Journal of Government and Economics 13 (2024) 100105

Contents lists available at ScienceDirect

Journal of Government and Economics

journal homepage: www.journals.elsevier.com/journal-of-government-and-economics

Safety effects of property rights contract changes: Evidence from field experience in fisheries[☆]

Akbar Marvasti

U.S. Department of Commerce, Southeast Fisheries Science Center, NOAA, 75 Virginia Beach Dr., Miami, FL 33149, United States

ARTICLE INFO

JEL classification:
J28
K20
Q20

Keywords:
Contract change
Occupational injuries
Difference-in-difference

ABSTRACT

I measure the effect of contract changes on selected fishery resources in the Gulf of Mexico (GoM). I apply the difference-in-difference approach to commercial fishery panel data. My cross-sectional units use the red snapper and grouper-tilefish fisheries in the GoM as treatment groups and the fisheries from same group of species in the U.S. South Atlantic (SA) as the control group. The results show that the grouper-tilefish individual fishing quota has improved commercial fishing safety in the GoM. The modest effect from the red snapper individual fishing quota program seems to be due to interrelatedness and economies of scope stemming from the multispecies nature of the reef fish fishery in the GoM.

1. Introduction

Recent time-series analyses have addressed improvements in commercial fishing safety in response to changes in fishery management regulations in the Gulf of Mexico (GoM), which is essentially a contract change. The contract in question privatized the use of common-property fishery resources. This paper presents new evidence that fishery management regulation can help reduce the rate of injury in commercial fisheries and that the magnitude of the impact depends on the expansion of the regulatory change. I use the difference-in-difference (DiD) approach in the design of a quasi-experimental study of occupational injuries that compares the outcomes of two fishery groups exposed to different management policies at different times.

Commercial fishing is by far the most dangerous industry in the U.S., with an average fatality rate of 132.1 per 100,000 full-time equivalent workers in 2020, compared to 97.1 for logging (Bureau of Labor Statistics, 2022). While working conditions, long and laborious hours, and harsh weather conditions are among the major contributing factors, fishery regulations such as quotas and seasonal closures also affect fishermen's risk-taking behavior and thus their accident propensity. A few studies have addressed the issue of commercial fishing safety. For example, Bergland and Pedersen (1997) use a theoretical model to examine the interaction between safety and fishery regulations and explore the moral hazard effects of public safety measures. Other studies of the fishing industry have addressed commercial fishermen's attitude towards risk and have generally found them to be risk-averse despite their chosen occupation (e.g., Bockstael and Opaluch, 1983; Mistiaen and Strand, 2000; Eggert and Martinsson, 2004; Smith and Wilen, 2005; Schnier et al., 2009).

Common property in fisheries is associated with several undesirable, inefficient outcomes including overcapitalization, decreasing total catches, and declining income for fishermen (Gordon, 1954; Cheung, 1970). Some management tools to prevent the extinction of fish species, like quota reductions and shortened seasons, have led to deterioration in safety in this already dangerous occupation. A combination of common quotas and seasonal closures has often been applied as fishery

☆ The opinions expressed herein are those of the author and do not necessarily reflect the views of NOAA. I am thankful to James Law at USCG for the accident data, Elizabeth Scott-Denton and Lawrence Beerkircher at NOAA for the observer data, and Matthew Varkony at NOAA for his assistance. I also appreciate the comments from the participants of the 2017 Western Economic Association Conference and Salvador Ortigueira on an earlier version of this paper.

E-mail address: akbar.marvasti@noaa.gov.

https://doi.org/10.1016/j.jge.2024.100105
Received 22 August 2023; Received in revised form 1 April 2024; Accepted 3 April 2024
Available online 20 April 2024

management tools in the U.S. and other parts of the world. This form of open-access fishery encourages fishers to harvest as much as possible before quota limits are reached and the fishery is closed. Contract changes in some fisheries of the GoM have modified property rights in the fisheries by excluding non-owners from access and allowing resource owners to collect rents. This fishery management method is commonly known as a limited access privilege program or individual fishing quota (IFQ) system. A simulation study by Costello, Gaines and Lynham (2008) involving 11,135 fisheries worldwide, provides evidence that IFQ programs can potentially prevent the collapse of fisheries and promote sustainable use of fish resources.[1] This change in the management regime is essentially a contract change that affects economic behavior and performance, including safety. Since commercial fishing is open year-round in an IFQ system, fishermen can utilize their allocation at any time. As a result, fishermen no longer race to catch fish before the common quota is depleted. The opportunity to fish at any time has also reduced the likelihood that fishermen will fish during bad weather. The underlying intuition regarding the safety effect is that when fishermen operate with personal quota allocations, they do not need to rush out to sea but can choose to fish during the most favorable weather conditions.

Although the amendment to the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 includes promotion of fishing safety as a goal, sustainability is its primary objective. As a result, the potential safety improvements outcome of fishery contract changes is rarely examined. However, a few recent studies have focused on occupational injuries in the reef fish fisheries of the GoM. Marvasti and Dakhlia (2017) use the Heckman two-step procedure to test the hypothesis that the change from a common-property regime, with quota restrictions and seasonality, to private ownership of share allocation without seasonal closures reduces the need to make risky trip decisions and improves safety in the commercial red snapper and grouper-tilefish fisheries. Their findings, using Centers for Disease Control (CDC) data, show that red snapper individual fishing quota (IFQ-RS) and grouper-tilefish individual fishing quota (IFQ-GT) programs in the GoM led to a sharp reduction in the rate of fatalities, in large part because of lower pressure to make risky trip decisions, in particular under adverse weather conditions. In another study, Dakhlia and Marvasti (2020) simulate a counterfactual scenario to find what weather conditions fishermen would brave if quota rights were not tradable and were thus not a factor in industry concentration. The authors argue that, in addition to the direct effect of regime shifts from common-pool to tradable individual quota rights, tradability of quota rights might lead to some fleet consolidation, along with a shift to larger vessels, which may also affect safety. This shift could reduce safety for several reasons: larger vessels are inherently more dangerous because they travel farther and rescue efforts take longer; they acquire rights to a larger share of the total allowable catch and therefore operate more often, making it more difficult to avoid adverse weather; and they take longer trips, which leads to crew fatigue. On the other hand, greater efficiency can lead to a reduction in the fleet-wide number of fishing trips and thus less exposure to risk. Because of these opposing effects, the net impact of any possible consolidation due to the regime change is undetermined and remains an empirical question. Dakhlia and Marvasti (2020) find that fleet consolidation has been incomplete and that it has been responsible for only 13.5% of the safety gains. The authors argue that even a complete consolidation, along with a shift to the most efficient (larger) vessels, would have an ambiguous and, in any event, quite modest impact on safety.

Another recent study that has addressed the safety effects of the IFQ program in U.S. waters uses the DiD approach to focus on the effect of high winds on the Pacific ground fish fishery (Pfeiffer and Grantz, 2016). The authors select the U.S. West Coast sablefish as the treatment group subject to IFQ change and compare it with two smaller fisheries in the same geographic area. Their results show that the propensity to fish in stormy weather conditions was reduced after the implementation of the catch share program in the fishery. While the authors establish the fishermen's shift in risk exposure after the introduction of the IFQ program, they do not extend the analysis to produce any evidence of enhanced safety in the fishery.[2]

In recent studies, interrupted time-series design has provided supportive evidence for the intervention effect of IFQ programs on reducing commercial fishing injuries (Marvasti and Dakhlia, 2017; Dakhlia and Marvasti, 2020). However, the DiD approach is more robust for policy analysis of observational data because it mimics an experimental research design by using panel data to measure the observed differences between treatment and control groups. Since the DiD approach avoids potential omitted variable bias, it has a more valid design than interrupted time-series design and provides a more robust tool for analyzing the impact of government regulations. Also, there is greater specificity in the DiD approach predictions. Of course, the DiD approach is not a panacea and has vulnerabilities in addressing omitted variables bias when a policy change is systematically related to factors that affect the outcome. The DiD approach also requires a few assumptions: treatment is unrelated to the outcome at the baseline, treatment and control groups have a parallel trend in their outcomes, the treatment and control groups have a stable composition, and there are no spillover effects (Roth, et al., 2022). Potential issues with using DiD include violation of its assumptions; this is especially true for the parallel trend assumption, which requires the difference between the treatment and control group to be constant prior to the intervention (Kahn-Lang and Lang, 2019; Roth, 2022). In other words, the outcomes of the treatment and control groups would have evolved similarly in the absence of treatment. My research design later inspects visual trends in both the rate of injuries outcomes and the DiD estimator.

