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Cooperation and sales revenue of fisheries: Evidence from France[#]

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Abstract: This paper relies on a natural experiment to study the short-term consequences of a reduction of the trawler fleet on the economic situation of fisheries. In the context of the Covid pandemic, a scenario of cooperation leading to a weekly rotation of trawlers was set up for four weeks in May 2020 in the port of Le Grau-du-Roi located in the Mediterranean Sea, but not in the nearby port of Sète. Using detailed transaction data, we rely on a difference-in-differences strategy to assess the impact of the large decrease (around 45%) in the number of trawlers selling fish on a daily basis during the cooperation period. We show that the daily sales revenue per active trawler has increased more in Le Grau-du-Roi than in Sète (around 20%) due to higher fish catches, presumably due to a decrease in congestion. However, we find that the evolution of the total revenue per trawler has been much lower (around 40%) in Le Grau-du-Roi than in Sète because of the cooperation, meaning that the decrease in fishing time has not been offset at all by the increase in daily sales revenue.

Keywords : fisheries, fish markets, sales revenue, difference-in-differences estimation

JEL Classification : Q22

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1. Introduction

According to the Food and Agricultural Organization of the United Nations, about one-third of the fish stocks are being overfished around the world (FAO, 2020). With a proportion exceeding 60%, the most overfished area is the Mediterranean Sea. From the management perspective, the Common Fisheries Policy in the Mediterranean has essentially focused on the control of fishing effort and fishing capacity. Fleet reduction through temporary cessation of activity, payback and decommissioning of trawlers has been implemented to preserve fish stocks, but the lower number of vessels has not proved sufficient to allow the recovery of stocks (STECF, 2017a, 2017b)¹. The recent plan for demersal fisheries introduced in Western Mediterranean relies on the concept of “maximum allowable fishing effort”, leading to a maximum number of fishing days per year (Lizaso et al., 2020)². Curiously, little is known about the impact of a large reduction in fishing effort (either through fewer trawlers or fewer fishing days) on fish markets as well as on the economic situation of fisheries (Guillen and Maynou, 2016; Sabatella et al., 2017). In this paper, we focus on this issue using the following natural experiment. In 2020, fish markets have been strongly impacted by the Covid health crisis, especially in France. The national lockdown decided in that country from mid-March to mid-May 2020 led to a generalization of teleworking and to the closure of restaurants, schools and markets, which strongly reduced the demand for fish. In such context, a scenario of cooperation leading to a weekly rotation of trawlers was set up for four weeks in May 2020 in the port of Le Grau-du-Roi, located in the Mediterranean Sea. The fleet of trawlers above 18 meters was split in two and each trawler spent time fishing only two weeks out of four. Conversely, in the nearby port of Sète which shares very similar characteristics in terms of number of trawlers, characteristics of vessels and fish species caught, time spent on fishing by trawlers was not modified.

Our paper assesses the short-term consequences of this cooperation on sales revenue of fisheries. The situation under consideration is characterized by both a negative demand shock due to the pandemic and a negative supply shock due to the cooperation. On the one hand, both shocks should lead to a lower total quantity of fish landed. On the other hand, the effect on fish prices cannot be signed at the equilibrium. While prices should fall with the negative demand shock, they are conversely expected to increase with the negative supply shock due to the inverse relationship between price and quantity. In an open access fishery, a large decrease in the fleet size fishing in the same area may further influence the quantity of fish caught by each trawler in case of congestion.

¹ The number of fishing units active in Mediterranean fisheries has decreased by 30% over the 1995-2016 period, corresponding to a decrease of about 1.5% per year (Maynou, 2020).

² See Regulation (EU) 2019/1022 of the European Parliament and of the Council of 20 June 2019 establishing a multiannual plan for the fisheries exploiting demersal stocks in the western Mediterranean Sea, <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L:2019:172:FULL&from=EN>. According to the multi-annual management plan adopted in June 2019, the fishing effort regime for trawlers should achieve an overall reduction of 40% in 2025.

Knowing to what extent a decrease in fishing effort affects the economic situation of fisheries, both at the trawler level and at the global fishery level, is thus a central question with important public policy implications.

The focus on a natural experiment provides a unique opportunity to bring answers to this issue. While natural experiments have now a long history in economics and more generally in social sciences (Meyer, 1995; Dunning, 2012), their application in studies dealing with fisheries management remains scarce. Noticeable exceptions are Grafton et al. (2000) on the British Columbia halibut fishery, Repetto (2001) on scallop fisheries in the United States and Canada, or more recently Chavez et al. (2021) on the Pacific Anchoveta fishery in Southern Peru and Northern Chile. We consider a difference-in-differences (DID hereafter) setting to assess the causal impact of the cooperation implemented in Le Grau-du-Roi. The DID estimator is a common tool used for impact evaluation studies which is based on a combination of treatment-control and before-after group comparisons (Angrist and Krueger, 1999; Imbens and Wooldridge, 2009; Abadie and Cattaneo, 2018; Gobillon and Wolff, 2020).

Our empirical analysis is based on a unique data set of transactions achieved in the Mediterranean fish markets from January 2019 to August 2020, with around one million transactions in Le Grau-du-Roi and Sète over that period. For each fish lot sold a given day, the dataset includes detailed information on value, quantity and fish characteristics as well as on the vessel's identifier, so that we can calculate the sales revenue for any trawler on a daily basis. As the rotation of trawlers in Le Grau-du-Roi has been implemented during four weeks, we begin by considering a control period of exactly four weeks following the cooperation and compare how the sales revenue generated by a trawler on a given day has evolved between Le Grau-Du-Roi (treated market) and Sète (control market). We study the robustness of our results by considering different time windows for the control period. We compare not only the sales revenue generated each day of sale, but also the total revenue over the period for each trawler as well as the total revenue within the fish market.

We proceed in the following way. We begin by estimating the impact of cooperation on the number of trawlers selling fish each day in a given fish market. We find that the fall in the number of trawlers selling on a daily basis during the cooperation was around 45% higher in Le Grau-du-Roi than in Sète. So, the cooperation has drastically reduced the fishing effort in Le Grau-du-Roi. Then, we focus on revenue received each day of sale by a given trawler. Our estimates show that the increase in daily sales revenue per trawler between the control period and the four weeks of cooperation has been substantially more important in Le Grau-du-Roi than in Sète, with an order of magnitude of around 20%. We establish a causal link between the cooperation period and the increase in sales revenue. When simulating fictitious shocks of cooperation over four weeks at other periods of the year, we find no difference in the evolution in sales revenue per trawler between Le Grau-du-Roi and Sète.

We find that change in sales revenue is strongly related to increased quantities of fish caught by each trawler, while prices have remained stable over the period. The positive effect of quantity remains challenging in terms of interpretation. A large decrease in the number of trawlers will reduce total catches of fish, but the positive consequences on the fish stock are mainly expected in the medium and in the long run. Our findings suggest that decreasing substantially the fishing effort may increase the quantity of fish caught by each trawler even in the very short run, presumably because of reduced competition in the same fishing areas. Finally, we show that the evolution of total revenue per trawler has been much lower in Le Grau-du-Roi than in Sète because of the cooperation (around 40%). This means that the decrease in fishing time has not been offset by the increase in daily sales revenue, but the decrease in total revenue would have been worse (around 10 percentage points) without the additional catches of fish during the cooperation period.

The reminder of our contribution is organized as follows. In Section 2, we describe the context in which the decision of cooperation was implemented and discuss the expected effects of cooperation. Section 3 presents the transaction data. Section 4 investigates the impact of cooperation on the number of trawlers selling fish each day. In Section 5, we assess the effect of cooperation on the sales revenue received by a trawler each day of sale. In Section 6, we account for both the decrease in fishing time and increase in sales revenue to calculate the change in total revenue at the trawler level and at the fish market level. Finally, Section 7 concludes.

