical evidence on the incentives that access to subsidies can generate for unauthorized fishing activity. Unauthorized fishing is understood as fishing activity conducted by a vessel in foreign waters where it does not have an access

agreement. Such practices fall under the concept of environmental injustice, where the provision of subsidies reduces marginal costs and increases the benefits of national fishing fleets at the expense of exploiting the natural resources of other nations. This has been shown to contribute to other social problems such as piracy (Phayal et al., 2024, Mitchell and Schmidt, 2024, Denton and Harris, 2021).

In this article, I use a newly released dataset containing individual-level information on trawler fishing vessels compiled by Wang et al. (2023) from the Marine Fishing Vessel Dynamic Management System of Zhejiang province, which has the largest fishing fleet in the East China Sea. Additionally, I use information from Global Fishing Watch to measure real-time fishing behavior. To characterize the type of fishing according to authorization status, I use data from the Fishing Access Agreements database provided by the Sea Around Us platform. With this information. The objective of this study is to evaluate the effect of the subsidy program reform implemented in China in 2016 on unauthorized fishing activity.

The reform introduced multiple discontinuities in subsidy allocation: one based on vessel size (Wang et al., 2023) and another based on gross tonnage and engine power (Englander et al., 2023). Given the composition of the dataset, the second discontinuity does not allow differentiation between binding and non-binding vessels, so I use the discontinuity introduced by vessel size. Vessels just over 30 meters in length received approximately 19% more in subsidy payments than those under 30 meters.

The redesign of China's subsidy allocation program motivates the implementation of a regression discontinuity model. However, the reform impacted not only the margin around the cutoff but also the continuum of vessels. For some, the subsidy reduction compared to the previous year was much greater, but it decreased for all. Thus, a difference-in-differences (DiD) estimation can capture more information than a regression discontinuity (RD) model, given that RD estimates are local and concentrated around the cutoff point. Considering these factors, I prefer to use a DiD model to obtain more generalizable estimates, differentiating the vessel population by size in accordance with the program's design; comparing vessels over 30 meters with those under 30 meters.

The results suggest that following the reform, vessels receiving higher subsidies, compared to those receiving lesser amounts, increased their fishing efforts in foreign waters while reducing their total fishing hours within Chinese territory. Furthermore, I find that although compliance levels are high in comparison to the global average—95.1% versus 61%, respectively—vessels that receive a greater amount of subsidies report a higher incidence of unauthorized fishing activities, particularly in Taiwanese waters and disputed areas.

This article contributes to the literature by quantifying the relation between fuel subsidy and unauthorized fishing activity. The results highlights the complex interplay between subsidy allocation and fishing behavior, revealing that increased financial support could incentivize illegal practices. The significant rise in fishing efforts in foreign waters may indicate

a strategic shift among subsidized vessels seeking to maximize their operational efficiency and profit margins. Despite relatively high compliance rates, the correlation between subsidy levels and unauthorized fishing underscores the need for enhanced regulatory frameworks and monitoring mechanisms to ensure that financial incentives do not undermine sustainable fishing practices.

The remainder of the article is structured as follows: Section 2 provides a description of the fuel subsidy program reform introduced in China in 2016. Sections 3 and 4 describe the data and the empirical model used, respectively. Finally, Section 5 presents the results, and Section 6 discusses the findings and concludes the article.

2 Background

The East China Sea has long been a region of historical disputes between neighboring countries over sovereignty and the rights to exploit marine resources. Chinese fishermen have increasingly become central figures in maritime conflicts within these contentious regional waters. China's governmental policies and strategies have directly or indirectly influenced the presence of Chinese vessels in disputed territories, thereby contributing to the escalation of tensions between the countries involved (Zhang, 2016). In many instances, China's maritime territorial claims diverge from those recognized under international law (Radio Free Asia, 2024), which partly explains the persistent presence of Chinese vessels in these contested areas.

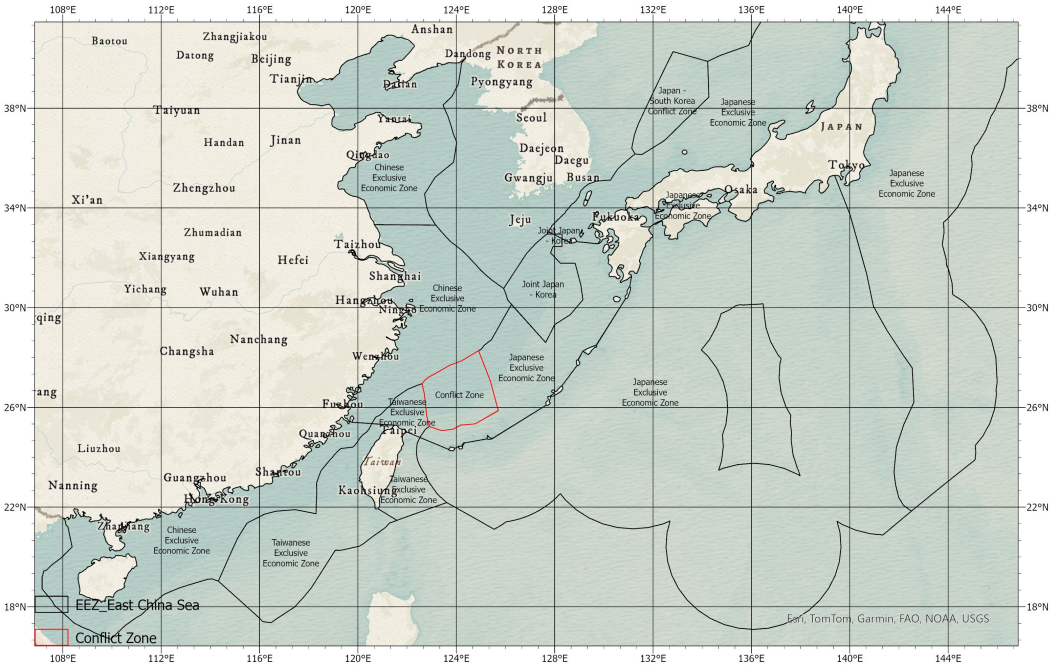


Figure 1. The East China Sea Map.

In recent years, the expansion of Chinese fishing fleets has emerged as one of the primary threats to overexploitation and unauthorized fishing in the waters of the Sea of Japan. Between 2018 and 2020, Chinese vessels were detected, on average, approximately 4,341 times within Japanese territorial waters, with a significant concentration of incidents occurring in the disputed areas around the Diaoyu/Senkaku Islands. One of the main explanations for this trend is that these vessels are often en route to North Korean waters, where fishing agreements and authorizations are in place. This situation underscores the complex geopolitical and environmental challenges posed by the increasing presence of Chinese fishing activities in contested maritime regions (Sato and Chadha, 2022, Reuters, 2024). Another focal point of tension has been the presence of fishing activities in Taiwanese territory, particularly in the territorial waters around Kinmen, which extend approximately halfway to the Chinese coast, or roughly 4 km (2.5 miles) to the north and northwest (Radio Free Asia, 2024). Figure 1 shows the territorial waters of each country.

Regarding the fishing access relationships between China, Taiwan, and Japan, there are currently no formal agreements in place between China and Taiwan or Japan. This absence of agreements can be attributed to the concerns expressed by the Japanese and Taiwanese governments regarding the sustainability of their territorial waters. Additionally, the historical context of relations among these countries has further complicated the possibility of establishing such agreements.