I measure the effect of both the IFQ-RS and the IFQ-GT programs in the GoM on occupational injuries using a DiD approach. Given the multispecies nature of reef fish fisheries in the GoM, and consequently the economies of scope, the IFQ-RS may not have altered fishermen's safety behavior as much as did the expansion of the IFQ-GT program,

[1] Multiple solutions could remedy the inefficiencies of common property fisheries. In other words, the government does not need to privatize common properties fisheries. Johnson and Libecap (1989) use the example of shrimp fisheries in Galveston Texas in the 1970s to show that informal access control can at least temporarily remedy externalities and inefficiencies associated with common property. However, they argued that the heterogeneity of fishermen and cost of maintaining the catch and effort restrictions in the contract make it difficult to sustain this arrangement. Other studies provide more promising evidence of effective and sustainable privatization without the state. For example, Higgs (1979) shows how Native Americans implemented privatization by registering Washington Salmon site traps and restricting their use more than a century ago. Geloso and Foucher-Paquin (2023) also demonstrate that efficient arrangements also exist under statelessness or weak states. In the Canadian province of Quebec nearly two centuries ago, a monopoly in the fishing industry deterred overfishing by restricting the transformation of cod for export, not by traditional fishing effort or output restrictions.

[2] Pfeiffer and Grantz (2016) also present a "marginal rate of substitution between risk and financial gain (MRS)," which is motivated by an implied risk of injury based on a decision to take a fishing trip under high wind-speed conditions. However, no estimation is made linking high wind speed to the risk of injuries. Therefore, their estimated MRS does not follow a traditional MRS between the risk of injury and earning (wages) in the literature, which is based on the estimation of an injury function (Viscusi, 1993). Also, the authors use trip-level total fishing revenues in their estimation as a proxy for the earning variable, instead of traditional crew revenue-sharing earnings. Furthermore, the parallel trend assumption is not examined in the study by Pfeiffer and Grantz (2016).

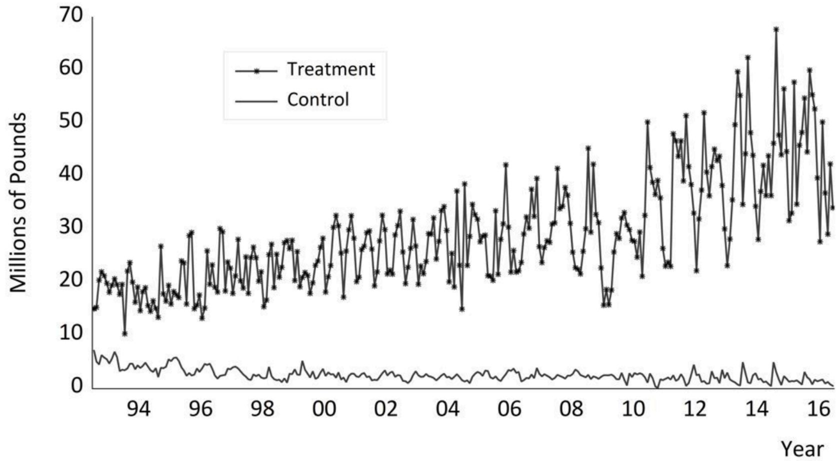

Fig. 1. Monthly landings for red snapper and grouper tile fisheries in GoM (treatment) and SA (control).

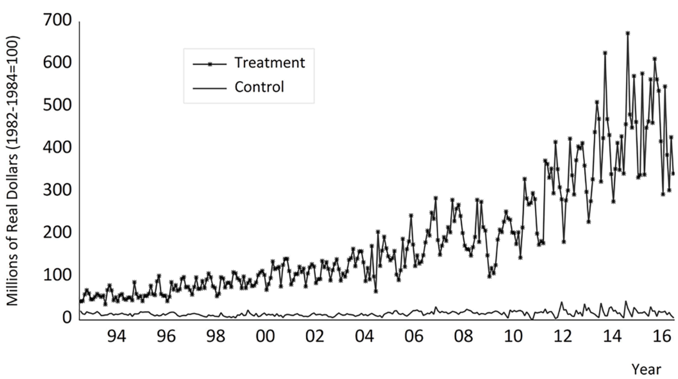

Fig. 2. Monthly revenues for red snapper and grouper tile fisheries in GoM (treatment) and SA (control).

with its much wider coverage of fish species.[3] To investigate this matter, I proceed by presenting the background for the IFQ programs in the GoM. Then I present the research design for analyzing the effect of the IFQ programs and a DiD model that captures differences in the rate of incidents in selected commercial fisheries of the GoM. In Section 3.1, I evaluate the data with regards to the assumption of parallel trends. My results suggest that the treatment group has experienced a lower rate of incidents than the control group and that these safety improvements can be mainly attributed to the IFQ-GT program. In other words, when there is a privatization of the commons, fishermen engage in less risky behavior, which can be seen in the injury rates in this study.

2. Background

The analysis in this paper involves the same groups of fisheries in two geographic locations in the U.S. waters. The red snapper and grouper-tilefish fisheries in the GoM is the treatment group, while the same fisheries operating in the South Atlantic (SA) are used as the control group. Figs. 1 and 2 present the monthly landings and revenues for the treatment and control groups. The treatment and control groups operate in different geographic areas, but they are subject to rather similar weather conditions. Red snapper and grouper-tilefish are popular reef fish species and have been subject to various management tools since 1990 by the GoM Fishery Management Council, in coordination with the coastal states. Quota management in the commercial red snapper fishery established a total allowable catch in 1990, allocating 51% of the quota to the commercial sector and the remaining 49% to the recreational sector. The total commercial red snapper quota has fluctuated over time in response to concerns regarding the overfishing of the stock. These quota reductions led to fishery closures, sparking the race to fish, or a "derby", in subsequent years (Waters 2001). In fact, while seasonal closures have occurred in other GoM fisheries, the red snapper seasonal closures and ensuing fishing derbies were the most extreme.[4] Subsequent red snapper management measures, including an endorsement system in 1993 that was converted to a two-tier license limitation system in 1998, a 10-day open season each month, and a quota increase in 1996, alleviated the derby problem. Nonetheless, dockside prices remained low until 2007, when the IFQ-RS program was implemented, replacing the two-tier license limitation program. This effectively expanded the commercial harvest season from approximately 85 days a year to year-round. Since then, prices appear to have stabilized at higher levels, and the derby fishing problem has been practically eliminated. Fig. 3 shows the number of active vessels engage in harvesting red snapper and grouper tilefish in the GoM and SA. The declining pattern of active vessels in the GoM, which began prior to the IFQ programs, continued with consolidation favoring larger vessels. While there were twice as many active commercial red snapper and grouper tilefish fishing vessels in the GoM as in SA in 1993, in recent years the number has become similar.