2. Context and expected effects

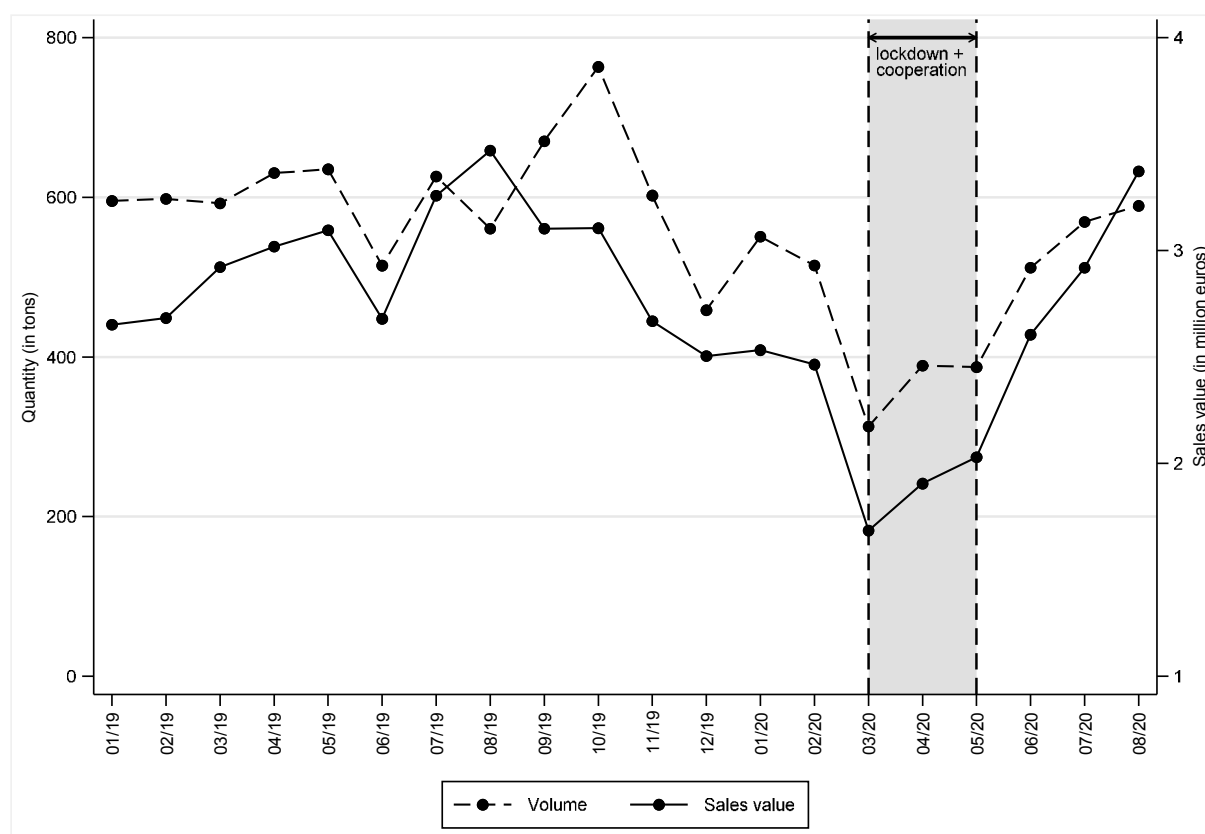
The situation of cooperation that we study took place in the context of the Covid pandemic that hit France in the first months of 2020. The first positive cases were officially recorded on January 24, 2020. At the beginning of March, the number of confirmed cases was around 200. Elementary schools and high schools were gradually being closed and the complete closure of all schools took place on March 12. On March 14, the Prime Minister decided the closure of all non-essential public places. In the aftermath, the President of the Republic announced a lockdown (home confinement) that took effect from March 17 at noon. Travels had to be reduced to the bare essentials and companies had to organize themselves to facilitate remote work. Cafés, restaurants and collective catering were closed, followed by a closure of open-air markets starting from March 24. As the number of cases progressively decreased during April, a deconfinement was implemented on May 11.

The lockdown has led to a massive contraction of economic activity. According to INSEE, GDP in volume declined by -13.8% in the second quarter of 2020 after -5.9% in the first quarter³. The

³ See https://www.insee.fr/fr/statistiques/fichier/version-html/4638729/CNT2020-t2_PE_.pdf

recession was clearly due to the shut-down of non-essential activities during the lockdown, leading to a substantial fall in household consumption expenditures of -11% during the second quarter of 2020. In such setting, a large part of the traditional outlets for seafood products including fish stores, fish departments of supermarkets, restaurants as well as collective catering was no longer available. This sharp drop in demand led to a large decrease in both volumes and values exchanged on fish markets from March to May 2020. Figure 1 shows the impact of the lockdown on the monthly volume and sales value observed in the four Mediterranean fish markets (Le Grau-du-Roi, Sète, Agde, Port-La-Nouvelle). Between February and March 2020, the monthly volume was divided by 1.65 (from 515 to 313 tons) and the sales value was divided by 1.68 (from 515 to 313 tons) and the sales value was divided by 1.68.

Figure 1. Monthly volume and sales value in Mediterranean fish markets



Source: authors' calculation, RIC data January 2019-August 2020.

Note: the area in grey corresponds to the months during which both the lockdown period (from March 17, 2020, to May 11, 2020) and the cooperation period (from May 5, 2020, to May 29, 2020) occurred.

On a market, the consequences of a negative demand shock can be signed without ambiguity. With a fixed supply, both the price P and the quantity Q will decrease at the equilibrium. This implies that the total revenue of the fishery $R = P * Q$ will also decrease. Suppose that the fleet comprises n identical trawlers with similar characteristics and fishing effort, so that $Q = n * Q_i$ with Q_i the quantity of fish per trawler. This means that the revenue per trawler R_i will be reduced after the

demand shock due to a negative price effect. In such depressed context, a scenario of cooperation leading to a rotation of trawlers was organized in the port of Le Grau-du-Roi. The mechanism implemented there was designed to adjust to market demand conditions. By substantially reducing the number of trawlers going out to sea through a local agreement, the aim was to reduce the volumes landed in the fish market of Le Grau-du-Roi and thus guarantee sufficient price levels in the context of a reduced demand.

The market of Le Grau-du-Roi is a cooperative managed by the fishermen themselves. The rotation was decided by skippers in conjunction with the director of the cooperative⁴. The cooperation was implemented from Tuesday, May 5 to Friday, May 29, 2020. The beginning of the cooperation thus coincided with the last week of the lockdown. The cooperation concerned only trawlers over 18 meters, whose contributions in Le Grau-du-Roi were around 80% in terms of volume and 70% in terms of sales value. The corresponding fleet, which includes 17 trawlers fulfilling the size criteria, was divided into two such that one half went out from May 5-11 and May 18-22 and the other half went out from May 12-15 and May 25-28. When they were not at sea, the crews were placed under a partial unemployment scheme with an activity allowance partially paid by the State. On the buyers' side, there was no particular organization and all buyers who wanted to purchase seafood products in the fish market of Le Grau-du-Roi (or in other fish markets) could do so.

The fishery under consideration is open access and trawlers from the various ports can go fishing in the same places. Nevertheless, French trawlers in the Mediterranean face a few constraints with respect to their fishing effort⁵. First, each day of trawl fishing is limited to a maximum of 15 hours per day within the limit of five fishing days per week. The trawlers under consideration make one-day fishing trips : they can leave the port starting from 3 am and must be back at 6 pm at the latest. Second, the total fishing effort allowed in 2021 was 10545 days, corresponding to an average of 183 days per trawler. This threshold was 11400 days in 2020, corresponding to an average of 200 days per vessel. Third, there are specific time-area closures. For instance, the area called CGPM is closed from November to April and there is an area between 90 to 100m isobaths closed from September to April. Those restrictions concern all trawlers.

A unique feature is that there was no mechanism of rotation in the other Mediterranean ports. During the period of cooperation, trawlers located in the ports of Sète, Agde and Port-La-Nouvelle could go fishing at sea. However, fishermen were facing the same depressed demand conditions and could be subject to the risk of unsold products and low prices. On a market, both a negative demand

⁴ The scenario of cooperation was decided during a meeting where around three-quarters of the fishermen were represented. Those who were not present were notified and complied with this arrangement, but there was no written agreement. We thank Perrine Cuvilliers for the description of the local context.

⁵ For details, see <https://www.comite-peches.fr/peche-et-monde-maritime/plan-de-gestion-europeen-pour-les-especes-demersales-de-mediterranee-occidentale/>.

shock and a negative supply shock lead to mixed predictions. On the one hand, the total quantity is expected to decrease due to both the negative demand and negative supply effects. On the other hand, the impact on price cannot be signed at the equilibrium. While the negative demand shock should reduce price, the negative supply shock has the opposite effect.

In Appendix A, we present a simple theoretical framework to study the effect of cooperation on the vessel's revenue R_i on the supply side. We consider two cases depending on whether the quantity of fish caught by each trawler depends on the number of other trawlers fishing. When there is no congestion effect (meaning that Q_i does not depend on n), a lower number of trawlers reduces mechanically the total quantity of fish caught and this contributes to a rise in fish prices on the market. When there is competition in fishing between trawlers (congestion effect), the situation may be different depending on the elasticity of fish caught with respect to the number of trawlers. If the congestion is high, then a reduced number of trawlers may lead to an increase in the total quantity of fish caught. This would in turn contribute to the price decrease and the economic situation of each trawler could even worsen under cooperation, even if such scenario seems unlikely.

As we consider an open access fishery, congestion may be a concern especially as trawlers of ports located nearby will essentially fish in the same area. Thus, the decision of cooperation could lead to a rise in the quantity of fish caught per trawler even in the short run, but the large cut in trawlers fishing is expected to reduce the total quantity landed. Overall, the new equilibrium on the fish market will depend on the intensity on both the negative demand and supply shocks, so that assessing the impact of cooperation on both prices and quantities deserves an empirical investigation.

A final element of context concerns the existence of public aids related to the pandemic. Specifically, ship owners whose fishing activities were suspended during at least 15 days during the lockdown could receive a financial compensation up to 30% of their average sales⁶. The eligibility period for this measure was from March 12, 2020 through May 31, 2020. This public scheme was available to all fishermen whatever their location. Put in different words, fishermen in Le Grau-du-Roi and fishermen in ports located nearby had the same incentives to reduce their activity whatever their location. At the same time, the compensation rate was low (30%) and did not necessarily compensate fixed costs. Therefore, it could be much more profitable for fishermen to catch and sell fish even in a context of reduced demand.