The lack of formal fishing access agreements is significant, particularly considering the ongoing territorial disputes in the East China Sea, where both Taiwan and Japan have established a bilateral fisheries agreement. This agreement, signed on April 10, 2013, allows for reciprocal fishing rights in overlapping exclusive economic zones, thereby isolating China in the context of these maritime disputes. The agreement reflects a strategic approach by Taiwan and Japan to manage their fishing interests while setting aside sovereignty issues to foster cooperation and reduce tensions in the region (The Diplomat, 2018).

The presence of Chinese vessels in these territories is largely explained by their significant overcapacity (Wang et al., 2023) and the policies aimed at strengthening China's food security (Zhang, 2016). These factors have incentivized the expansion and increased prevalence of Chinese fishing activities in many foreign waters. Coupled with the provision of subsidies, this has stimulated greater fishing activity and heightened tensions between countries, particularly when such activities occur outside the framework of international agreements (Zhang, 2016).

3 Institutional and Policy Overview

3.1 Fuel subsidy program reform

China has distinguished itself as one of the nations with the largest fishing fleets in the world. The dynamics of its fishing activities have had a global impact, driven by the high

domestic demand for seafood products. Consequently, for decades, the Chinese government has promoted policies aimed at strengthening its fishing exploitation capacity.

During the 1980s, the Chinese government insulated its economy from fuel price fluctuations through the provision of subsidies. The Chinese Communist Party (CCP) purchased gasoline at high prices and sold it in the domestic market at lower prices. However, by the early 2000s, it began to experience significant budget deficits, which contributed to the decision in 2006 to re-expose the national economy to international fuel prices. This change created a shock in vulnerable sectors, including the fishing sector. Consequently, subsidies were provided only to these more vulnerable sectors according to a series of parameters. Regarding the fishing sector, the allocation of subsidy was based on fuel consumption, gear type, engine power, and vessel size.

In 2016, the CCP decided to reform its fisheries subsidy program in response to international pressures regarding the impacts of subsidies on ecosystem sustainability and in promotion of its new "Ecological Civilization" agenda. Additionally, the program, as it was designed, contributed to high levels of subsidy expenditure, fuel consumption, and overfishing. The reform was primarily based on classifying vessels larger than 12 meters into 12 groups according to their size. Then, based on the vessel's gear type, a subsidy coefficient was assigned that negatively weighted those gear types that were more harmful. Furthermore, the baseline fuel price standard was reduced by 18% per year. The subsidy payment follows the following formula:

$$\begin{aligned} \text{Subsidy} = {} & \text{Baseline Fuel Price Standard} \\ & \times \text{Average Engine Power per Length Class Bin} \\ & \times \text{Revised Subsidy Coefficient} \end{aligned}$$

The reform introduced multiple discontinuities in subsidy allocation: one based on vessel size (Wang et al., 2023) and another based on gross tonnage and engine power (Englander et al., 2023). In terms of vessel size, the subsidy payments decreased for all vessels; however, the decrease was smaller for larger vessels compared to smaller ones (Figure 1).

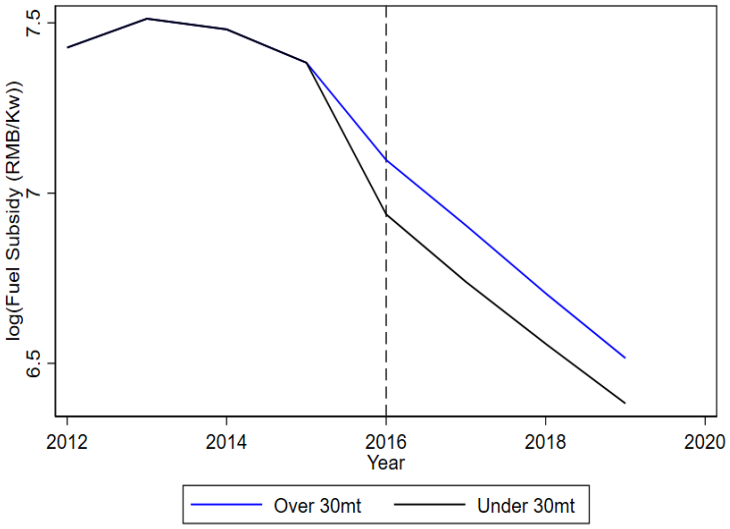


Figure 1. Fuel subsidy payments. Author, using information from Global Fishing Watch and Wang et al. (2023) database.

3.2 Quota management program and Vessel buyback program

The management context of the fishing sector in China is complex, involving the integration of various programs aimed at reconciling economic growth with sustainable sector development. Alongside the subsidy program, since 2002, the Vessel Buyback Program (VBP) has been implemented. This program provides funds to fishermen willing to exit the fishing market and transition to non-fishing activities, coupled with the relinquishment of the power quota granted for vessel operation.

The purpose of the VBP is to remove from the fishing industry those vessels that have a greater impact on the ecosystem, such as trawlers. This program is grounded in the Quota Management Program for fishing power, which operates in conjunction with the Licensing System. Under this system, each vessel must annually undergo registration, inspection, and management with the Ministry of Agriculture to obtain a fishing license. The Licensing System was introduced as a tool to curb the disproportionate growth in the number of vessels. New vessels could only be constructed by acquiring the licenses of outgoing vessels, thus creating a market for licenses. These programs collectively aim to achieve "negative growth."

Despite the CCP's efforts to control the environmental impacts of the fishing fleet size, these measures had limited effects due to the coexistence and poor design of the subsidy program, which encouraged fishermen to remain in the market. This situation changed with the 2016 reform. Savings from the redesign of the subsidy program allowed for an increase in the bonuses granted through the VBP, this increase was more significant in the province of Zhejiang as part of its own objective to reduce the size of its fishing fleet (Wang et al.,

2023), contributing to the reduction of the fishing fleet's capacity through subsidy reductions. Given the structure and combination of the programs, trawler-type vessels were immediately impacted, as they were the primary target of the program due to their harmful nature (Figure 2).

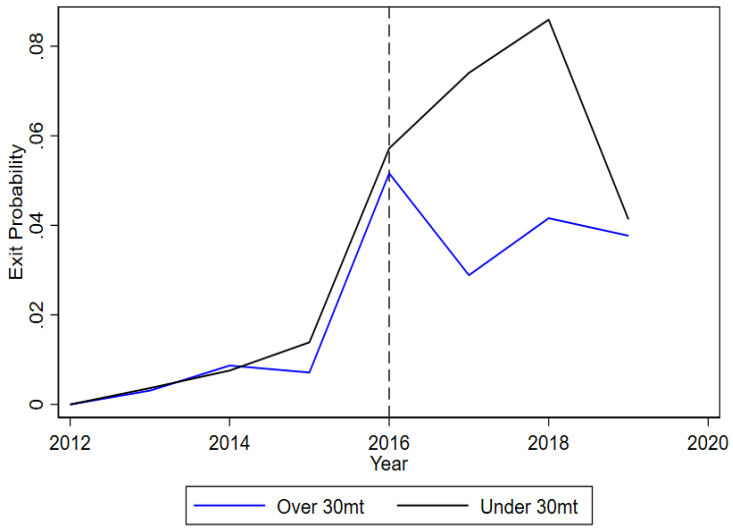


Figure 2. Exit probability. Author, using information from Global Fishing Watch and Wang et al. (2023) database.

Thus, the Chinese case represents a valuable opportunity to evaluate how fishing incentives and decisions are affected by changes in subsidy provision and opportunity costs, as measured by the offer of exit bonuses from the fishing market. This scenario also allows for an assessment of the impact on the dynamics of unauthorized fishing activities. By removing incentives in fishing such as those associated with subsidies, it would be expected that levels of overcapacity (Wang et al., 2023), overexploitation (Englander et al., 2023) and the level of IUU fishing could be reduced.