The grouper-tilefish fishery is composed of thirteen species that are harvested jointly with red snapper. This fishery has also been under various management controls, including quotas, since the early 1990s. In January 2010, the IFQ-RS program was complemented by an IFQ program for the grouper-tilefish species (IFQ-GT). The combined IFQ programs constitute 81% of the landings and 86% of the revenue generated from reef fish fisheries in the GoM (Overstreet, et al. 2017). Because of the multi-species nature of the red snapper and grouper-tilefish fisheries, the IFQ-GT program might have contributed to a geographic expansion of red snapper landings by allowing the trading of share allocations between these two programs. This geographic

[3] Safety considerations are affected by the expansion of the IFQ program in a multispecies fishery because of the relationship between risk and reward (earnings). In commercial fishery, earning revenues is a motive to take a fishing trip. When fishers notice that their ability to land fish is secured by the IFQ allocations they hold, they are more likely to avoid taking trips under poor weather conditions. In other words, when more species are subject to IFQ programs, there is less need to risk an accident at sea.

[4] It is notable that two other species have been subject to more restrictive seasonal closures. In fact, fishing for goliath grouper, a reef fish species, has been banned since 1990. The fishing season for blacktip shark, not a reef fish, has also been closed frequently.

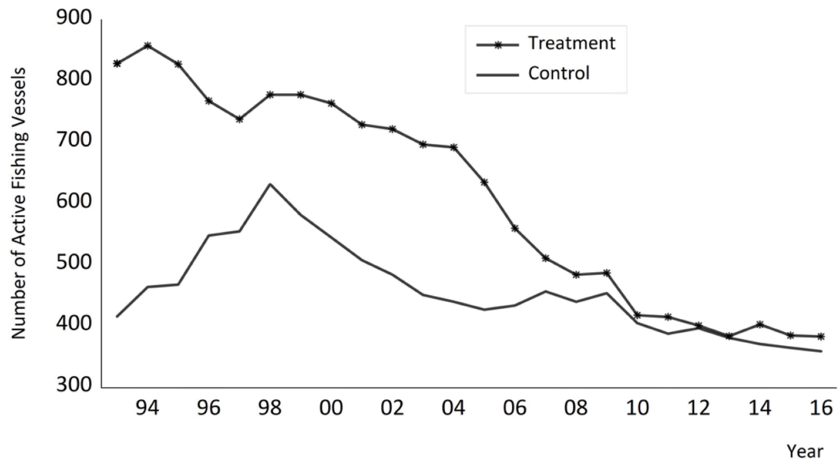

Fig. 3. Number of active fishing vessels in the red snapper and grouper tile fisheries in GoM (treatment) and SA (control).

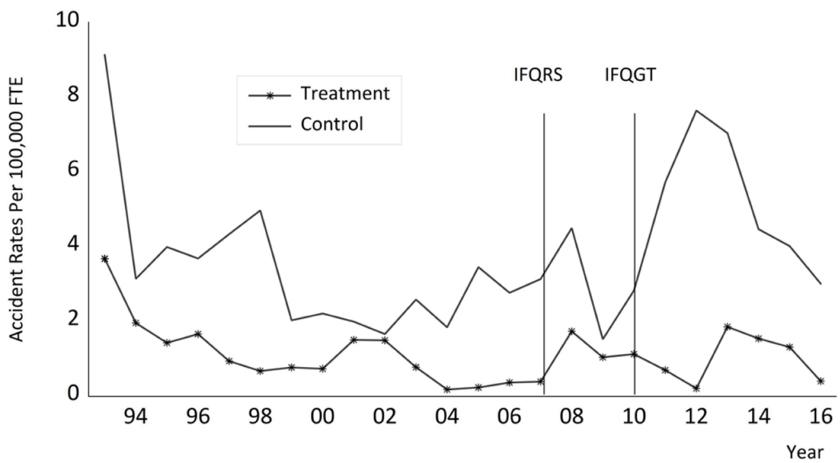

Fig. 4. Accident rates for the treatment and control groups and IFQ events.

expansion has been aided by the rebuilding of red snapper stocks in West Florida, as well as a general increase in population (NOAA, 2013).

The SA fisheries region includes federal waters ranging from North Carolina to Key West in east Florida and is managed by the SA Fishery Management Council, in coordination with the coastal states. Red snapper and grouper-tilefish fisheries are also popular in the SA region. However, their landings are only a fraction (approximately 15 percent) of the GoM landings for the same species. While some reef fish species in the SA, such as red snapper, have also been overfished and been subjected to various stock management policy tools such as quota and size limit, an IFQ program has not been introduced in these fisheries.

Interactions among landings of reef fish create synergies affecting production cost. In general, economies of scope reveal whether there is a cost advantage in producing several outputs. In many commercial fisheries, economies of scope create a cost advantage by jointly harvesting several species. Jensen (2002) believes that the presence of economies of scope in a fishery might be explained by seasonal harvest patterns or the spatial distribution of fish stocks that cause cost complementarity in harvesting several outputs jointly. Gear used to capture fish, such as nets, baited hooks, and traps, usually intercepts multiple fish species. Therefore, fishing technology essentially embodies economies of scope and produces a mix of the various species available in the sea. While commercial reef fish fishermen in the GoM can target a different species mix by engaging different gear types at different locations, times of the year, and depths, targeting involves additional costs that fishermen often prefer to avoid.

Another regulatory change that is likely to have impacted the level of occupational injuries in commercial fisheries of both the treatment and control groups is the introduction of the NOAA observer programs in the GoM in the 1990s and in the SA in 2005. These programs target commercial vessels harvesting different species groups such as pelagic fish, reef fish, and shrimp. While the observer programs are designed to ensure the safety of the observers travelling on the commercial fishing vessels and often only include a fraction of all annual trips, they might have contributed to the reduction in the number of injuries.[5]

3. Empirical approach

3.1. Research design

The design of the empirical analysis in this paper aims to limit the confounding effects of safety trends in the GoM fisheries that might be

[5] Observers receive about 2 weeks of training, half of it on vessel safety issues, before they begin their work, and take refresher courses every three years. Before each trip, observers inspect the vessel to make sure that it meets USCG regulations. If not, they will not travel with the vessel and will report it for violations. Observers will also refuse to take a trip if the vessel does not have a valid Commercial Fishing Vessel Safety Examination certificate, which the USCG considers optional, but which NOAA requires if the observers are on board. However, the vessel cannot be hindered from taking the fishing trip without the observer.

Table 1
Illustration of the DiD Estimator Using Daily Means for All Accident Cases Injury Rates Per 100,000 FTE for the Treatment (GoM RS or GT) vs. Control (SA RS or GT) Groups.

Groups	Before IFQ-RS (1993–2006)	After IFQ-RS (2007–2016)	After-Before (Percentage Change)	Before IFQ-GT (1993–2009)	After IFQ-GT (2010–2016)	After-Before (Percentage Change)
Control	3.41	4.39	+29%	3.35	4.96	+48%
Treatment	1.17	1.02	−13%	1.14	1.01	−11%
δ_1			−42%			−59%

Table 2
Trip-Level Descriptive Statistics- Daily Averages (1993–2016).