3. Data

⁶ For details on the public aid scheme, see <https://www.circulaires.gouv.fr/jorf/id/JORFTEXT000041841508>.

In France, seafood products are sold in fish markets called “*halles à marée*”. They correspond to physical places where seafood products are first marketed when they are landed in ports. In 2019, quantities sold in those markets by French vessels represented 173,812 tons for a sales value of 599 million euros (FranceAgriMer, 2020). In 2019, there were 37 fish markets along the French coasts : 33 in the English Channel and in the Atlantic Ocean, and 4 in the Mediterranean Sea⁷. Here, we consider a natural experiment which concerns the Mediterranean coast. In this area, the four fish markets were in decreasing order of sales value in 2019: Le Grau-du-Roi (12.555 million euros with 2,413 tons sold), Sète (10.867 million euros with 2,389 tons sold), Agde (7.357 million euros with 1,424 tons sold), and Port-La-Nouvelle (5.538 million euros with 1,415 tons sold) (FranceAgriMer, 2020).

To assess the impact of cooperation implemented in Le Grau-Du-Roi, we rely on detailed transaction data collected by FranceAgriMer through the network of French fish markets (called “*Réseau Inter Criées*”, RIC hereafter). The RIC data includes all transactions completed each day in all French fish markets. The database comprises a small number of variables. For each fish lot, we know the detailed characteristics of the fish, including fish species, size, presentation and quality, the quantity sold and the sale value from we deduce the price per kilo, the date of sale, the location of sale (fish market), and both seller and buyer identifiers. Since we are able to identify the vessels, we can count the number of trawlers selling their fish lots each day in each market and thus evaluate the effect of the cooperation on both sales, prices and volumes sold.

The dataset covers the period from the beginning of January 2019 to the end of August 2020. When considering all vessels (whatever their size), the database includes around 2,3 million transactions for the four fish markets of Le Grau-du-Roi (778,347 transactions, 33.6%), Sète (658,088 transactions, 28.4%), Agde (497,183 transactions, 21.5%) and Port-La-Nouvelle (381,238 transactions, 16.5%). When focusing on trawlers of 18 meters and over, the sample reduces to 1,882,355 transactions with 629,658 in Le Grau-du-Roi (33.5%) and 567,683 in Sète (30.2%). The contributions of Le Grau-du-Roi and Sète to the total sales value over the period are 34.6% and 36.5%, and 31.0% and 36.6% when considering the total volume.

In what follows, we will focus on the fish markets of Le Grau-du-Roi and Sète. Indeed, both markets are very similar with respects to both number of transactions, quantity and sales value, while Agde and Port-La-Nouvelle correspond to much smaller fish markets with a contribution to total sales comprised between 14% and 15% per market. Also, there are differences in the composition of the fleet since the number of trawlers over 18 meters is twice lower in Agde (N=9) and Port-La-Nouvelle

⁷ Fish prices and species differ between the Atlantic and Mediterranean markets (Gobillon and Wolff, 2016). On average, prices are around one-third higher on the Mediterranean coast compared to markets on the Atlantic coast net of fish characteristics (species, size, presentation, quality) as well as buyer and seller time-invariant heterogeneity.

(N=7) than in Le Grau-du-Roi (N=17) and Sète (N=18). Trawlers have quite similar characteristics in those two ports although vessels are slightly larger in Sète compared to Le Grau-du-Roi. The average size ranges between 22 and 24 meters, the average engine power is between 318 and 330 kwh and the average gross tonnage is 121.1 in Sète against 92.1 in Le Grau-du-Roi. Finally, when looking at the composition of fish species landed, we find large similarities between both markets. Among the top six species in terms of sales value, five are common to Le Grau-du-Roi and Sète : octopus (1st in Le Grau-du-Roi with 16.5%, 3rd in Sète with 12.6%), hake (2nd with 12.2%, 2nd with 14.0%), sole (3rd with 8.2%, 5th with 5.4%), mackerel (4th with 6.0%, 4th with 6.0%) and monkfish (6th with 5.0%, 5th with 17.0%).

In what follows, we will compare how the various outcomes under consideration (daily number of trawlers, sales revenue, quantity, price) have changed over time in Le Grau-du-Roi and Sète. For that purpose, we turn to usual DID estimators (Angrist and Pischke, 2008; Wooldridge, 2010). In our setting, Le Grau-du-Roi is the treated fish market in which a scenario of cooperation leading to a rotation of trawlers was implemented, while Sète is the control fish market in which no cooperation occurred.

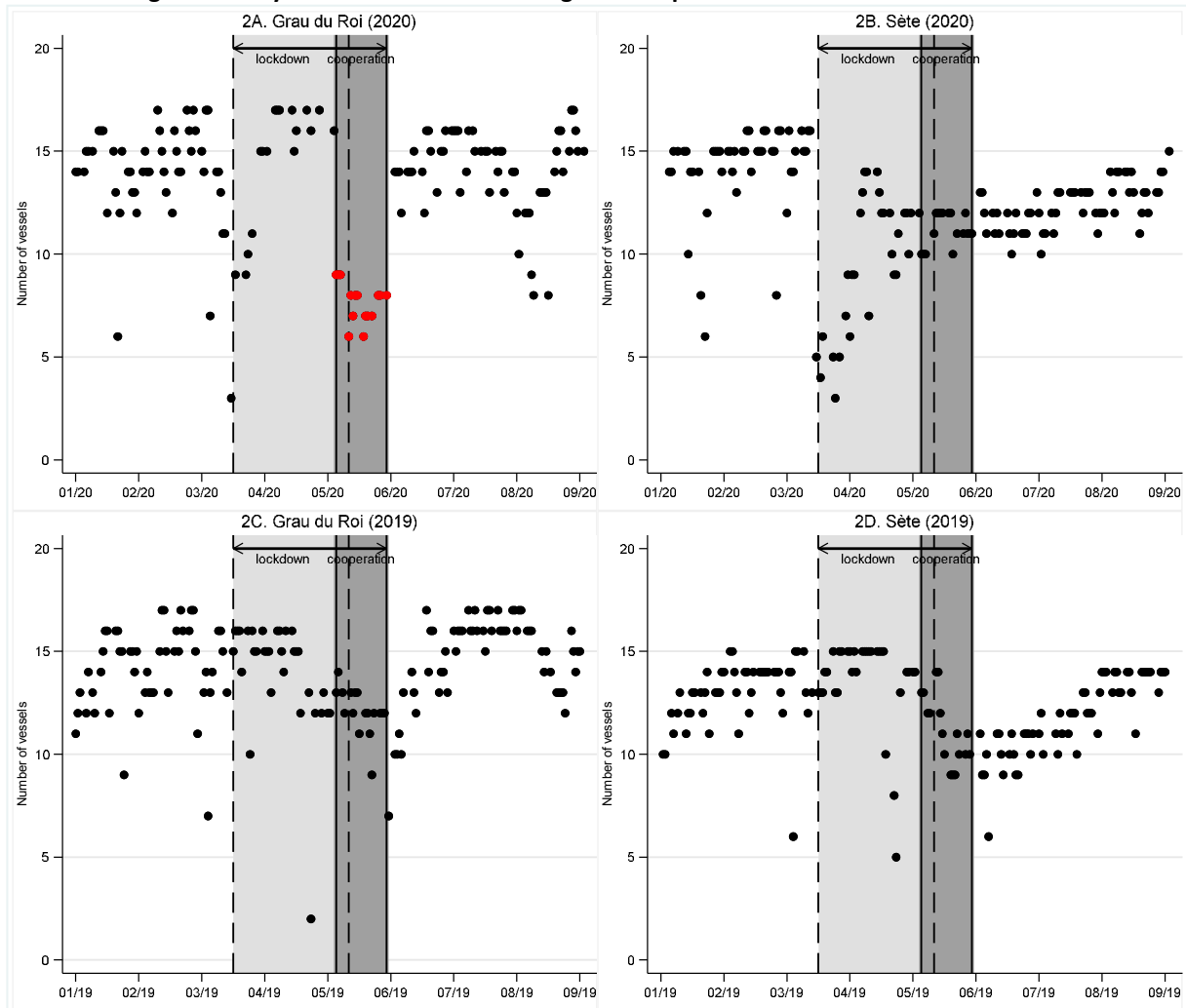
4. The impact of cooperation on the number of trawlers

We begin by quantifying the impact of the rotation mechanism on the number of trawlers over 18 meters selling fish each day in Le Grau-du-Roi during the year 2020. For that purpose, we use the transaction database as we have the vessel identifier for each lot of fish sold during a given day. As shown in Figure 2A, the average number of trawlers in Le Grau-du-Roi was around 15 in January and February 2020. This number strongly reduced to around 10 two weeks before and two weeks after the beginning of the lockdown, after that period there was an increase between 15 and 17 trawlers in April. The reduction of the size of the fleet was substantial during the cooperation period (bullets being in red), with a number of trawlers mainly ranging between 7 and 8. Afterwards, the number of trawlers returned to its value observed at the beginning of the year, with between 14 and 16 trawlers selling fish each day in June and July.