4 Data

4.1 Descriptive and Sources

To examine the relationship between access to fuel subsidies for industrial fishing vessels and fishing activity, I utilize data from two primary sources: i) a newly released database compiled by Wang et al. (2023) that contains individual-level administrative data on fishing vessels registered in the Marine Fishing Vessel Dynamic Management System of the Zhejiang provincial government. This administrative platform comprises five modules corresponding

to each section of the vessel management activities: engine power quota, vessel name, vessel inspection, vessel registration, and fishing license; and ii) data from Global Fishing Watch (GFW), which provides information on the number of fishing hours conducted by each vessel at a resolution of 0.01 degrees per pixel on a daily basis.

The database from Wang et al. (2023) contains reports from 7,592 vessels constructed between 1988 and 2011. A total of 3,354 vessels, representing 44% of the sample, were successfully matched with GFW data.

Table 1: *Summary Statistics of the main outcome variables*

	Min	**25%**	**50%**	**Mean**	**75%**	**Max**	**Obs**
Total fishing hours	0	0	0	1.25	1.03	45.39	5,074.669
Total fishing hours (Without 0)	0.00	0.93	2.07	3.63	4.57	45.39	1,752,117
Authorized fishing hours	0	0	0	1.31	1.15	45.39	4,827.774
Authorized fishing hours (without 0)	0.00	0.93	2.07	3.63	4.57	45.39	1,737,173
Unauthorized fishing hours	0	0	0	0.25	0	39.06	246,895
Unauthorized fishing hours (without 0)	0.00	0.70	2.03	4.16	5.30	39.06	14,944
Fuel subsidies (RMB/kW)	331	958.75	1608.48	1375.27	1774.08	1830.72	5,074,669
Authorization status	0	-	-	95.1%	-	1	5,074,669
Exit Probability	0	-	-	2.25%	-	1	5,074.669

Note: Fishing hours are presented as total hours per pixel/day. Fuel subsidies are expressed as the annual payment in Chinese Yuan (RMB) per Power (KW). Each pixel has a resolution of 0.01 degrees, approximately 1km x 1km.

4.2 Summary of Data

The resulting database comprises fishing activity in hours per day/pixel for 3,354 trawler vessels from Zhejiang province in China for the period 2012-2019. The database also includes the characteristics of the vessels, records of the fuel subsidy payments received, and records of exits through the vessel buyback program.

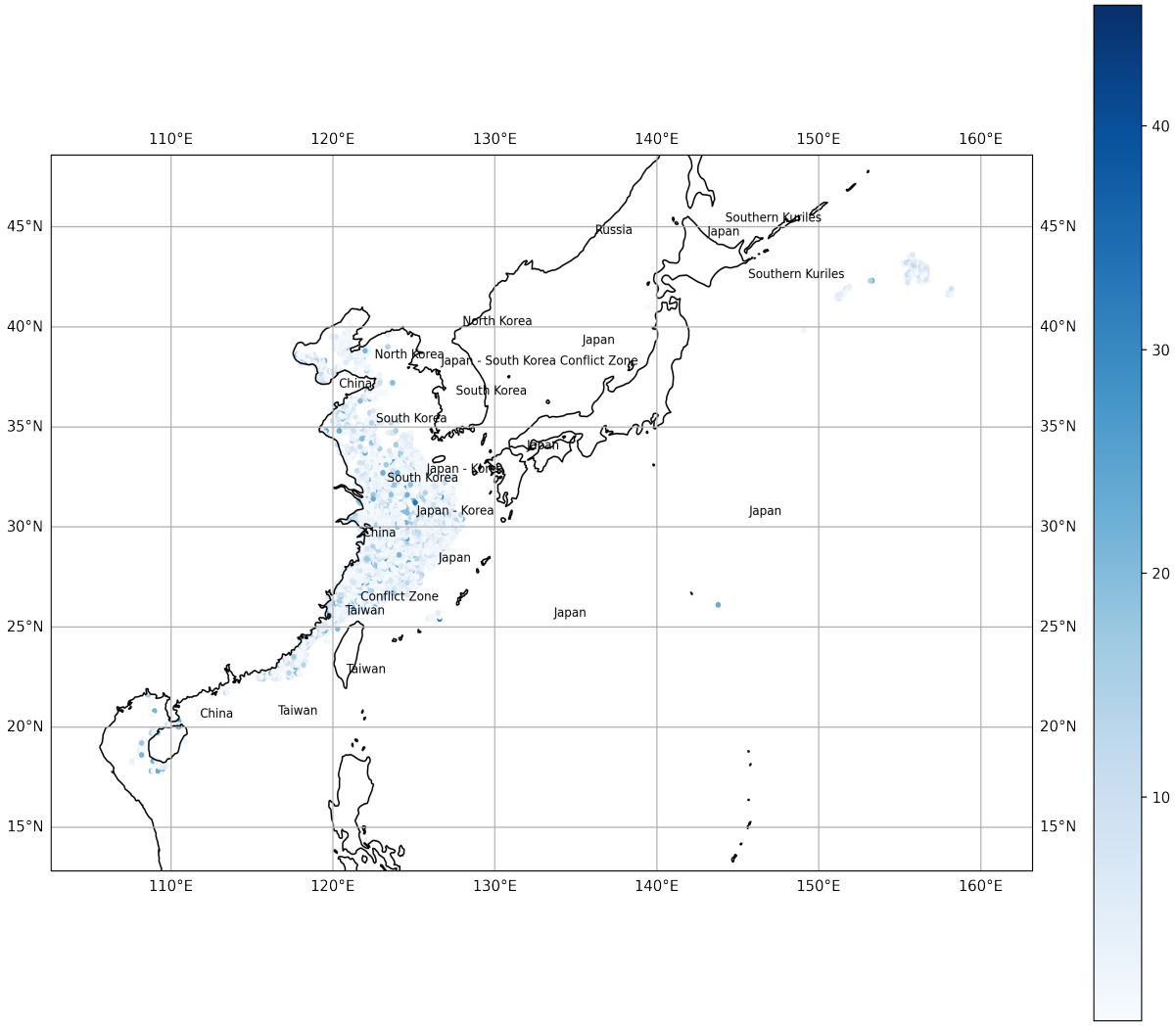


Figure 3. Coverage of Chinese Trawler Vessel's Fishing activity. Author, using information from Global Fishing Watch and Wang et al. (2023) database. Each pixel has a resolution of 0.01 degrees, approximately 1km x 1km.

The descriptive statistics for the outcome variables are presented in Table 1. On average, vessels spend 1.25 hours/day/pixel on fishing activities (3.63 hours/day/pixel for positive fishing hours). In terms of authorization status, vessels average 1.31 hours/day/pixel in authorized fishing and 0.25 hours/day/pixel in unauthorized fishing. For positive fishing hours, the averages are 3.63 and 4.16 hours/day/pixel, respectively. No-positive fishing hours refers to the pixels where fishing vessels passed through but did not engage in any fishing activity. This indicates the transit from one fishing location to another.

Figure 3 illustrates the extent of the fishing activity of the vessels in the database, along the eastern coast of China. For positive fishing hours, vessels fished an average of 3.67

hours/day/pixel in national territory, 4.90 hours/day/pixel in Taiwanese territory, 4.57 hours in the joint regime area between Japan and Korea, 3.70 hours in disputed zones, and 3.67 hours in Japanese territory (Table 2). Figure A2 shows the distribution of vessel length.