Variables	Description	GoM Red Snapper and Grouper Tilefish (Treatment)		SA Red Snapper and Grouper Tilefish (Control)	
		Pre-IFQ-GT	Post-IFQ-GT	Pre-IFQ-GT	Post-IFQ-GT
INJ_{it}	Daily injury rate per 100,000 FTE	0.46 (0.84)	0.18 (0.12)	2.34 (1.85)	3.69 (2.00)
FAT_{it}	Daily fatality rate per 100,000 FTE	0.65 (0.45)	0.69 (0.42)	0.83 (0.63)	1.39 (0.76)
MIS_{it}	Daily missing rate per 100,000 FTE	0.22 (0.19)	0.40 (63)	0.49 (0.91)	0.24 (0.14)
$All\ CASES_{it}$	Daily all accident cases rate per 100,000 FTE	1.14 (1.04)	1.01 (0.75)	3.35 (2.20)	4.96 (2.03
$CREW_{it}$	Number of crew on the fishing vessel	2.44 (0.37)	2.52 (0.35)	1.76 (0.20)	1.77 (0.16)
$DAYS_{it}$	Days at sea per trip	3.65 (1.10)	3.81 (1.37)	1.55 (0.39)	1.40 (0.29)
REV_{it}	Real fishing gross revenue per crew (in thousands, using CPI, all items, 1982–1984=100)	0.09 (0.06)	0.22 (0.15)	0.02 (0.01)	0.03 (0.03)
$LENGTH_{it}$	Length of the vessels in feet	36.63 (3.02)	36.04 (3.01)	30.36 (1.62)	30.32 (1.58)
HP_{it}	Average horsepower of the vessel	317.11 (46.05)	368.90 (93.84)	305.98 (34.16)	355.34 (103.49)
$VGROSST_{it}$	Vessel gross weight in tons	23.81 (6.48)	21.93 (6.62)	12.24 (4.91)	12.69 (4.69)
$VHULLG_{it}$	Fraction of vessels with hull made of fiberglass	0.45 (0.39)	0.94 (0.07)	0.48 (0.41)	0.96 (0.03)
$DFUEL_{it}$	Fraction of vessels using diesel fuel	0.41 (0.38)	0.74 (0.14)	0.35 (0.31)	0.62 (0.09)
$VAGE_{it}$	Vessel Age	19.03 (5.56)	26.60 (3.55)	18.52 (4.84)	26.61 (2.29)
$GEAR\text{-}H_{it}$	Percentage of vessels with hook and line as the top gear	0.72 (0.13)	0.70 (0.15)	0.60 (0.14)	0.61 (0.12)
OBS_{it}	Number of vessels with NOAA observers on the board	0.31 (0.91)	3.61 (2.52)	0.01 (0.07)	0.02 (0.17)
WS_t	Wind speed measured as meter per second (m/s) averaged over an eight-minute period for buoys	6.06 (1.87)	5.97 (1.87)	6.87 (1.89)	5.52 (1.45)
N	Number of observations	6209	2557	6209	2557

Standard deviations are in parentheses.
Data Sources:
1. Commercial fishery vessel accident data come from the U.S. Coast Guard (USCG).
2. Red snapper and grouper-tilefish trip-level data on revenue, number of crew, and days at sea come from the National Marine Fisheries Service Coastal Logbook System.
3. Vessel characteristics data for red snapper and grouper-tilefish vessels come from the NMFS's SERO survey of reef fish permit holders.

independent of the IFQ policy choice, which has altered the commercial fishing arrangements in the area in terms of both the ownership of the right to fish and the flexibility to choose when to fish. The treatment of the reef fish fisheries has been executed in two stages: the IFQ program in the RS fishery in 2007 followed by the IFQ-GT program in 2010. The compounded treatment effect of the IFQ program might be stronger after the second IFQ program was introduced into the multispecies reef fish fisheries of the GoM. The selection of the same group of fisheries in another region of the country where the fisheries have not been subject to the IFQ regulatory change as the control group fits the typical design of quasi-experimental empirical studies.

Since the weather conditions in the two geographic areas somewhat vary, wind speed is included in the model as an additional control variable.

The causal effects of the IFQ program treatment condition revolve around rate of injury outcomes that would prevail each day in each unit on average under the alternative levels of treatment. I use $i = 1, 2$ to index my cross-sectional units of red snapper (or grouper-tilefish) in the GoM and in the SA, and $t = 1, \ldots 8766$ to index the number of days during the study period. Dummy variables are used to identify the fishery groups and time periods a fishery is subject to an IFQ program.

Holding to the parallel trend assumption is a key requirement of the DiD method, because if the assumption is violated, estimation of the causal effect is biased. Kahn-Lang and Lang (2019) argue that logical reasoning related to parallel trends is important, in addition to rigorous testing. The control group in this study is made of the same group of species fished in the SA as the GoM treatment group. Also, the type of vessels, gears, and weather conditions are about the same. Therefore, the level of risk associated with operating in the two regions are expected to be similar prior to the introduction of the IFQ programs. To examine the parallel trend assumption, I first checked the pre- vs. post-IFQ behavior of the commercial fishing injury rates using a graphic presentation in Fig. 4.[6] Visual inspection of the data over time shows that while the treatment group accident rates are below the rates for the control group, the depiction of the pre-IFQ rates does not follow the standard DiD models of constant differences due to the presence of some randomness in commercial fishing accidents. However, the gap seems to have widened since the introduction of the IFQ-GT program in 2010. I next consider the manual calculation of the DiD estimator (δ_1) by comparing the mean of daily injury rates of all accident cases per 100, 000 FTE for the periods before and after the IFQ programs in Table 1 (Wooldridge, 2013, p. 457). Both the pre-IFQ-RS and pre-IFQ-GT injury rates are significantly lower for the treatment group than for the control group. After the institution of the IFQ programs, the injury rates drop by 13 percent and 11 percent for the IFQ-RS and IFQ-GT programs, respectively. On the other hand, the injury rates rose only 29 percent for the IFQ-RS control group, while it increased for the IFQ-GT control group by 48 percent. As a result, the DiD estimator dropped by 42 percent for the IFQ-RS, while it fell by 59 percent for the GT-IFQ, suggesting that the IFQ has been effective in improving safety in the RS and GT fisheries relative to the control group. Unlike the simple DiD

[6] RS and GT are often fished together by reef fish vessels, and the USCG reports injury cases for the fisheries together. Therefore, the solid line in Fig. 4 captures injury cases for RS and GT fisheries combined.