In Figure 2B, we investigate the number of trawlers selling fish each day in Sète. Interestingly, the profiles in the fish markets of Le Grau-du-Roi and Sète are very similar in January and February 2020, with around 15 trawlers selling fish per day on average. Then, the lockdown led to a huge decrease in Sète during the second part of March. Starting from the mid of April, the number of trawlers selling fish daily was around 12 per day, but there was absolutely no decrease in this number of trawlers in Sète during the cooperation period in Le Grau-du-Roi. Obviously, this was expected as no rotation was implemented in Sète. In Figure 2C and 2D, we replicate the same analysis from January to August 2019. Both in Le Grau-du-Roi and Sète, the number of trawlers remains fairly flat from January to the

mid of April 2019, then this number decreases slightly. Although not exactly at the same level (with slightly more trawlers per day in Le Grau-du-Roi than in Sète), we find very similar profiles in both fish markets during the period from May 5 to May 29, 2019. So there was no fall in 2019 as observed in 2020, which was again expected at there was no rotation of trawlers in Le Grau-du-Roi in 2019.

Figure 2. Daily number of trawlers selling seafood products in Le Grau-du-Roi and Sète



Source: authors' calculation, RIC data January 2019-August 2020.

Note : the area in light grey corresponds to the lockdown period (from March 17, 2020, to May 11, 2020), the area in dark grey corresponds to the cooperation period (from May 5, 2020, to May 29, 2020). The same fictitious periods are considered for 2019.

We turn to an econometric analysis to evaluate the impact of the rotation on the fleet. Let n_{mt} be the number of trawlers selling fish in market m on day t . We have either $m = \mathcal{G}$ for Le Grau-du-Roi or $m = \mathcal{S}$ for Sète. We denote by \mathbb{C}_t the cooperation period such that $\mathbb{C}_t = 1$ from May 5, 2020, to May 29, 2020, and $\mathbb{C}_t = 0$ otherwise. We are interested in an estimation of the partial derivative $\frac{\partial n_{mt}}{\partial \mathbb{C}_t}$. As a preliminary step, we study the magnitude of the change around the discontinuity for the fish market of Le Grau-du-Roi ($m = \mathcal{G}$). Specifically, we compare the daily number of trawlers selling fish during the 24-days cooperation period with a period of exactly similar length (24 days) beginning just after the end of the cooperation period (from May 30, 2020, to June, 18, 2020). For that purpose, we consider the following before-after estimator:

$$\ln n_{gt} = \alpha_0 + \alpha_C * \mathbb{C}_t + w_t + \varepsilon_{gt} \quad (1)$$

where α_0 and $\alpha_{\mathcal{C}}$ are parameters to estimate, w_t is a calendar day fixed effect, and ε_{gt} is a residual with $E[\varepsilon_{gt}] = 0$. For the fish market of Le Grau-du-Roi in 2020, the sample includes 29 observations and we obtain an estimated parameter $\hat{\alpha}_{\mathcal{C}} = -0.605$ with $t = -14.99$. As expected, the cooperation period has a large impact since the rotation mechanism has reduced by $(\exp(-0.605) - 1) * 100 = -45.4\%$ the number of trawlers selling fish each day in Le Grau-du-Roi⁸. By comparison, we estimate the same regression using the same before-after periods for the year 2019. The before period (fictitious cooperation) is assumed from May 5 to May 29, 2019, and the after period is assumed from May 30 to June 18, 2019. In that case, the sample includes 31 observations and we obtain an insignificant value for $\hat{\alpha}_{\mathcal{C}}$ with $t = -0.27$. The null assumption $H_0: \hat{\alpha}_{\mathcal{C}} = 0$ is hence accepted, which was expected due to the lack of cooperation in 2019.

The main drawback of the before-after estimation strategy is that there may be changes around the discontinuity due to seasonal effects. For instance, there may be different weather conditions in May and in June, there may be different fish species to catch due to differences in sea temperature, and prices may vary on fish markets due to demand effects (with more tourists along the Mediterranean coast in June than in May for instance). All those features should affect incentives for trawlers to go fishing. As we have two different fish markets, we consider a DID estimation strategy to compare whether the cooperation period has modified differently the number of vessels in Le Grau-du-Roi and Sète, respectively. Let \mathcal{G} be a dummy variable corresponding to Le Grau-du-Roi such that $\mathcal{G} = 1$ when $m = \mathcal{g}$ and $\mathcal{G} = 0$ when $m = \mathcal{s}$. The parameter of interest is $(E[n_{\mathcal{G}=1, \mathcal{C}_t=1}] - E[n_{\mathcal{G}=1, \mathcal{C}_t=0}]) - (E[n_{\mathcal{G}=0, \mathcal{C}_t=1}] - E[n_{\mathcal{G}=0, \mathcal{C}_t=0}])$. The DID specification is:

$$\ln n_{mt} = \alpha_0 + \alpha_{\mathcal{g}} * \mathcal{G}_{mt} + \alpha_{\mathcal{C}} * \mathcal{C}_t + \delta_{\mathcal{g}\mathcal{C}} * \mathcal{G}_{mt} * \mathcal{C}_t + w_t + \varepsilon_{mt} \quad (2)$$

where $\delta_{\mathcal{g}\mathcal{C}}$ indicates whether the difference in the daily number of trawlers between the cooperation and the non-cooperation period is different between the treated fish market (Le Grau-du-Roi) and the control fish market (Sète)⁹. For the sake of robustness, we assess the effect of cooperation with respect to different control periods. In four cases, we focus on changes around the discontinuity and consider different time windows: 25 days after the end of cooperation (from May, 30 to June, 28), 25 days before (from April, 10 to May, 4), 50 days after (from May, 30 to July, 18), and 50 days before (from March, 16 to May, 4). In doing so, we seek avoiding a comparison of situations with very different demand conditions. In a fifth scenario, we estimate the same regression with data from January to August as control, the four weeks of cooperation being excluded from the control period.

⁸ For a model of the form $\ln Y = a_0 + a_1 * X + \varepsilon$, the marginal effect of X when X is a dummy variable is $(\exp(a_1) - 1) * 100$.

⁹ We include a quartic time trend in the regression. Excluding the time trend or considering alternative profiles for the time trend has no incidence on our estimates.

We report the DID estimates in Table 1. Whatever the time windows, we find an insignificant coefficient for the cooperation dummy while the coefficient associated to the fish market of Le Grau-du-Roi is positive. Our main result is that the term corresponding to the interaction of the cooperation period and Le Grau-du-Roi is negative and significant. The magnitude of the marginal effect is substantial, ranging from -55.6% (50 days before) to -39.8% (January to August). As a consequence of the rotation implemented in Le Grau-du-Roi, the decrease in trawlers selling fish each day has been much more important in Le Grau-du-Roi than in Sète from May, 5 to May 29, 2020. When comparing the cooperation period with the 25 or 50 following days, the fall in the number of trawlers has been around 44%-45% higher in Le Grau-du-Roi than in Sète. This order of magnitude is rather similar to what is found over the whole year (-40%)¹⁰.

We have also compared the effect of the cooperation period in 2020 with the effect of a fictitious cooperation period in 2019 using a difference-in-difference-in-differences estimator (TID hereafter). The TID results (not reported) are very consistent with those obtained from the DID. The interaction term crossing the cooperation period, Le Grau-du-Roi and 2020 is always negative and significant. Around the discontinuity, the differential effect is about -32% / -34% when considering either 25 or 50 days after, -37.7% when considering the whole period from January to August, and up to -57% / -60% when considering either 25 or 50 days before. As we include in the TID regression data from 2019 during which no cooperation occurs, we can rule out the possibility that the difference between both fish markets could stem from differences not related to the cooperation in Le Grau-du-Roi. Overall, we conclude that the rotation of trawlers implemented in Le Grau-du-Roi had a massive impact on the daily number of vessels selling fish, while such negative shock was not observed in Sète.

Table 1. Effect of cooperation on the logarithm of the daily number of trawlers selling seafood products (DID estimates)

Variables	Treated period	Rotation from May 5 to May 29, 2020				
	Control period	(1) 25 days after	(2) 25 days before	(3) 50 days After	(4) 50 days before	(5) January to August
Cooperation		-0.028 (-0.42)	0.064 (0.62)	-0.024 (-0.42)	0.120 (1.02)	0.001 (0.02)
Le Grau-du-Roi		0.197*** (6.04)	0.382*** (7.47)	0.217*** (10.36)	0.435*** (6.45)	0.127*** (4.16)
Cooperation x Le Grau-du-Roi		-0.577*** (-11.33)	-0.765*** (-11.40)	-0.599*** (-13.81)	-0.813*** (-10.11)	-0.507*** (-10.39)
Day of the week + quartic daily trend	YES	YES	YES	YES	YES	YES
Number of observations		61	54	93	80	298
R ²		0.861	0.821	0.868	0.775	0.276

Source: authors' calculation, RIC data January 2019-August 2020.

Note: estimates from linear regressions, with robust standard errors. Significance levels for t-values in parentheses are 1 (***) , 5% (**) and 10% (*).