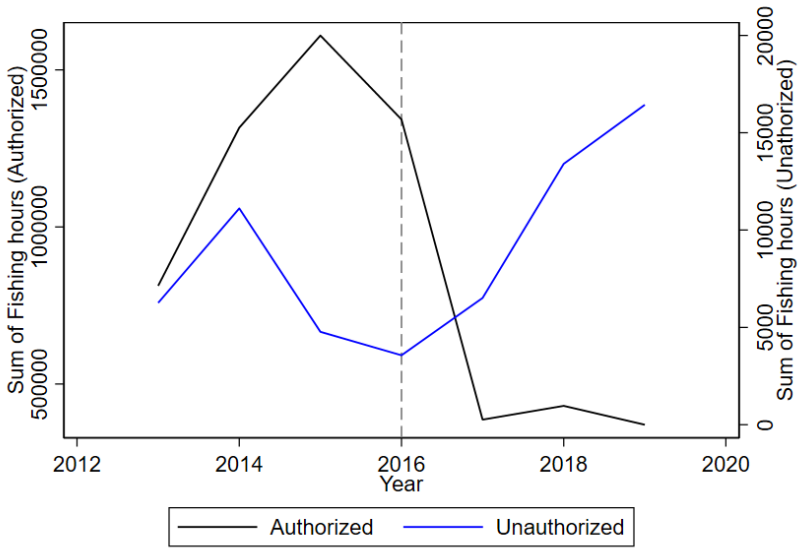
Table 2: *Chinese Fishing Activity by Countries and Sovereign*

Country	**Sovereign**	**Agreements**	**Fishing Hours**		
			Obs	**Mean**	**SD**
China	China	-	1.466.579	3.67	4.28
South Korea	South Korea	Yes	1.107	3.95	4.87
Taiwan	Taiwan	No	2.872	4.90	5.46
Conflict Zone	Disputed	No	2.111	3.70	4.60
Japan - Korea	Joint Regime	No	1.198	4.57	5.87
Japan	Japan	No	525	3.97	4.63

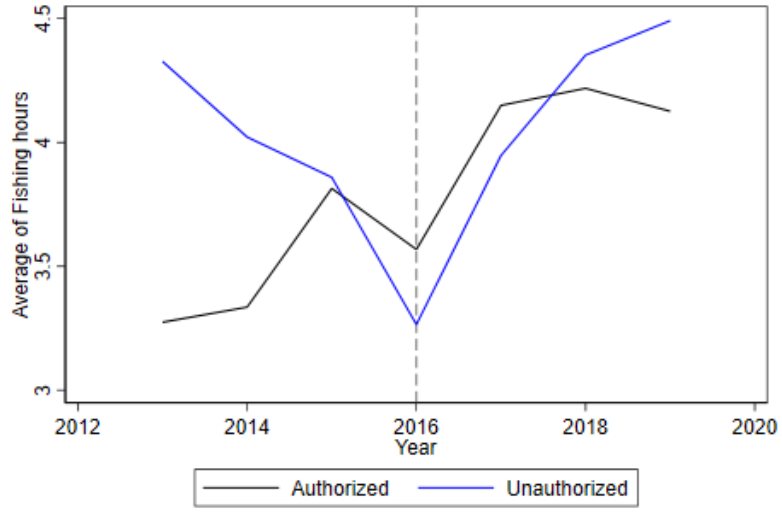
Note: The agreements were defined according to the internal fishing access agreements dataset from Sea Around Us. The existence of an agreement is determined by whether a formal agreement was signed between the parties for the years under analysis.

Regarding the authorization status of fishing activity I use the Sea Around Us (SAU) fishing access agreements database. Fishing activity will be considered authorized if there is a formal fishing agreement between the parties. This is because the SAU database contains vessel detection information based on Global Fishing Watch data, necessitating a distinction between the types of access contained in the database used. Table A2 shows the fishing agreements that China had during the analysis period[1]. Figure 4 shows the evolution of fishing according to its type of authorization for the years 2012-2019. Panel (a) displays the total sum of fishing hours/day/pixel, indicating that vessels engaged in more authorized fishing hours before the subsidy program reform in 2016, but this trend reversed post-reform. Similarly, panel (b) presents the average fishing hours/day/pixel, showing similar pattern.

[1]For agreements with unspecified end year, I assume that the agreement is still valid, which biases the authorization status towards authorized rather than unauthorized, therefore, the results obtained could be interpreted as a lower bound



(a) *Total Fishing Efforts*

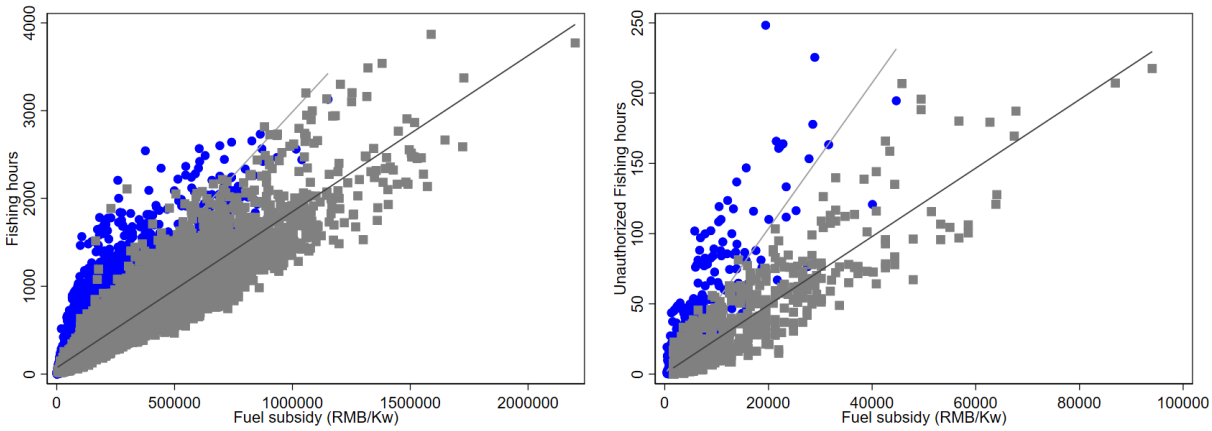


(b) *Average Fishing Efforts*

Figure 4: Fishing Efforts by authorization status. Note: Panel (a) shows the total fishing efforts for authorized and unauthorized fishing, and panel (b) shows the average total fishing efforts.

The hypothesis to be evaluated in this paper is linked to the role of access to subsidies as an incentive for increased development of fishing activity, greater capacity to fish in foreign waters, and in turn, increased development of unauthorized fishing activity. Figure 5 depicts the relationship between the number of fishing hours and payments for fuel subsidies before and after the reform. It is observed that after the reform, for each RMB/Kw received as

part of the subsidy, vessels engaged in a greater number of fishing hours compared to activity levels before the reform, with the same trend observed for unauthorized fishing hours. This result is explained by the lower access, in general, to subsidies for all vessels after the reform compared to the records before the reform, as will be further detailed later on.



(a) *Total Fishing Efforts* ***(b)*** *Unauthorized Fishing Efforts*

Figure 5. The relationship between fishing efforts and fuel subsidy payments before and after reform. Note: The figure show in blue the total and unauthorized fishing efforts after reform; and the results before reform are displayed in gray.