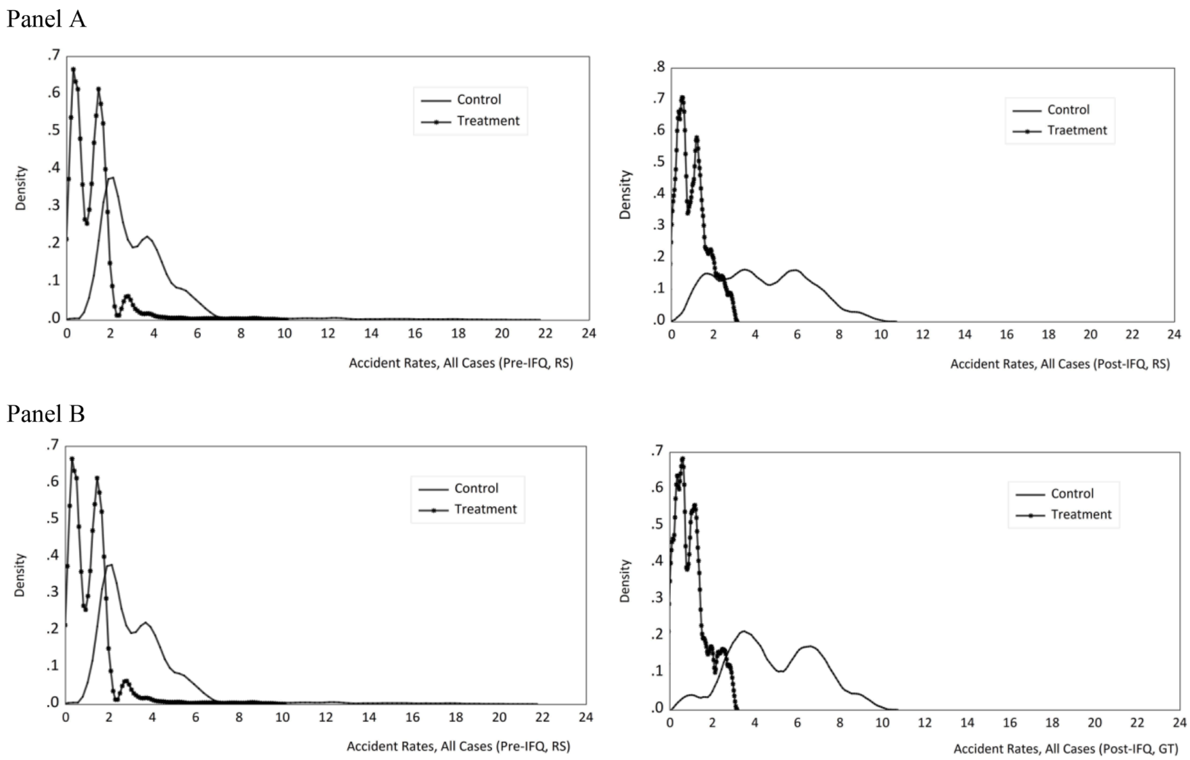

Fig. 5. Kernel Density estimates of accident rates before and after IFQ-RS (Panel A) and IFQ-GT (Panel B).

estimator in Table 1, the regression estimates of eq. (1) include other covariates controlling for possible systematic changes in the populations over the pre- and post-IFQ periods. I expect the differences in the rate of injuries trend to be constant between the treatment and control groups after controlling for the confounding effects (unique factors in the treatment and control groups). The findings from the occupational accident literature based on time-series data show that weather conditions are the primary cause of injuries in GoM fisheries (Marvasti and Dakhlia, 2017; Dakhlia and Marvasti, 2020). However, wind speed, which is commonly used to capture differences in weather condition in these studies, is rather similar in the treatment and control regions.

3.2. Model

I estimate the difference between outcome measures at two time points for both the treated observations (GoM fisheries participating in the IFQ program) and the control (the SA red snapper and grouper-tile fisheries, which are not participating in the program) and then compare the groups. I use panel data of GoM commercial red snapper and grouper-tilefish fisheries with cross-sectional units in the GoM and the SA. I divide my time series into two periods: one with no IFQ in either fishery group and another when the IFQ program was applied to red snapper and grouper-tilefish fisheries. Therefore, 2007 and 2010 are considered as alternative treatment dates, as those were the years when the IFQ-RS and IFQ-GT were introduced. Accordingly, I specify my DiD model for the injury rate for the *i*th fishery during the t period as:

$$y_{it} = \beta_0 + \delta_0 IFQ_{it} + \beta_1 d_{it} + \delta_1 IFQ_{it} \cdot d_{it} + \beta_2 Z_{it} + S_t + u_{it}, \qquad (1)$$

where IFQ_{it} is the intervention variable represented by a dummy variable, which takes the value of 1 when the IFQ program is present; d_{it} is another dummy variable distinguishing the selected group (GoM red snapper and grouper-tilefish equals 1) from the control group (SA fisheries equal zero); $IFQ \cdot d_{it}$is an interaction variable; Z_{it} is a vector of control variables including vessel characteristics, number of crew, presence of observers on the vessel, labor compensation, and wind speed; S_t is the month (deterministic seasonality) fixed effect; and u_{it} is idiosyncratic errors.[7] The coefficient of the interaction term, δ_1, is the DiD estimator, which measures the average effect of the IFQ program on the rate of injury. The DiD estimator is essentially a dummy variable that takes the value of one for the treatment groups in the second period. The hypothesis to be tested is that IFQ programs have resulted in a drop in occupational injuries in the red snapper and grouper-tilefish fisheries in the GoM, i.e., δ_1 is negative and statistically significant. The policy indicator is exogenously determined because the fisheries are managed by the GoM Fishery Management Council, in coordination with the coastal states, and the IFQ programs are administered by the National Marine Fisheries Service's (NMFS) Southeast Regional Office (SERO).[8]

Tests of normality for the response function show that neither measure of safety (injury rates) is normally distributed. For example, the Jarque-Bera test for all types of accident cases is 461,334 (Prob. 0.00), rejecting the null hypothesis of normality. Lack of normality in the response distribution persists with alternative methods such as the Cramer-von Mises, Watson, and Anderson-Darling tests. I use the Generalized Linear Mixed Model (GLMM), applying a maximum likelihood method, to estimate the parameters of Eq. (1), assuming an exponential response distribution.

To check the robustness of the results, I use a falsification test. In addition, to avoid multicollinearity since vessel characteristics tend to be correlated, I construct the first principal component from vessel characteristics including age, hull make, length, horsepower, and

[7] The control variables were selected based on the previous literature showing that various vessel characteristics affect the likelihood and severity of commercial fishing accidents. Marvasti, A., and Dakhlia, S. (2017) and Dakhlia, S., and Marvasti, A. (2020) provide more detailed discussions.

[8] The GoM Fishery Management Council and the SA Fishery Management Council are separate organizations responsible for the conservation and management of fishery resources in Federal waters in the respective geographic areas. Each Council typically includes a couple of fishermen; however, they make up a small minority of the 17 voting members.

weight, as well as crew size. The first principal component of the uncorrelated linear combination of the original variables explains 44 percent of the variance and has an eigenvalue of 2.63. This first principal component is used in an alternative specification of the model to further examine the robustness of the findings.

4. Data

I build a daily average panel data set for 1993–2016 for the treatment and control groups. For this purpose, I use red snapper and grouper-tilefish trip-level data on landings, revenues, vessel characteristics, number of crew, and days at sea for the GoM and SA regions from the National Marine Fisheries Service Coastal Logbook system. Vessel characteristics data come from the SERO's survey of reef fish permit holders. Due to the multi-species nature of the GoM reef fish fisheries, the treatment group data are the same for the red snapper and grouper-tilefish trips.

The GoM commercial fishery vessel accidents data come from the U. S. Coast Guard (USCG), which reports commercial fishing accidents leading to fatal and non-fatal injuries as well as employees reported missing during commercial fishing trips.[9] Since the number of missing cases is relatively small, I analyze them as a part of "all" types of accident cases. The observer data for reef fish in the GoM and SA regions come from NOAA's National Observer Program.[10] Table 2 presents the descriptive statistics for the variables during the pre- vs. post-IFQ-GT periods for the main and control groups. Although the red snapper and grouper-tilefish fisheries are similar in the two geographic regions in terms of targeted fish, gears and vessel age, there are not identical. For example, vessels in SA are typically a slightly shorter, use fewer number of crews and take shorter trips than the Gulf fleet. This variation is probably based on the size and the location of fish stocks. It is also notable that while a transition from steel and wood to fiberglass fishing vessels, which is more durable and lighter, has occurred, this change is common among the fleets in both regions as Table 2 shows.

Since work in the fishing industry does not follow a standard 40-hour week, I construct a measure of full-time equivalent (FTE) employment for the commercial fishing industry in the GoM by multiplying the number of crewmembers by number of days at sea to arrive at the total number of crew days used in the industry. I then multiply the sum of this measure across vessels by three, assuming that crewmembers are at risk during the entire trip. The 365-day backward moving average of FTE and USCG accidents is used to calculate the rate of fatal injuries, non-fatal injuries, and all types of accident cases, combined.