¹⁰ When the comparison is made with the period before the cooperation, the differential is even higher (-53.5% with 25 days before and -55.6% with 50 days after). This is due to some seasonality effect with more trawlers fishing in March and April compared to May and June.

5. The effect of cooperation on daily sales revenue

We begin with a comparison of trends in sales revenue for trawlers selling their fish in Le Grau-du-Roi and Sète. In Figure 3, we report the average revenue per day of sale for each week from January 2020 to August 2020. Prior to the implementation of the cooperation, the revenues of trawlers in Le Grau-du-Roi were on average lower than those of trawlers in Sète, except for the first week of the lockdown period. The average revenue of a trawler from the beginning of January to mid-March 2020 was 305.3 euros lower in Grau-du-Roi than in Sète (2327.0 against 2632.3 euros). The situation reversed during the cooperation period and the average revenue became higher in Le Grau-du-Roi than in Sète (+113.4 euros, 2788.1 against 2674.7 euros)¹¹. Then, from June to August, there was a return to the initial situation with a higher average revenue for trawlers in Sète.

Figure 3 also shows changes in quantities and prices over the period. The situations in the two fish markets are different. During the period before lockdown, trawlers sold less fish on average in Le Grau-du-Roi compared to Sète (-165.5 kilos, 440.7 against 606.2 kilos), while the average price was higher in Le Grau-du-Roi than in Sète (+94 cents, 5.28 against of 4.34 euros per kilo). During the lockdown period, the difference observed in total revenue is mainly explained by an increase in the quantity sold per vessel in Le Grau-du-Roi. In both fish markets, trawlers sold more or less the same quantities (645.3 kilos in Le Grau-du-Roi and 657.8 kilos in Sète), while the price remained higher in Le Grau-du-Roi compared to Sète (+25 cents, 4.32 instead of 4.07 euros per kilo). Once the cooperation period was over, trawlers in Le Grau-du-Roi sold lower quantities on average and the price per kilo was higher. The same pattern was observed during the first months of the year 2020.

To estimate the impact of the cooperation period on sales revenue of trawlers, we consider again a DID strategy and compare changes in the daily sales revenue for trawlers in Le Grau-du-Roi and Sète during the cooperation period and a control period. Using the previous notation and defining by R_{it} the sales revenue of a trawler i at date t (t being a day of sale), we estimate the following model¹²:

$$\ln R_{it} = \alpha_0 + \alpha_C * C_t + \delta_{gC} * G_{it} * C_t + \theta_i + w_t + \varepsilon_{it} \quad (3)$$

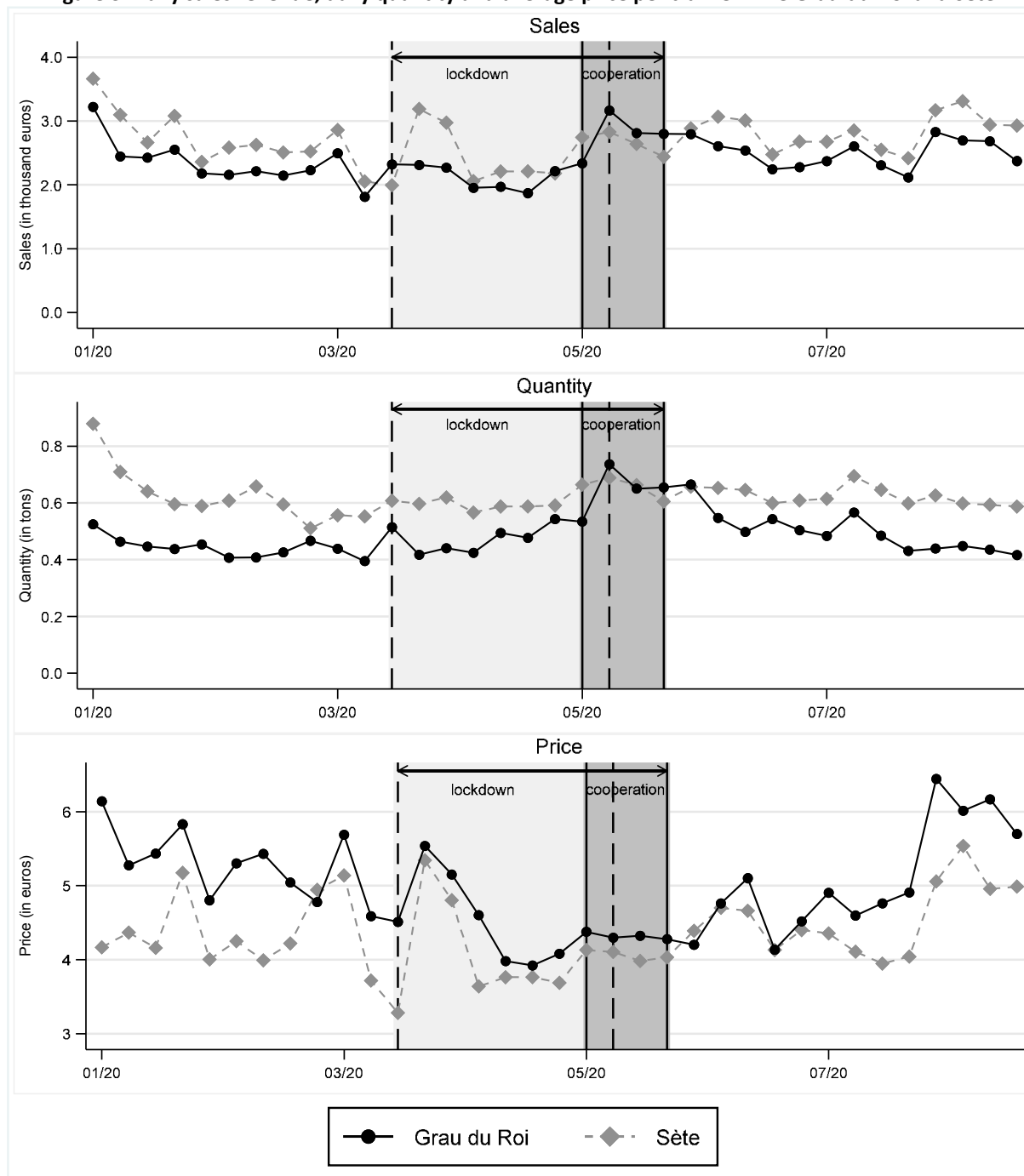
In (3), the coefficient δ_{gC} indicates whether the variation in the average sales revenue between the cooperation period and the control period is different between Le Grau-du-Roi and Sète. We introduce in the regression a trawler fixed effect θ_i which is expected to pick up all observed and unobserved time-invariant characteristics of trawlers. This includes technical characteristics of the trawlers like size or engine power. As a consequence, we exclude the variable G_{it} from the list of

¹¹ The increase in sales revenue essentially begins in the second week of the cooperation period, but the first week corresponds to the last week of the lockdown.

¹² We do not control for any covariates in our DID regression. By construction, the total revenue is the sum of the revenue for each fish species, so it depends in some sense on the composition of fish species caught. As trawlers of Le Grau-du-Roi and Sète catch fish in the same area, they catch the same fish species and the composition of species remains random anyway. For the sake of robustness, we have estimated regressions with the proportion of the most important fish species caught as covariates and obtain very similar results.

regressors as each trawler always sells fish in the same market over the period¹³. Again, we consider different control periods to estimate the DID regression : 25 days after the end of cooperation, 25 days before, 50 days after, 50 days before, and from January to August.

Figure 3. Daily sales revenue, daily quantity and average price per trawler in Le Grau-du-Roi and Sète



Source: authors' calculation, RIC data January 2019-August 2020.

Note: the area in light grey corresponds to the lockdown period (from March 17, 2020, to May 11, 2020), the area in dark grey corresponds to the cooperation period (from May 5, 2020, to May 29, 2020). The same fictitious periods are considered for 2019.

¹³ The coefficient associated to G_{it} is not identified because of the inclusion of the fixed effect θ_i .

We report the DID estimates in Table 2. Whatever the length of the control period, we find a positive and significant coefficient for the interaction term crossing the cooperation period with Le Grau-du-Roi. This means that the increase in sales revenue between the control and cooperation periods has been higher in Le Grau-du-Roi than in Sète. The order of magnitude is around 23% when the comparison is with the four or eight weeks following cooperation, around 16% when the comparison is with the four or eight preceding weeks, and 21% when considering the whole year. For the sake of robustness, we have estimated an extended set of DID regressions for which the control period was allowed to range between 10 and 120 days before the cooperation and between 10 and 90 days after the cooperation (with a step of 10 days). The corresponding results confirm that the DID marginal effect is essentially comprised between 15% and 20%.