Difference in unauthorized fishing hours between vessels smaller and larger than 30 meters increases in favor of larger vessels after the reform (Figure 6). Figure A3 shows unauthorized fishing hours by countries. Particularly in Taiwan, smaller vessels exhibited higher levels of activity before the reform. However, following the reform, this relationship reversed, with the gap becoming more pronounced. These fact suggests the need to evaluate this relationship in greater detail.

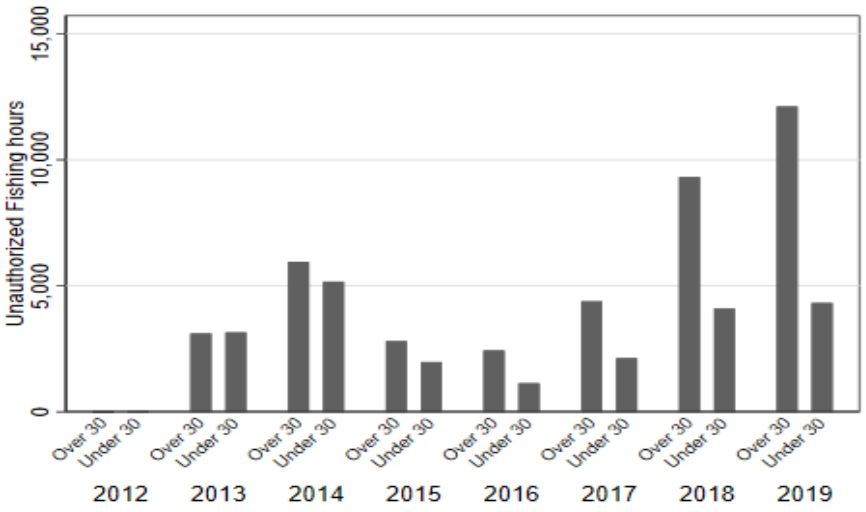


Figure 6. Total Unauthorized Fishing Efforts by vessel length over years. Author, using information from Global Fishing Watch and Wang et al. (2023) database.

5 Empirical Model

To estimate the effect of subsidy allocation on fishing activity and the number of unauthorized fishing hours, I use a main specification of Difference-in-Differences (DiD) design according to the following specification:

$$y_{izt} = \alpha_1 D_i + \alpha_2 Post_{t_y} + \beta D_i \times Post_{t_y} + \gamma_i + \phi_z + \rho_t + \epsilon_{izt} \tag{1}$$

Where y is the outcome variable of fishing efforts for vessel i at pixel z on the day t. The variable $D_i = \mathbb{1}\{\text{Vessel Length} \geq 30\}$ indicates whether the vessel has a length greater than 30 meters. This is an arbitrary threshold chosen based on the evaluation of subsidy access distribution by vessel size. $Post_{t_y}$ takes the value of 1 from year $t_y = 2016$,when the subsidy program reform was implemented, and 0 otherwise. The variables γ_i, ϕ_z y ρ_t represent vessel fixed effects, pixel fixed effects, and time fixed effects, respectively. The coefficient of interest is β which captures the effect of the reform to the fuel subsidy program by large vessels.

To avoid potential bias from manipulation of the treatment assignment rule, the database consists of vessels built before 2012. Given this, and considering that D_i is a characteristic that does not vary over time in the analysis period, there is no reason to believe that D_i is correlated with unobserved factors that determine the outcome variable. Therefore, it is not necessary to include additional covariates.

Taking into account the distribution of vessels by size, the regressions are estimated for vessels around the 30-meter threshold. As the main estimation, the regressions are conducted for vessels between 25 and 35 meters. After the reform, vessels larger than 30 meters received

approximately 19% more subsidy payments compared to vessels smaller than 30 meters.

Building on equation (1), I made the following change: similar to Wang et al. (2023), I replaced $\beta D_i \times Post_{t_y}$ with $\beta_j D_i \times Post^j_{t_y}$ for $j = 2012, ..., 2019$, where $Post^j_{t_y} = \mathbb{1}\{t = j\}$. This allows me to obtain the treatment effect over the years, thus conducting an event study that shows the effect of the subsidy program reform over time. To ensure the correct estimation of the causal effect of the change in subsidy access on unauthorized fishing activity using the difference-in-differences method, it is necessary to satisfy the following assumptions: i) *No anticipation*. This refers to the assumption that fishermen did not have the opportunity to adjust vessel characteristics to take advantage of the treatment assignment rule. To prevent any bias, only vessels built before 2012 are considered. ii) *Parallel trends*. This assumption presupposes that the fishing behavior of vessels that had access to more subsidies and those that had access to fewer subsidies follows parallel trends before the reform. Graphical representations of this assumption are presented in the Figure A1.

6 Results

6.1 Main findings

Table 3 presents the results of the impact of the reform of the fuel subsidy program on fishing activity variables. It is observed that on average, after the reform, vessels larger than 30 meters experienced a decrease of 1.3% in the total number of fishing hours compared to fishing conducted before the reform and by smaller vessels. Similarly, it is observed that these vessels decreased the total hours of fishing in national waters by 1.4% and increased fishing activity in foreign waters and high seas by 5%.

Table 3: *Average treatment effect of fuel subsidy program reform on fishing activity*

	Total fishing hours		National fishing hours		Fishing hours in foreign waters	
	(1)	(2)	(3)	(4)	(5)	(6)
1.Treated*1.Post	-0.034***	-0.013***	-0.0363***	-0.014***	0.036***	0.005**
	(0.001)	(0.001)	(0.002)	(0.002)	(0.003)	(0.003)
FE	No	Yes	No	Yes	No	Yes
Mean$_{<2016}$ Log(y_{izt})	0.48	0.48	0.49	0.49	0.07	0.07
N Treated	598.302	598.302	546.096	546.096	52.206	52.206
N Control	470.168	470.168	433.061	433.061	37.107	37.107
Observations	4,300,681	4,300.602	4,092,151	4,092,146	208.530	208.348

Note: The outcome variables are expressed in log. Vessel, year, month and pixel FE are included.

When looking at where these increases in fishing in foreign waters occurred, it is observed

that fishing hours in countries without a fishing access agreement increased by 12.8% (Table 4). Following the reform, fishing activity by larger vessels began to migrate from national territory to foreign territory, explained by lower relative marginal costs due to access to subsidies. This increased foreign activity manifested in a significant increase in unauthorized fishing activity. Table A1 presents the results of the placebo test for periods prior to the reform. No significant effects are found[2] that would suggest the results in Table 4 are biased by factors preceding the subsidy program reform.

Table 4: *Average treatment effect of fuel subsidy program reform on unauthorized fishing activity*

	Unauthorized fishing hours (*log*)			
	(1)	(2)	(3)	(4)
1.Treated*1.Post	-0.005	0.189**	0.156**	0.128**
	(0.04)	(0.06)	(0.06)	(0.07)
FE	No	*i*	*i,t*	*i,t,z*
Mean$_{<2016}$ Log(y_{izt})	0.99	0.99	0.99	0.99
N Treated	1.842	1.842	1.842	1.842
N Control	983	983	983	983
Observations	8.812	8.725	8.725	8.681

Note: The outcome variables are expressed in log. Vessel, year, month and pixel FE are included.

The effect of the reform on unauthorized fishing activity was consistent over time and intensified as the years passed. Figure 7 presents the estimates from equation (1) relative to the year of the reform. It can be observed that the number of unauthorized fishing hours increased from the first year, but it became significant from the year 2017 onwards, remaining so in the year 2019, before the pandemic. Figure A4 presents event study results for Taiwan, Japan and Disputed zones. It is observed that the increase in unauthorized fishing activity occurs primarily in disputed zones and in Taiwan.