Because of the lack of fishery-specific data on labor compensation, nonstandard working hours, and the large percentage of self-employed workers, finding an accurate measure of compensation for fishery labor is complex. I use the average daily gross revenue per crewmember as a proxy for wages (earning), which is consistent with the common practice of revenue sharing in the industry. Of course, in fishery revenue-sharing arrangements, some variable costs, such as expenses for fuel and bait, are typically subtracted from gross revenues before the crew share, typically one-third, is determined (McConnell and Price 2006). My data suggest that crewmembers in the red snapper and grouper-tilefish fisheries are indeed being paid 21% of gross revenues, on average, as labor compensation. Then for both the treatment and control groups, the labor compensation ratio is multiplied by the daily gross real revenues per vessel from the landing data. To arrive at the daily revenues for captain and crew, the result is divided by the number of days at sea, assuming that the daily revenues are constant during the trip but vary across trips. The 365-day backward moving average method is also used to calculate the daily revenues for captain and crew, which helps deal with zero values when vessels are docked.

Since two property rights contract changes occurred during the study period, the data analyses that follow first consider the entire sample for each of the changes. I then divide the sample into pre- and post-IFQ periods: 1993–2009 for the IFQ-RS program with intervention in 2007, and 2008–2016 for the IFQ-GT program with intervention in 2010. The kernel density distributions for the divided samples are depicted in Fig. 5, which compares the accident rates for the treatment and control groups (IFQ-RS program in panel A and IFQ-GT program in panel B). The RS accident rate probability distribution has a wider range after the IFQ program and a higher peak than before the RS-IFQ program, while the GT accident rate probability distribution has a narrower range after the IFQ program and a higher peak than before the GT-IFQ program.

Table 3
GLMM Parameter Estimates of Accident Rates for Red Snapper (1993–2016, $N = 16{,}799$).

Variables	Model 1 (FAT)	Model 2 (INJ)	Model 3 (All)
$IFQ\text{-}RS_{it}$	−0.800***	0.449***	−0.550***
	(0.039)	(0.040)	(0.038)
d_{it}	0.282***	2.920***	1.413***
	(0.046)	(0.045)	(0.045)
$IFQ\text{-}RS_{it}\text{-}d_{it}$ Interaction	0.221***	−1.296***	−0.225***
	(0.041)	(0.042)	(0.041)
REV_{it}	−0.538***	0.654***	0.181
	(0.119)	(0.127)	(0.123)
$DAYS_{it}$	0.017*	−0.001	0.013
	(0.010)	(0.010)	(0.010)
$CREW_{it}$	−0.378	−0.753***	−1.232***
	(0.237)	(0.198)	(0.217)
$LENGTH_{it}$	−0.008	0.038***	−0.044***
	(0.017)	(0.014)	(0.015)
$CREW_{it}/LENGTH_{it}$	8.414	20,391***	38.651***
	(8.621)	(7.552)	(8.079)
$VAGE_{it}$	0.008***	−0.015***	−0.010***
	(0.002)	(0.002)	(0.002)
HP_{it}	0.236*	−0.329***	−0.034
	(0.137)	(0.132)	(0.120)
$VGROSST_{it}$	0.026***	0.009***	0.021***
	(0.002)	(0.002)	(0.002)
$VHULLG_{it}$	−0.093	−0.242***	−0.469***
	(0.085)	(0.083)	(0.083)
$DFUEL_{it}$	−0.887***	−0.612***	−0.439***
	(0.095)	(0.094)	(0.094)
OBS_{it}	−0.026***	−0.031***	−0.013*
	(0.007)	(0.067)	(0.068)
GEAR-H	0.135**	0.051***	0.082
	(0.065)	(0.064)	(0.065)
WS	−0.001	−0.011**	−0.001
	(0.005)	(0.005)	(0.005)
Month FE	Yes	Yes	Yes
Constant	0.207***	−1.784***	−0.739
	(0.593)	(0.518)	(0.556)
−2 Res Log Likelihood	25,229	29,349	56,025
AIC	25,285	29,405	56,081

Standard errors are in parentheses. ***, and ** denote statistical significance at the 99 and 95 percent levels, respectively.

[9] There is no indication that the marine accident data collection by the USCG has changed during the study period. When marine accidents occur, USCG begins an investigation to ascertain the causes of an accident, number of casualties, and personnel behavior to determine whether remedial measures should be taken and whether any violation of Federal laws and regulations has occurred. The results of such investigations play a major role in changing the existing marine safety laws and regulations and developing new rules. The investigations also help implement new marine safety technologies. For more information, see: https://www.dco.uscg.mil/Our-Organization/Assistant-Commandant-for-Prevention-Policy-CG-5P/Inspections-Compliance-CG-5PC-/Office-of-Investigations-Casualty-Analysis/2692-Reporting-Forms-NVIC-01-15/

[10] The NOAA's National Observer Program reports observer activities based on the vessel identification and departure and arrival dates. The calculation of the daily number of vessels under the observer programs considers both the number of vessels as well as the duration of the trips with observers on board.

Table 4
GLMM Parameter Estimates of Accident Rates for Grouper-Tilefish (1993–2016, N = 16,799).

Variables	Model 1 (FAT)	Model 2 (INJ)	Model 3 (All)
$IFQ\text{-}GT_{it}$	−0.145***	−0.316***	−0.197***
	(0.038)	(0.042)	(0.039)
d_{it}	0.786***	2.385***	1.652***
	(0.049)	(0.051)	(0.050)
$IFQ\text{-}GT_{it}\text{-}d_{it}$ Interaction	−0.462***	−0.561***	−0.508***
	(0.044)	(0.047)	(0.045)
REV_{it}	0.051	0.233	0.515***
	(0.128)	(0.124)	(0.130)
$DAYS_{it}$	0.051***	−0.023**	0.037***
	(0.010)	(0.010)	(0.010)
$CREW_{it}$	−0.400***	0.064	−1.072***
	(0.239)	(0.199)	(0.217)
$LENGTH_{it}$	−0.018	−0.008	0.027*
	(0.017)	(0.014)	(0.015)
$CREW_{it}/LENGTH_{it}$	9.632	−12.567	32.090***
	(8.631)	(7.588)	(8.070)
$VAGE_{it}$	0.010***	−0.026***	−0.010***
	(0.002)	(0.002)	(0.002)
HP_{it}	0.426***	−0.509***	0.087
	(0.190)	(0.114)	(0.130)
$VGROSST_{it}$	0.022***	0.015***	0.020***
	(0.002)	(0.002)	(0.002)
$VHULLG_{it}$	0.022	−0.230***	−0.223***
	(0.081)	(0.079)	(0.079)
$DFUEL_{it}$	−0.692***	−0.569***	−0.430***
	(0.092)	(0.093)	(0.094)
OBS_{it}	0.030***	−0.106*	0.008
	(0.007)	(0.007)	(0.007)
GEAR-H	0.160***	0.026	0.133**
	(0.064)	(0.065)	(0.064)
WS	0.012***	−0.022***	0.002
	(0.005)	(0.005)	(0.005)
Month FE	Yes	Yes	Yes
Constant	−0.286	1.089**	−0.603***
	(0.596)	(0.522)	(0.558)
−2 Res Log Likelihood	25,405	29,610	56,106
AIC	25,461	29,666	56,162

Standard errors are in parentheses. ***, and ** denote statistical significance at the 99 and 95 percent levels, respectively.

Table 5
GLMM Parameter Estimates of Accident Rates for Red Snapper (1993–2009, N = 11,702).