Table 2. Effect of cooperation on sales revenue of trawlers (DID estimates)

Variables	Rotation from May 5 to May 29, 2020					
	Treated period Control period	(1) 25 days after	(2) 25 days before	(3) 50 days After	(4) 50 days before	(5) January to August
A. DID estimates – Fish markets = Grau du Roi and Sète – Year = 2020						
Cooperation		-0.211*** (-2.75)	0.096 (1.61)	-0.260*** (-3.74)	0.071 (1.29)	0.046** (2.01)
Cooperation x Le Grau-du-Roi		0.205*** (5.18)	0.159*** (4.18)	0.208*** (6.52)	0.150*** (3.91)	0.191*** (6.52)
Day of the week + quartic daily trend	YES	YES	YES	YES	YES	YES
Vessel fixed effects	YES	YES	YES	YES	YES	YES
Number of observations		675	586	1,109	845	3,817
R ²		0.080	0.269	0.072	0.223	0.105

Source: authors' calculation, RIC data January 2019-August 2020.

Note : estimates from fixed effect regressions, with robust standard errors. Significance levels for t-values in parentheses are 1% (*), 5% (**) and 10% (*).

We have also estimated the impact of the cooperation period on sales revenue using a TID estimator to the 2019 and 2020 period. When the control period is either 25 days after or 25 days before, we find very similar results using the DID and TID estimators with a marginal effect of around 20%. When the comparison is made with the period of 50 days after, the TID estimator remains significant but it is about half the size of the DID estimator (around 10%). We have further investigated why trawlers in Le Grau-Du-Roi performed better in terms of revenue than trawlers in Sète in May 2019. A close look at the composition of fish species sold by trawlers shows that from May to July 2019 the number of lots of common octopus was twice as large in Le Grau-du-Roi as in Sète (N=7,544 against N=3,825), while the number of lots of octopus was much more similar from May to July 2020 (N=3,334 against N=2,792). The average price of octopus was 7.21 euros per kilo in 2019, which is an explanation of the additional revenue of trawlers in Le Grau-du-Roi in June and July 2019 compared

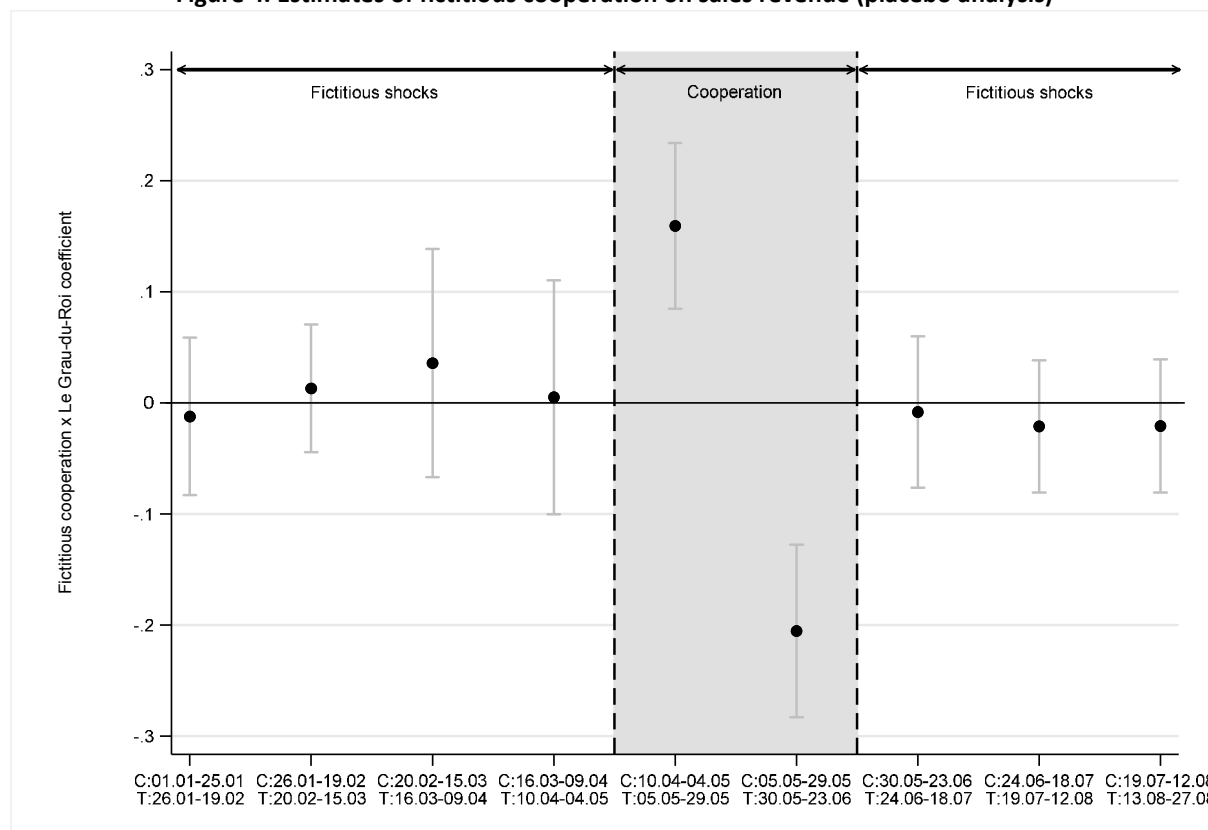
to Sète¹⁴. Overall, the comparison between 2020 and 2019 indicates that the cooperation has led to increased sales revenue for trawlers in Le Grau-du-Roi compared to Sète.

Next, we turn to a placebo analysis to prove that the significant DID coefficient is a consequence of the cooperation period. For that purpose, we simulate fictitious cooperation periods at other points of time. Since the duration of the cooperation period is 25 days, we consider fictitious treatment periods of 25 days which we compare to control periods of 25 days (so time windows of 50 days in all). We assume that the treated period is always after the control period. For instance, if we consider the period from January 1st to February 19th, we assume a control period from January 1st to January 25th and a fictitious cooperation from January 26th to February 19th. We repeat the procedure till the end of August 2020. At the end, we obtain nine point estimates of the impact of cooperation among which seven are fictitious periods (in the sense that there was no cooperation) and two correspond to situations impacted by the cooperation implemented in Le Grau-du-Roi : from April 10th to May 29th with a cooperation from May 5th to May 29th, and from May 5th to June 23rd with a fictitious cooperation from May 30th to June 23rd (in that case, the control period is when cooperation occurs). We present our results in Figure 4. Assuming a fictitious treatment from January 26th to February 29th, we find that this shock translates into a DID coefficient that is very small and not significant at all. This result was expected as there was no cooperation in February 2020. The next three DID estimates corresponding to a fictitious cooperation from February 20 to March 15, from March 16 to April 9 and from April 10 to March 4, respectively, are also very low in magnitude and the null hypothesis of no difference between Le Grau-du-Roi and Sète cannot be rejected. The next estimate corresponds to the “true” cooperation period, from May 5th to May 29th, and thus the DID estimate is 17.2% (see column 2, panel A, Table 3). When considering the period from May 5th to June 23rd, the control period is in fact that during which cooperation occurs while there is no cooperation in the fictitious treated period from May 30th to June 23rd. In that case, the DID estimate associated to the fictitious treatment corresponds to the opposite of the true DID estimate and is thus -18.5% (column 1, panel A, Table 3)¹⁵. Finally, for the last three periods (from May 30th to August 27th) during which no cooperation occurred, the DID coefficient associated to a fictitious shock is not statistically different from zero. Again, this was expected as no cooperation took place.

¹⁴ When excluding that fish species (common octopus), we find an increase of 37.5% in the TID coefficient when comparing the cooperation period with the 50 following days.

¹⁵ Let $\mathbb{F}_t = 1 - \mathbb{C}_t$ be the period of fictitious cooperation. Using (3), it follows that $\ln R_{it} = \alpha_0 + \alpha_C * (1 - \mathbb{F}_t) + \delta_{gC} * \mathcal{G}_{it} * (1 - \mathbb{F}_t) + \theta_i + w_t + \varepsilon_{it}$ and thus the DID regression is $\ln R_{it} = (\alpha_0 + \alpha_C) - \alpha_C * \mathbb{F}_t + \delta_{gC} * \mathcal{G}_{it} - \delta_{gC} * \mathcal{G}_{it} * \mathbb{F}_t + \theta_i + w_t + \varepsilon_{it}$. The coefficient associated to the interaction term $\mathcal{G}_{it} * \mathbb{F}_t$ is thus $-\delta_{gC}$.

Figure 4. Estimates of fictitious cooperation on sales revenue (placebo analysis)



Source: authors' calculation, RIC data January 2019-August 2020.