[2]With the exception of Post > 2013, although this effect disappears when fixed effects are considered.

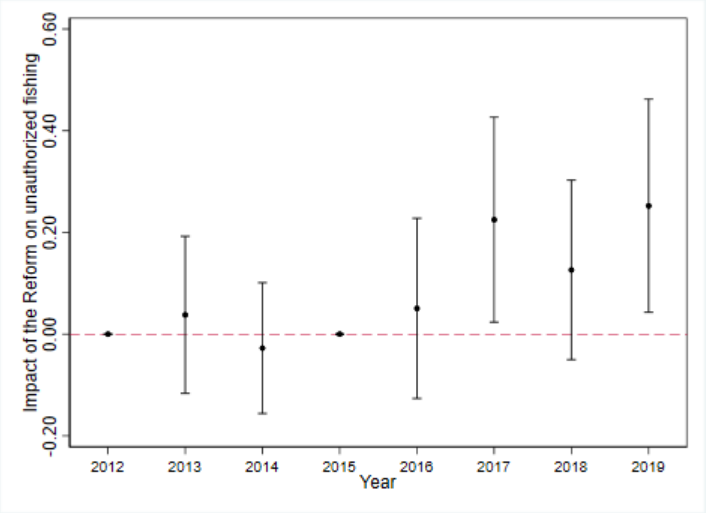
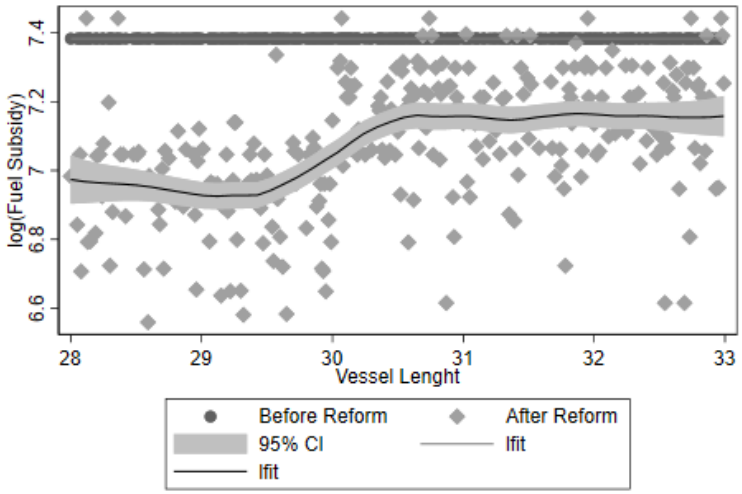


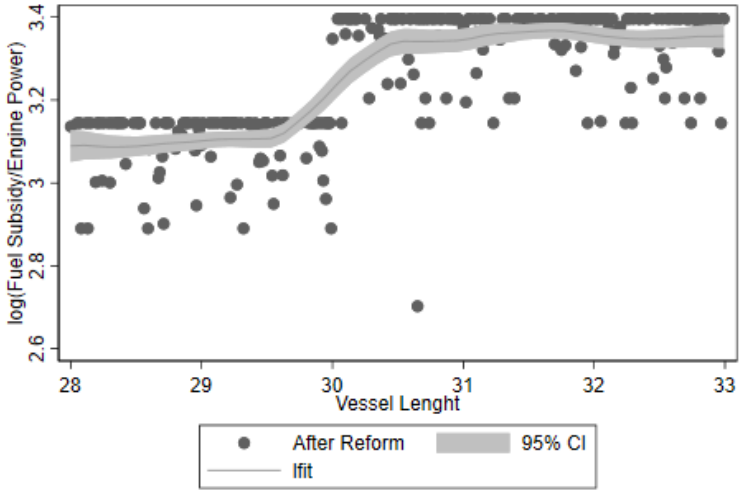
Figure 7: Event study of fuel subsidy program reform effect on unauthorized fishing hours. Note: The vertical bars indicate the confidence intervals at 10%.

6.2 Mechanism

The key factor explaining the findings is access to fuel subsidies, which contributes to vessels conducting a greater number of fishing hours and also incentives them to engage in unauthorized fishing activity due to lower opportunity costs.



(a) *Fuel Subsidy Access in 2015-2016*



(b) *Fuel Subsidy Access in 2016*

Figure 8. The relationship of Fuel subsidy payments per KW and vessel length in 2015 and 2016. Note: Panel (a) shows the total fuel subsidy payments before and after reform, and panel (b) shows the total fuel subsidy payments per Kw of engine power after reform.

Figure 8 depicts the payments for fuel subsidies made before and after the reform. In panel (a), it is observed that before the reform, vessels received the same payments regardless of size, whereas after the reform was introduced, the total subsidies decreased, more pronounced for vessels smaller than 30 meters (panel b). Table 5 displays the effect of the reform on subsidy access and the probability of exiting the fishing market. It is observed that after the reform, vessels larger than 30 meters received 15.8% more subsidies than vessels below 30 meters,

and furthermore, larger vessels had a 2.5% lower probability of exiting the market. This is consistent with the results presented by Wang et al. (2023).

These results suggest that given the increased access to subsidies, vessels had a lower marginal cost of fishing, which allowed them to engage in fishing activities over longer distances. As a result, fishing hours in foreign waters increased, aligning with the findings of Englander et al. (2023). Additionally, unauthorized fishing activity increased due to lower relative opportunity costs.

Table 5: *Average treatment effect of fuel subsidy program reform on fuel subsidy access and exit probability*

	Fuel subsidy (*log*)		Exit Probability	
	(1)	(2)	(3)	(4)
1.Treated*1.Post	0.141***	0.158***	-0.018***	-0.025***
	(0.0004)	(0.0003)	(0.0003)	(0.0004)
FE	No	Yes	No	Yes
Mean$_{<2016}$ Log(y_{izt})	7.45	7.45	0.009	0.009
N Treated	598.302	598.302	598.302	598.302
N Control	470.168	470.168	470.168	470.168
Observations	4,300,681	4,300.602	4,300,681	4,300.602

Note: The outcome variables in columns (1)-(2) are expressed in log. Vessel, year, month and pixel controls are included.

6.3 Elasticity of unauthorized fishing with respect to fuel subsidy

Despite the results presented in Table 4, we observe that the response of vessels engaging in unauthorized fishing activity is inelastic to the provision of subsidies. Following the approach of Englander et al. (2023), I compare the effect of the reform on fishing efforts with the effect on the amount of subsidy received and find that for both authorized and unauthorized fishing activities, elasticity is less than 1 (Table 6). This suggests that, on average, changes in the amount of subsidy will not result in a proportional response in the number of fishing hours. In the case of unauthorized fishing, this may be explained by the fact that other important factors influencing fishermen's decision-making regarding illegal activities, such as the probability of being caught, which play a significant role in their risk aversion.

Table 6: *Estimated Elasticities of Fishing Hours with Respect to Subsidy Received*

	Unauthorized fishing hours (*log*)			Authorized fishing hours (*log*)		
	RF	FS	Elasticity	RF	FS	Elasticity
	(1)	(2)	(3)	(4)	(5)	(6)
1.Treated*1.Post	0.149**	0.165***	0.90	-0.012***	0.158***	-0.076
	(0.063)	(0.006)		(0.001)	(0.0002)	
FE	Yes	Yes		Yes	Yes	
Observations	10.079	10.079	10.079	4.300.602	4.300.602	4.300.602

Note: The outcome variables are expressed in log. Vessel, year, month and pixel FE are included. Following Englander et al. (2023), RF (reduced form) is the effect of the policy on log fishing hours; FS (fisrt stage) is the effect of the policy on log fuel subsidy received, and elasticity is the reduced form divided by the first stage.