Variables	Model 1 (FAT)	Model 2 (INJ)	Model 3 (All)
$IFQ\text{-}RS_{it}$	−1.055***	0.678***	−0.674***
	(0.050)	(0.050)	(0.047)
d_{it}	−0.488***	2.843***	0.870
	(0.070)	(0.070)	(0.068)
$IFQ\text{-}RS_{it}\text{-}d_{it}$ Interaction	0.903***	−1.295***	0.234***
	(0.058)	(0.058)	(0.056)
REV_{it}	−1.534***	−1.411***	−1.084***
	(0.253)	(0.261)	(0.264)
$DAYS_{it}$	−0.015	−0.009	−0.005
	(0.014)	(0.013)	(0.013)
$CREW_{it}$	−0.110	0.197	−0.573**
	(0.312)	(0.241)	(0.279)
$LENGTH_{it}$	−0.042**	−0.018	0.010
	(0.022)	(0.017)	(0.020)
$CREW_{it}/LENGTH_{it}$	−0.447	−18.501**	−13.502
	(11.264)	(9.304)	(10.360)
$VAGE_{it}$	−0.003	−0.030***	−0.020***
	(0.003)	(0.002)	(0.002)
HP_{it}	−0.044	−0.622**	−0.276
	(0.283)	(0.278)	(0.273)
$VGROSST_{it}$	0.040***	0.010***	0.019***
	(0.003)	(0.002)	(0.003)
$VHULLG_{it}$	−0.229**	−0.511***	−0.647***
	(0.117)	(0.113)	(0.113)
$DFUEL_{it}$	−0.736***	−0.114	−0.109
	(0.130)	(0.128)	(0.127)
OBS_{it}	−0.040**	−0.068***	−0.044***
	(0.017)	(0.018)	(0.017)
GEAR-H	−0.050	0.542***	0.313***
	(0.085)	(0.086)	(0.086)
WS	0.013**	−0.007	0.004
	(0.006)	(0.006)	(0.006)
Month FE	Yes	Yes	Yes
Constant	1.850***	0.343	0.917
	(0.756)	(0.622)	(0.695)
−2 Res Log Likelihood	14,818	20,634	37,407
AIC	14,874	20,690	37,463

Standard errors are in parentheses. ***, **, and * denote statistical significance at the 99, 95, and 90 percent levels, respectively.

5. Results and discussion

Before focusing on the subsamples, I examine the effect of IFQ programs on the rate of incidents using the entire sample period. The parameters of Eq. (1) for the rate of fatal injuries, non-fatal injuries, and all cases of commercial fishing accidents are reported in Tables 3 and 4 for the IFQ-RS and IFQ-GT, respectively. While the DiD estimator for the IFQ-RS in Table 3 is statistically highly significant for non-fatal-injuries and all cases, with the expected negative signs, the DiD estimator for fatal cases is positive. The DiD estimator results for the IFQ-GT in Table 4 are consistently negative and highly significant across various models, supporting the hypothesis that the IFQ programs are effective in reducing occupational injuries. The coefficient of the DiD estimator for the IFQ-GT program, all cases, in Table 4 is also twice as large as its counterpart for the IFQ-RS program from Table 3. To elaborate, the results suggest that the GT-IFQ in 2010 reduced the rate of fatalities by about half and led to a 56 percent reduction in the rate of non-fatal injuries. The all-cases rate also dropped by 51 percent. On the other hand, a comparable estimate of the DiD estimator for the overall effect of RS-IFQ is half as large as the GT-IFQ.

Next, I estimate the model using the subsamples for a more robust examination of the effect of each event and focus on the time period when only one effect has occurred. For this purpose, I first turn to a more restrictive division of the time period to show the effect of the IFQ-RS: 1993–2009. Table 5 presents the results. The DiD estimator shows that only non-fatal injuries have dropped after the institution of the IFQ-RS. It is notable that the IFQ-RS subsample allows only two years to observe the response to the property rights contract change.

Finally, I present the results for the effect of the IFQ-GT for the 2008–2016 period in Table 6. The DiD estimator results are robust to a more selective time span of the data, confirming the positive effect of the IFQ-GT program on improvements in safety at sea for only non-fatal accidents. In comparison to the full sample results in Table 4, the DiD estimators from the restricted sample suggest a weaker reaction of the response variable for non-fatal injuries to the IFQ-GT than the DiD estimators from the full sample.

My falsification tests focus on the IFQ-GT program, where the program appears to have been effective in reducing injuries. The results of the falsification tests are rather mixed when I select 2011 as the treatment date and run the regressions for the 2008 to 2016 period. The falsification test holds for the injury cases but is rejected for fatalities and all types of accidents. I then select 2009 as the treatment date and use 2008–2016 data. Again, the falsification test holds only for the injury cases. When the entire sample is used, the falsification test is rejected for all alternative dependent variables.

For further cross-examination of the falsification results for the key IFQ program, vessel characteristics are replaced with the first principal component for the vessel characteristics to avoid multicollinearity. The new coefficient estimates for the DiD falsified estimator for the 2011 IFQ-GT treatment date using the 2008 to 2016 period in the regression produced t-values of −23.08, −1.71, and −16.07 for fatal, non-fatal, and all cases, respectively. Therefore, the falsification test holds only for non-fatal injury cases at the 5% level. Falsifying the introduction of the IFQ-GT event to 2009 produced t-values of −3.7, +0.14, and +7.09 for

Table 6
GLMM Parameter Estimates of Accident Rates for Grouper-Tilefish (2008–2016, $N = 6555$).

Variables	Model 1 (FAT)	Model 2 (INJ)	Model 3 (All)
$IFQ\text{-}GT_{it}$	−0.556***	−0.491***	−0.590***
	(0.047)	(0.047)	(0.047)
d_{it}	−0.667***	−2.885***	−1.640***
	(0.062)	(0.062)	(0.063)
$IFQ\text{-}GT_{it}\text{-}d_{it}$ Interaction	1.012***	−0.137***	0.897***
	(0.065)	(0.065)	(0.065)
REV_{it}	−0.011	0.418***	0.611***
	(0.150)	(0.151)	(0.152)
$DAYS_{it}$	0.003	0.002	0.013
	(0.017)	(0.017)	(0.016)
$CREW_{it}$	−0.488	−0.808**	−1.130***
	(0.408)	(0.395)	(0.391)
$LENGTH_{it}$	0.024	0.045	0.027
	(0.029)	(0.028)	(0.028)
$CREW_{it}/LENGTH_{it}$	13.475	28.150**	35.848***
	(14.351)	(13.958)	(13.840)
$VAGE_{it}$	0.010*	−0.006	−0.003
	(0.005)	(0.005)	(0.005)
HP_{it}	−0.025	−0.500***	−0.088
	(0.155)	(0.138)	(0.142)
$VGROSST_{it}$	0.009***	0.010***	0.025***
	(0.003)	(0.003)	(0.003)
$VHULLG_{it}$	0.139	0.150	0.250
	(0.271)	(0.269)	(0.269)
$DFUEL_{it}$	−0.343**	−0.011	−0.015
	(0.170)	(0.170)	(0.170)
OBS_{it}	−0.003	−0.065***	−0.007
	(0.008)	(0.007)	(0.008)
GEAR-H	0.099	−0.233**	−0.264***
	(0.100)	(0.099)	(0.100)
WS	−0.001	0.001	0.015*
	(0.008)	(0.008)	(0.008)
Month FE	Yes	Yes	Yes
Constant	−0.701	−0.189	0.179
	(1.033)	(0.991)	(1.004)
−2 Res Log Likelihood	12,648	9133	23,339
AIC	12,704	9189	23,395

Standard errors are in parentheses. ***,**, and * denote statistical significance at the 99, 95, and 90 percent levels, respectively.

fatal injuries, non-fatal injuries, and all cases, respectively. Consequently, the falsification test holds only for non-fatal injury and all cases at the 5% level. To summarize, the falsification test results from estimates using the first principal component are similarly mixed.[11]

While the IFQ-GT results are not robust based on the falsification test results, they are consistent with the findings by Marvasti and Dakhlia (2017) and show that the IFQ-GT is two times more effective in reducing fatal injuries in the commercial red snapper and grouper-tilefish fisheries than the IFQ-RS. Using DiD estimators +0.22 and −0.46 for fatal injuries from a comparable sample in Tables 3 and 4, the IFQ-GT is very effective in reducing fatal injuries, while the IFQ-RS shows no impact on fatal injuries. Therefore, the expected effect of the IFQ-RS program in 2007 may need to be discounted. In other words, the addition of the IFQ-GT program in 2010 expanded the scope of the IFQ programs in reef fish fisheries, enhancing their effectiveness in reducing occupational injuries. Other studies of the effectiveness of IFQ programs in multi-species fisheries point out that these programs are more effective in influencing behavior when they are imposed on all fisheries targeted by a fleet. This is true about the level of effort, capacity, and choice of departure time for trips (Clark, et al., 1979; Squires and Kirkley, 1996; Felthoven, et al., 2009).