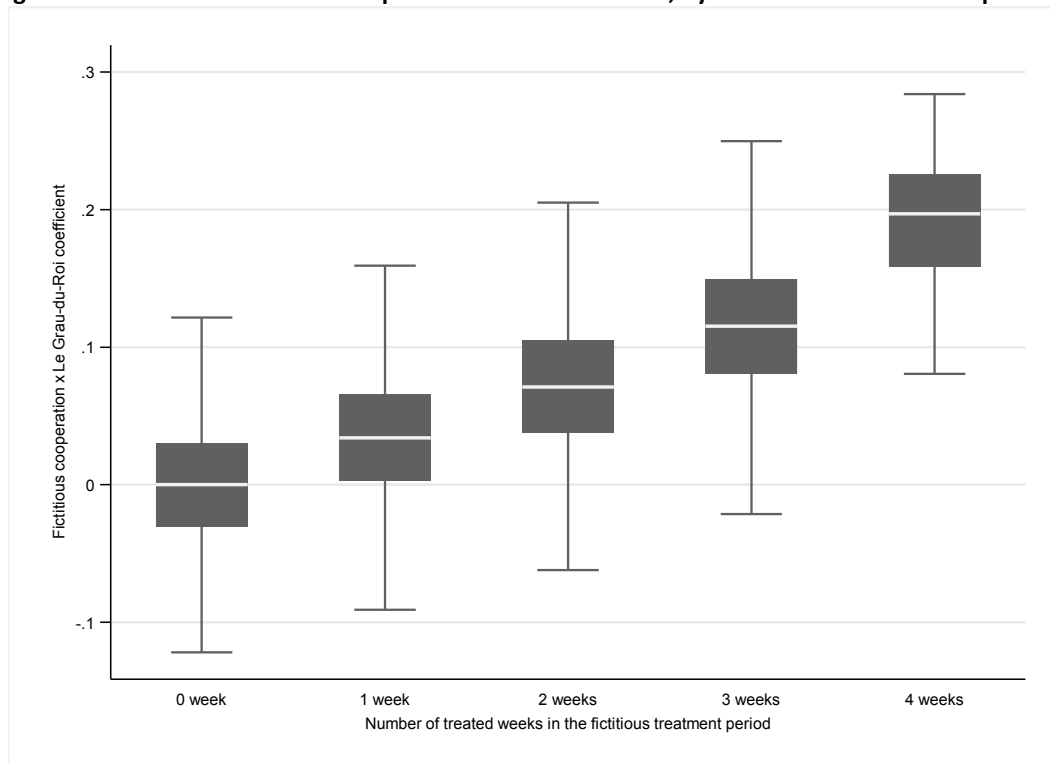
Note: the area in grey corresponds to the period during which the cooperation took place. The DID estimates are obtained from fixed effect regressions. Confidence intervals at the 95 percent level are calculated using robust standard errors.

A potential shortcoming of our previous analysis is that we only focus on adjacent periods of four weeks, which gives us a limited number of placebo estimates. We extend the procedure by generating periods of four weeks such that each week is drawn randomly within the 35 weeks available in our data for the year 2020. We proceed in the following way. First, we generate two random draws of four numbers such that each number corresponds to a given week between January and August 2020. The first draw defines the control period and the second draw defines the fictitious cooperation period. Second, we calculate the number of weeks corresponding to the real cooperation period (May 2020) in each sequence of four weeks. We keep draws such that there was no week belonging to May 2020 in the control period and at least one week (and up to four) belonging to May 2020 in the treated period. Third, when the above conditions were satisfied, we estimate the DID regression for each draw using equation (4) and focus on the interaction term crossing the treated period and Le Grau-du-Roi. This procedure was replicated 100,000 times.

We present our results in Figure 5 where we consider box plots showing the median, the 25th percentile and the 75th percentile of the interaction term as well as the upper and lower adjacent values. We draw five box plots depending on the number of weeks (from 0 to 4) belonging to May

2020 in the fictitious four-weeks cooperation. Our results confirm the role of the cooperation period in the increase in sales revenue per trawler in Le Grau-du-Roi compared to Sète. Clearly, the magnitude of the interaction term increases as the number of weeks belonging to May 2020 increases in the simulated sequence of four weeks of cooperation. When there is no week of May 2020 in the simulated treated period, the magnitude of the average interaction term is -0.1%. Then, the average interaction term increases gradually with the number of weeks of May 2020 included in the treated period: 3.6% with one week, 7.4% with two weeks, 12.2% with three weeks and 21.8% with four weeks which is very close to the estimates reported in Table 2. Thus, we conclude that the effect we obtain using the DID specification is causal and related to the decision of cooperation in Le Grau-du-Roi.

Figure 5. Estimates of fictitious cooperation on sales revenue, by number of weeks of cooperation



Source: authors' calculation, RIC data January 2019-August 2020.

Note : each box plot shows the median, 25th percentile and the 75th percentile as well as the upper and lower adjacent values. Estimates are obtained using 100,000 simulations.

Finally, we seek to understand to what extent the different changes in daily sales revenue between trawlers located in Le Grau-du-Roi are due to changes in quantity or changes in price. By construction, the sales revenue is $R = P * Q$. Taking the logarithm, the derivation with respect to any variable z gives $\frac{d \ln R}{dz} = \frac{d \ln P}{dz} + \frac{d \ln Q}{dz}$, so that the total effect of the DID interaction term on sales revenue is the sum of a price effect and a quantity effect. Thus, we estimate the DID regression model given by (3) with the logarithm of the price and the logarithm of the quantity as dependent

variables, respectively. Following our previous approach, we consider five different periods of control to assess the effect of cooperation (25 days after, 25 days before, 50 days after, 50 days before, from January to August).

We report the DID estimates for sales revenue, price and quantity in Table 3. In column (1), we consider a control period of 25 days after the cooperation. The DID estimate for quantity is slightly lower than that for sales revenue, while that for price is insignificant. Clearly, the average sales revenue has improved for trawlers in Le Grau-du-Roi because trawlers have caught and sold more fish during the cooperation period (compared to those in Sète), while fish prices have remained unchanged. The contribution of the quantity effect to the total effect amounts to 91.2%. The importance of quantity of fish sold is observed whatever the time windows. For instance, the contribution of the quantity effect is 96.6% with a time windows of 50 days after the end of cooperation and even greater than 100% with a time windows of 50 days before, meaning that the increase in sales revenue per trawler would have been even higher if fish prices would not have decreased in Le Grau-du-Roi.

Table 3. Effect of cooperation on quantity, price and revenue

Variables	Treated period	Rotation from May 5 to May 29, 2020				
		Control period	(1) 25 days after	(2) 25 days before	(3) 50 days After	(4) 50 days before
DID estimates – Fish markets = Grau du Roi and Sète – Year = 2020						
A. Effect on sales revenue						
Cooperation x Le Grau du Roi	coef.	0.205***	0.159***	0.208***	0.150***	0.191***
	t-value	(5.18)	(4.18)	(6.52)	(3.91)	(6.52)
	%	100.0	100.0	100.0	100.0	100.0
B. Effect on quantity						
Cooperation x Le Grau du Roi	coef.	0.187***	0.145***	0.201***	0.192***	0.275***
	t-value	(3.73)	(3.39)	(5.26)	(4.91)	(8.30)
	%	91.2	91.2	96.6	128.0	144.0
C. Effect on price						
Cooperation x Le Grau du Roi	coef.	0.018	0.014	0.008	-0.042	-0.084**
	t-value	(0.66)	(0.50)	(0.31)	(-1.39)	(-3.87)
	%	8.8	8.8	3.8	-28.0	-44.0

Source: authors' calculation, RIC data January 2019-August 2020.

Note : estimates from fixed effect regressions, with robust standard errors. Significance levels for t-values in parentheses are 1% (*), 5% (**) and 10% (*).

6. Discussion

The issue of overfishing is a serious concern for many fisheries. This is particularly the case in the Mediterranean where effort-reducing policies have been implemented to align fishing capacity with fish resources. However, the impact of a reduction in the trawler fleet on the economic situation of fisheries remains poorly documented. The decision of cooperation taken in Le Grau-du-Roi in May 2020 corresponds to a natural experiment that allows us to study the consequences of a large and spatially localized reduction in fishing effort. Using transaction data, our empirical analysis compares

two fish markets geographically close and very similar with respect to their trawler fleet, Le Grau-du-Roi and Sète. Estimates obtained using a DID strategy provide several results of interest.

The first result concerns the impact of cooperation on the fishing effort. When considering the number of trawlers selling their catch each day as outcome, we find that the rotation implemented in Le Grau-du-Roi led to a decrease in the number of trawlers which was 45% more important in Le Grau-du-Roi than in Sète when the control period selected for the comparison is near the cooperation period. The difference is 40% with the period from January to August 2020. This variation is slightly smaller than the expected impact at the vessel level. Each trawler based in Le Grau-du-Roi remained in port two weeks out of the four weeks when cooperation took place, which corresponds to a differential of 50% with respect to Sète where the trawlers were not impacted. This suggests that a small number of vessels in Le Grau-du-Roi has also decided to spend less time fishing during the period.

The second result concerns the impact of cooperation on sales revenues generated each day. The comparison between Le Grau-du-Roi and Sète shows that the daily sales revenue per trawler increased faster in the former fish market. The differential is 23% when considering a control period of 25 days after the cooperation and 21% when considering the period from January to August 2020. The order of magnitude obtained for the daily revenue sales is not very sensitive to the time window selected for the control period. Furthermore, the simulation of situations of fictitious cooperation confirms that the difference in sales revenue between both markets observed in May 2020 is a consequence of cooperation. Indeed, no significant difference is observed between Le Grau-du-Roi and Sète when estimating the impact of a fictitious cooperation at other periods of the year.