7 Conclusion

This article examines the impact of subsidies provided to Chinese fishing vessels on unauthorized fishing activities, specifically assessing the level of compliance among Chinese fishermen with international fishing regulations. To achieve this, the study analyzes the effects of the 2016 reform of China's gasoline subsidy program and distinguishes between vessels operating in domestic waters and those in foreign waters. Furthermore, it differentiates between vessels fishing in countries with fishing access agreements and those without, with the latter considered unauthorized fishing activities, as defined by the FAO (2023) as illegal fishing. In this study, I propose a causal inference model that leverages the discontinuity based on vessel size and temporal differences imposed by the reforms. This model allows me to estimate the impact of increased access to subsidies on the decisions of industrial fishermen to engage in fishing activities in international waters of countries where the Chinese government lacks a fishing access agreement.

The results suggest that vessels receiving larger subsidies, compared to those receiving smaller amounts, increase their fishing efforts in foreign waters while reducing their activities within national territory. This outcome is associated with the finding that access to subsidies enables vessels to undertake longer fishing expeditions and travel greater distances (Englander et al., 2023). After the reform, vessels that received larger subsidies increased their unauthorized fishing activities, particularly in Taiwanese waters and disputed areas, which may have escalated tensions between the involved countries, as evidenced by recent news reports.[3] Despite these findings, the elasticity of unauthorized fishing hours to changes in the amount

[3]See: https://www.rfa.org/english/news/southchinasea/china-kinmen-intrusion-05102024034553.html and https://www.spf.org/iina/en/articles/furuya_02.html

of fuel subsidies is found to be inelastic. This could be explained by the fact that other important factors influencing fishermen's decision-making regarding illegal activities, such as the probability of being caught, among others, also play a significant role in their risk aversion.

One limitation of this study is related to the measurement of the fishing effort variable, which is reported by GFW as a prediction and serves as a proxy for the apparent number of fishing hours, and is linked to the detection of fishing vessels. We only consider vessels that can be publicly tracked via the Automatic Identification System (AIS), enabling the identification and origin of the vessels. Consequently, the results presented here represent a lower bound estimate, as it is possible that vessels may turn off their transmitters and locators to avoid detection when engaging in unauthorized activities, in addition to altering the transmitter to report a different location than the actual one (Paolo et al., 2024). Regarding location alteration, GFW manages this error by cross-referencing different data sources, which allows for a more accurate measure of the actual location where fishing activities occur. Another limitation concerns the use of the database compiled by Wang et al. (2023), which, being derived from administrative data within the subsidy program, has a low probability of detecting unauthorized fishing, given that participation in the program is contingent upon fishermen's compliance with regulations. Fishermen involved in unauthorized practices would be excluded from the program.

Overall, this article suggests that fishermen, in one way or another, exploit favorable cost conditions to maximize their benefits. In this case, we observe that they take advantage of their increased fishing capacity, granted by access to subsidies, to engage in more extensive fishing activities, including unauthorized fishing. This finding contributes to the discussion on the implications of providing subsidies for inputs, which has been shown to threaten the sustainability of ecosystems by increasing fishing efforts, traveling greater distances, and now, increasing IUU fishing.

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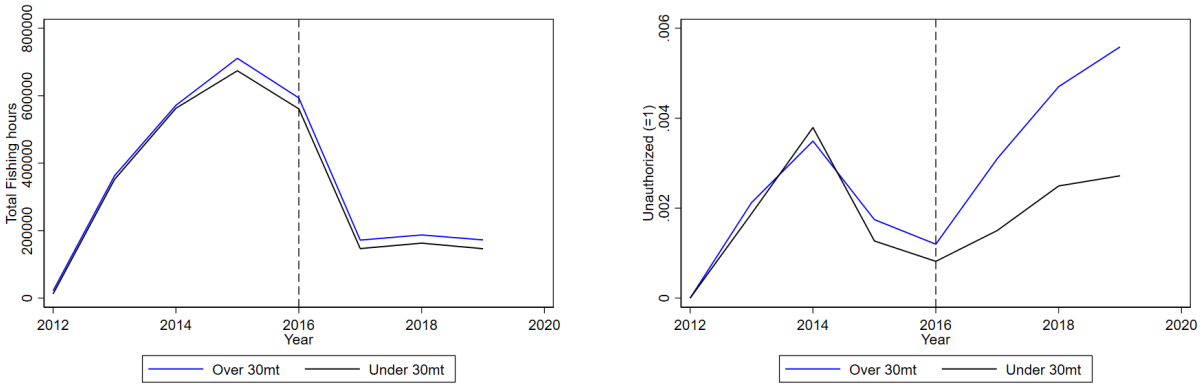
Appendix

A Additional Figures and Tables



(a) *Total Fishing Efforts* ***(b)*** *Unauthorized Fishing Status*

Figure A1: Parallel Trend. Note: Panel (a) shows the total fishing efforts by treatment, and panel (b) shows the unauthorized probability.

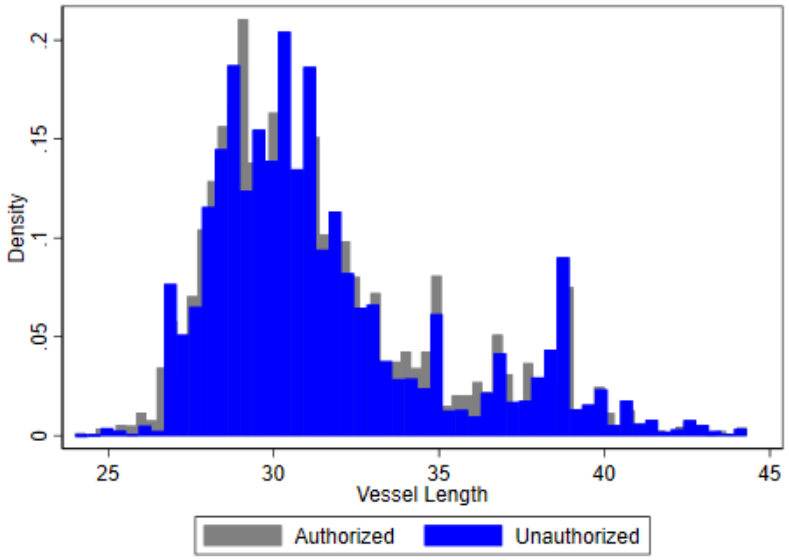
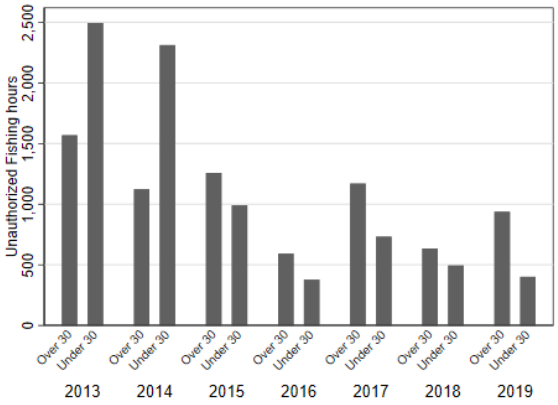
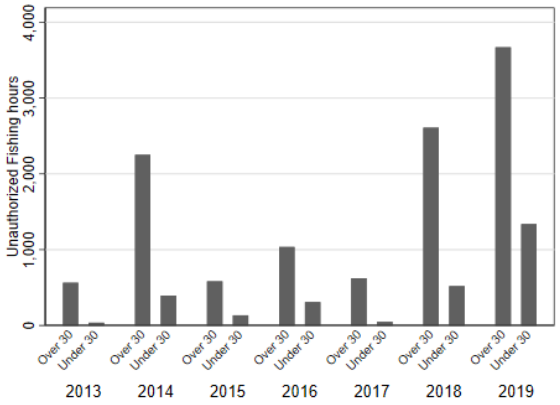