[11] Estimates of the models with the principal component are available upon request.

6. Conclusions

The focus of this paper has been on the safety effects of a contract change in the ownership of selected common-property fishery resources in the GoM. Specifically, I have examined the effect of the IFQ-RS and IFQ-GT programs, which have essentially altered the principles of access to the stocks of red snapper and grouper-tilefish in the GoM for commercial use. The DiD approach used in this study is a superior method for observational data as it mimics an experimental research design by control testing to understand causal processes, and it avoids potential omitted variable bias, thus serving as a robust tool to analyze the impact of government regulations for more informed policy conclusions. Here I use the red snapper and grouper-tilefish fishery in the SA, as the control group. The DiD approach allows a cross-examination of the findings from recent studies of the safety effects of the IFQ programs in the GoM, where the rate of accidents has dropped, though not steadily, in the years following the contract change.

The results suggest that the red snapper IFQ affected a portion of fishers' decisions regarding when and where to fish, but some trip decisions were still influenced by the old management system for grouper-tile fisheries. As a result, accidents continued to happen. The inclusion of the grouper-tile IFQ evened the playing field with regards to decision making for both fisheries as exemplified by further reductions in accidents. This study's most favorable results for safety improvements that can be linked to the IFQ programs come from estimates of the effect of the IFQ-GT program on fatal injuries and all cases. These findings are more robust than those of previous studies such as Marvasti and Dakhlia (2017). The apparent ineffectiveness of the IFQ-RS program in improving safety is due partly to the economies of scope stemming from the multispecies nature of the reef fish fishery in the GoM. In the presence of economies of scope and interrelatedness of products produced by a firm, it has been demonstrated that response to regulations is more complex and will be more effective when all products are subject to regulations. An extrapolation of the results for the DiD estimator to other commercial fisheries in the U.S. suggests considerable potential safety gains from implementing an IFQ program in other commercial fisheries nationwide.

CRediT authorship contribution statement

Akbar Marvasti: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing.

References

Bergland, H., Pedersen, P.A., 1997. Catch regulation and accident risk: the moral hazard of fisheries' management. Mar. Resour. Econ. 12 (4), 281–292.
Bockstael, N.E., Opaluch, P, 1983. Discrete modeling of supply response under uncertainty: the case of fishery. J. Environ. Econ. Manage 10 (2), 125–137.
Bureau of Labor Statistics, 2022. Civilian Occupations with High Fatal Work Injury Rates. https://www.bls.gov/charts/census-of-fatal-occupational-injuries/civilian-occupations-with-high-fatal-work-injury-rates.htm.
Cheung, S.N., 1970. The structure of a contract and the theory of a non-exclusive resource. J. Law Econ. 13 (1), 49–70.
Clark, C.W., Clarke, F.H., Munro, G.R., 1979. The optimal exploitation of renewable resource stocks: problems of irreversible investment. Econometrica 47 (1), 25–47.
Costello, C., Gaines, S.D., Lynham, J., 2008. Can catch shares prevent fisheries collapse? Science (1979) 321 (5896), 167–1681.
Dakhlia, S., Marvasti, A., 2020. Regulatory change, industry structure, and fatalities: the case of a Gulf of Mexico fishery. Rev. Ind. Org. 57 (1), 1–26.
Eggert, H., Martinsson, P., 2004. Are commercial fishers risk-lovers? Land. Econ. 80 (4), 550–560.
Felthoven, R., Horrace, W., Schnier, K., 2009. Estimating heterogeneous capacity and capacity utilization in a multi-species fishery. J. Product. Anal. 32 (3), 173–189.
Geloso, V., Foucher-Paquin, F., 2023. Weak states and the commons: fisheries and economic development in the Gaspé Peninsula Circa 1830. J. Gov. Econ. 10, 100071. Summer.
Gordon, H.S., 1954. The economic theory of a common-property resource: the fishery. J. Polit. Econ. 62 (2), 124–142.
Jensen, C.L., 2002. Applications of dual theory in fisheries: a survey. Mar. Resour. Econ. 17 (4), 309–334.

Johnson, R., Libecap, G.D., 1989. Contracting problems and regulation: the case of the fishery. Am. Econ. Rev. 72 (5), 1005–1022.
Higgs, R., 1979. Legally-induced technical regress in the washington salmon fishery institute for economic research. Discuss. Pap. Ser. 79 (7).
Kahn-Lang, A., Lang, K., 2019. The promises and pitfalls of differences-in-differences: reflections on 16 and pregnant and other applications. J. Bus. Econ. Stat. 38 (3), 613–620.
McConnell, K.E., Michael, P, 2006. The lay system in commercial fisheries: origin and implications. J. Environ. Econ. Manage 51 (3), 295–307.
Marvasti, A., Dakhlia, S., 2017. Red snapper and grouper-tilefish IFQ programs and occupational fatalities in the Gulf of Mexico. South. Econ. J. 83 (3), 705–720.
Mistiaen, J.E., Strand, I.E., 2000. Location choice of commercial fishermen with heterogeneous risk preferences. Am. J. Agric. Econ. 82 (5), 1184–1190.
NOAA, 2013. 2012 Gulf of Mexico Red Snapper Individual Fishing Quota Annual Report. National Marine Fisheries Service, Southeast Regional Office. July 29.
Overstreet, E., Perruso, L., Liese, C., 2017. Economics of the Gulf of Mexico Reef Fish Fishery- 2014. NOAA Technical Memorandum NMFS-SEFSC-716.
Pfeiffer, L., Grantz, T., 2016. The effect of rights-based fisheries management on risk taking and fishing safety. In: Proceedings of the National Academy of Sciences, 113, pp. 2615–2620.
Roth, J., 2022. Pre-test with caution: event-study estimates after testing for parallel trends. Am. Econ. Rev.: Insights 4 (3), 305–322.
Roth, J., Sant'Anna, P.H., Bilinksi, A., and Poe, J. 2022. What's trending in difference-in-differences? A synthesis of the recent econometrics literature. https://jonathandroth.github.io/assets/files/DiD_Review_Paper.pdf.
Schnier, K.E., Horrace, W.C., Felthoven, R.G., 2009. The Value of Statistical Life: Pursuing the Deadliest Catch. Center for Policy Research, Maxwell School, Syracuse University, Center for Policy Research Working Papers, p. 117.
Smith, M.D., Wilen, J.E., 2005. Heterogeneous and correlated risk preferences in commercial fishermen: the perfect storm dilemma. J. Risk Uncertainty 31 (1), 53–71.
Squires, D., Kirkley, J., 1996. Individual transferable quota in a multiproduct common property industry. Can. J. Econ. 29 (2), 318–342.
Viscusi, K.W., 1993. The value of risks to life and health. J. Econ. Lit. 31 (4), 1912–1946.
Waters, J.R., 2001. Quota management in the commercial red snapper fishery. Mar. Resour. Econ. 16 (1), 65–78.
Wooldridge, J.M., 2013. Introductory Econometrics: A Modern Approach. Cengage Learning, Boston, MA.