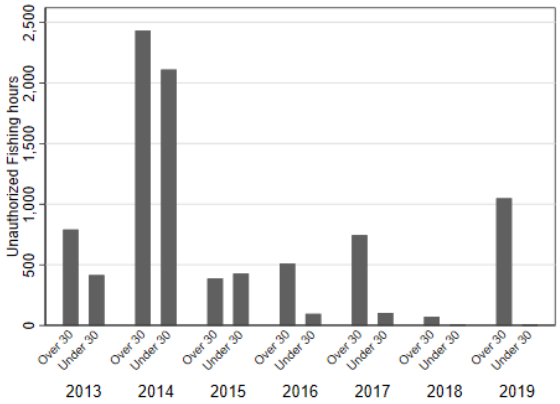
Figure A2: Distribution of Vessel Length.



(a) Taiwan

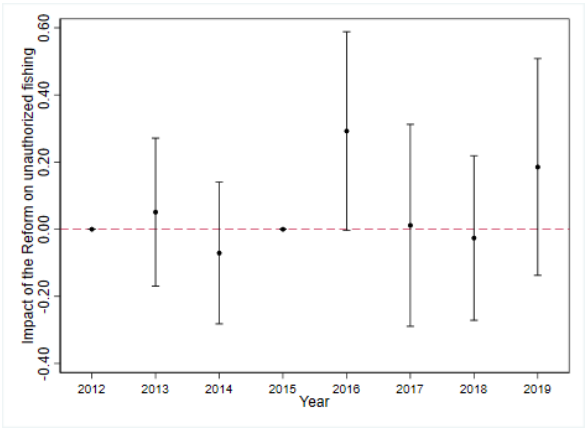


(b) Japan

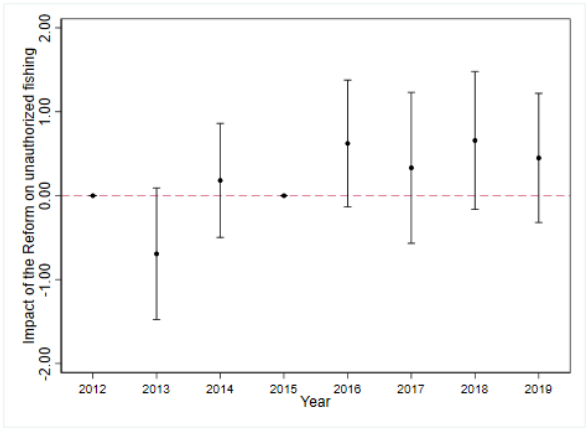


(c) Conflict Zone

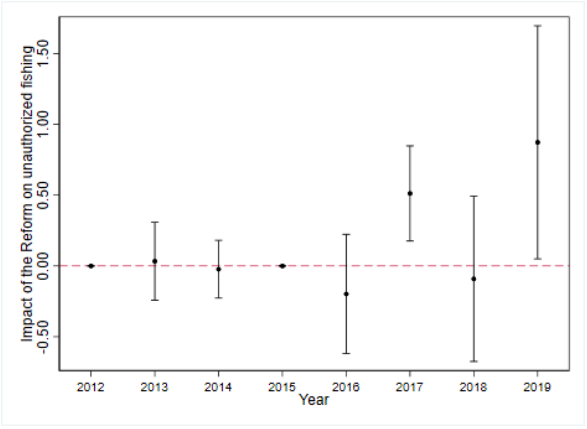
Figure A3: Total unauthorized fishing hours by vessel length over years. Note: Panel (a) shows the total chinese unauthorized fishing efforts in Taiwan, panel (b) shows the unauthorized fishing hours in Japan, and panel (c) shows the activity in Conflict zones.



(a) Taiwan



(b) Japan



(c) Conflict Zone

Figure A4: Event study of fuel subsidy program reform effect on unauthorized fishing hours by countries. Note: Panel (a) shows the effects in Taiwan, panel (b) shows the effect in Japan, and panel (c) shows the effects in Conflict zones. The vertical bars indicate the confidence intervals at 10%.

***Table A1**: Pre-Period Placebo Test*

	Unauthorized fishing hours (*log*)					
	Post > 2014		Post > 2015		Post > 2013	
	(1)	(2)	(3)	(4)	(5)	(6)
1.Treated*1.Post	0.031	-0.077	0.092	0.092	-0.010*	0.017
	(0.049)	(0.070)	(0.059)	(0.086)	(0.058)	(0.083)
FE	No	Yes	No	Yes	No	Yes
N Treated	2.931	2.931	2.302	2.302	4.204	4.204
N Control	1.799	1.799	1.245	1.245	3.200	3.200
Observations	5.265	5.162	5.265	5.162	5.543	5.162

Note: The outcome variables are expressed in log. Vessel, year, month and pixel FE are included.

***Table A2**: Chinese Internal Fishing Access Agreements*

Country Owned	Country Access	Start year	End year
Angola	China	2016	9999
Argentina	China	2020	2020
Benin	China	2015	9999
Cameroon	China	2018	9999
Côte d'Ivoire	China	2015	9999
Equatorial Guinea	China	2018	9999
Fiji	China	2018	2021
French Polynesia	China	2014	2019
Ghana	China	2019	9999
Guinea	China	2018	9999
Guinea-Bissau	China	2017	9999
Guyana	China	1996	9999
Liberia	China	2018	9999
Madagascar	China	2019	2021
Micronesia (Federated States of)	China	2020	2020
Mozambique	China	2018	2019
Nauru	China	2020	2020
Nigeria	China	2018	9999
Oman	China	2018	2019
Palau	China	2018	2019
Papua New Guinea	China	2016	2019
Peru	China	2010	2018
Senegal	China	2017	9999
Seychelles	China	2017	9999
Sierra Leone	China	2018	9999
Singapore	China	2017	2019
Somalia	China	2015	2019
Suriname	China	2018	2019
South Korea	China	2001	2019
Togo	China	2013	9999
Tuvalu	China	2020	2020
Uruguay	China	2018	2019
Vanuatu	China	2020	2020
Viet Nam	China	2017	2019
Angola	China	2016	9999
Argentina	China	2020	2020
Benin	China	2015	9999
Cameroon	China	2018	9999
Côte d'Ivoire	China	2015	9999
Equatorial Guinea	China	2018	9999
Fiji	China	2018	2021
Ghana	China	2019	9999
Guinea	China	2018	9999
Guinea-Bissau	China	2017	9999
Guyana	China	1996	9999
Liberia	China	2018	9999
Madagascar	China	2019	2021
Micronesia (Federated States of)	China	2020	2020
Nauru	China	2020	2020
Nigeria	China	2018	9999
Peru	China	2016	9999
Senegal	China	2017	9999
Seychelles	China	2017	9999
Sierra Leone	China	2018	9999
Togo	China	2013	9999
Tuvalu	China	2020	2020
Vanuatu	China	2020	2020

Source: Internal Fishing Access Agreements - Sea Around Us. Note: Country owned relates the countries with which China has had fishing access agreements. Values of 9999 in End year indicate that there is no specified termination date for the agreement.