The third result is that differences observed in sales revenue are explained by a quantity effect and not by a price effect. Prices changed very little over the period, which is probably related to the fact that while each trawler sold more fish, the total number of trawlers selling fish was at the same time reduced. The increase in quantities per trawler in Le Grau-du-Roi remains challenging in terms of interpretation. A first explanation could be increased fishing time per vessel, but that was not the case. Indeed, trawlers in Le Grau-du-Roi and Sète have both a maximum number of trawl hours per day (time to fishing areas and trawling time cannot exceed 15 hours, from 3am to 6pm) and a maximum number of fishing days. Given those constraints, fishermen use all their daily hours fishing when they are on sea, hours not fished leading to a loss of revenue¹⁶. A second explanation is related to congestion as trawlers fish in the same area. A large decrease in the number of trawlers may increase catches per trawler even in the short term due to the decrease in congestion. Vessels will be

¹⁶ In addition, we had some discussions with the officials of the local fisheries committee who confirmed the lack of change in fishing hours during the cooperation period.

less in competition over the same area and have therefore more opportunities to fish in areas with a high concentration of fish.

Whatsoever, this positive effect on the daily quantity sold does not compensate for the reduction in time spent at sea by trawlers. Our estimates allow us to provide an order of magnitude of how the total revenue per trawler has decreased as a result of the four-weeks cooperation period. Let $R_i^{\mathbb{C}}$ be the sales revenue of trawler i during the cooperation period \mathbb{C} . Let \mathbb{U} be the control period selected for the comparison with \mathbb{C} . We denote by $R_i^{\mathbb{U}}$ the corresponding sales revenue for trawler i . Since we estimate a DID regression explaining the total sales revenue R_i expressed in logarithm, then the term crossing the cooperation period with the Grau-du-Roi dummy is equal to $(\ln R_{i,g}^{\mathbb{C}} - \ln R_{i,g}^{\mathbb{U}}) - (\ln R_{i,s}^{\mathbb{C}} - \ln R_{i,s}^{\mathbb{U}})$, which may also be expressed as $\ln\left(\frac{R_{i,g}^{\mathbb{C}}/R_{i,g}^{\mathbb{U}}}{R_{i,s}^{\mathbb{C}}/R_{i,s}^{\mathbb{U}}}\right)$.

The total revenue of a trawler i can be expressed as $R_i^{\mathbb{C}} = d_{i\mathbb{C}}^{\mathbb{C}} * R_{it}^{\mathbb{C}}$, where $d_{i\mathbb{C}}^{\mathbb{C}}$ is the number of days when trawler i sell fish during the period \mathbb{C} and $R_{it}^{\mathbb{C}}$ is the average revenue per day of sale t for trawler i . For a vessel in Le Grau-du-Roi, the ratio $\frac{R_{i,g}^{\mathbb{C}}}{R_{i,g}^{\mathbb{U}}}$ is such that $\frac{R_{i,g}^{\mathbb{C}}}{R_{i,g}^{\mathbb{U}}} = \frac{d_{i,g}^{\mathbb{C}} R_{it,g}^{\mathbb{C}}}{d_{i,g}^{\mathbb{U}} R_{it,g}^{\mathbb{U}}} = 0.5 \frac{R_{it,g}^{\mathbb{C}}}{R_{it,g}^{\mathbb{U}}}$ since $d_{i,g}^{\mathbb{C}} = 0.5 * d_{i,g}^{\mathbb{U}}$: each trawler fished two weeks instead of four in Le Grau-du-Roi during the cooperation period. In Sète, the ratio $\frac{R_{i,s}^{\mathbb{C}}}{R_{i,s}^{\mathbb{U}}}$ is such that $\frac{R_{i,s}^{\mathbb{C}}}{R_{i,s}^{\mathbb{U}}} = \frac{d_{i,s}^{\mathbb{C}} R_{it,s}^{\mathbb{C}}}{d_{i,s}^{\mathbb{U}} R_{it,s}^{\mathbb{U}}} = \frac{R_{it,s}^{\mathbb{C}}}{R_{it,s}^{\mathbb{U}}}$ since $d_{i,s}^{\mathbb{C}} = d_{i,s}^{\mathbb{U}}$ (no change occurred in Sète with respect to the number of fishing days), which implies $\frac{R_{i,g}^{\mathbb{C}}/R_{i,g}^{\mathbb{U}}}{R_{i,s}^{\mathbb{C}}/R_{i,s}^{\mathbb{U}}} = 0.5 \frac{R_{it,g}^{\mathbb{C}}/R_{it,g}^{\mathbb{U}}}{R_{it,s}^{\mathbb{C}}/R_{it,s}^{\mathbb{U}}}$.

Expressed in logarithm form, the previous equality becomes $\ln\left(\frac{R_{i,g}^{\mathbb{C}}/R_{i,g}^{\mathbb{U}}}{R_{i,s}^{\mathbb{C}}/R_{i,s}^{\mathbb{U}}}\right) = \ln(0.5) + \ln\left(\frac{R_{it,g}^{\mathbb{C}}/R_{it,g}^{\mathbb{U}}}{R_{it,s}^{\mathbb{C}}/R_{it,s}^{\mathbb{U}}}\right)$.

According to the DID estimates reported in Table 2, the ratio $\ln\left(\frac{R_{it,g}^{\mathbb{C}}/R_{it,g}^{\mathbb{U}}}{R_{it,s}^{\mathbb{C}}/R_{it,s}^{\mathbb{U}}}\right)$ is approximately around 0.2 : sales in value have increased by 20% more in Le Grau-du-Roi than in Sète during the cooperation period. Thus, $\ln\left(\frac{R_{i,g}^{\mathbb{C}}/R_{i,g}^{\mathbb{U}}}{R_{i,s}^{\mathbb{C}}/R_{i,s}^{\mathbb{U}}}\right)$ is equal to $\ln(0.5) + 0.2 \approx -0.49$. For each trawler, the cooperation has resulted in an evolution of sales revenue of almost 40% lower in Le Grau-du-Roi compared to Sète¹⁷.

We can further investigate this issue by estimating a DID regression explaining the overall sales revenue per trawler instead of the sales revenue per day of sale. This strongly reduces the sample size, which now includes around 60 observations (approximately 15 trawlers per fish market observed during the cooperation period and the control period, with two markets). Taking the windows of 25 days following cooperation as control period, the interaction term crossing Le Grau-du-Roi and the cooperation period is significant and the evolution of the total revenue per trawler has been much lower (-41.7%) in Le Grau-du-Roi than in Sète. Not having fished during two weeks in

¹⁷ The change in sales revenue is $(\exp(-0.49) - 1) = -38.7\%$.

May 2020 was therefore not compensated for by the increase in daily sales revenue. Again, the difference observed at the trawler level between the two fish markets is fully attributable to cooperation. If we estimate the same DID regression with the 2019 data, the term of interaction between Le Grau-du-Roi and cooperation is never significant.

More generally, we can assess the sensitivity of daily sales revenue with respect to the number of trawlers. The procedure and results are described in Appendix B. Assuming that the number of trawlers is exogenous in the revenue equation, we find that a one-percent decrease in the number of trawlers is associated to a 0.356 percent increase in daily sales revenue per trawler when the control period is 25 days after cooperation. We consider the period of cooperation as an instrument to control for the possible endogeneity of the fleet size. Estimates from two-stage fixed effect least squares leads to very similar coefficients for the elasticity under exogeneity and with the instrumental variable specification. Depending on the selected control period, the elasticity of revenue with respect to fleet size ranges between -0.2 and -0.4.

Finally, we compare the change in total revenue calculated at the fish market level. Insofar as the differential estimated for the numbers of trawlers selling fish daily in Le Grau-du-Roi and Sète is a little less than 50% (around 45%), the comparison is expected to be slightly less unfavorable at the fish market level than at the trawler level. For that purpose, we compare the total revenue per fish market during and after the cooperation, so that the sample includes 4 observations. Using a 25-days windows after cooperation as control period, we find that the interaction term crossing the cooperation period and Le Grau-du-Roi is -0.483. Thus, the evolution of the total revenue has been substantially lower (-38.3%) in Le Grau-du-Roi than in Sète.

7. Conclusion

The control of fishing effort, either through a reduction in the number of trawlers or a maximum of number of fishing days per year, is still the main management strategy in Mediterranean Sea European countries. However, little is known on the implications of such restrictions on the economic situation of fisheries. This paper attempts to fill in this gap by studying the consequences of a decision of cooperation which divided by two the number of weeks spent on fishing in May 2020 in the port of Le Grau-du-Roi, located in the Mediterranean. In the context of the Covid pandemic, the situation under consideration is that of simultaneous negative shocks on demand and supply.

Our main results can be summarized as follows. On the one hand, the DID estimates show that the increase in daily sales revenue has been substantially higher in Le Grau-du-Roi than in Sète during the cooperation (around 20%), presumably because of a reduced competition between trawlers in the same fishing areas. On the other hand, the cooperation has substantially reduced the total sales revenue generated by each trawler. The large decrease in fishing time has not been compensated for

by the moderate increase in catches when trawlers were fishing. Nonetheless, the economic loss would have been even worse in Le Grau-du-Roi without those additional catches.

As they stand, our results have important public policy implications. In the Western Mediterranean Sea, the European multi-annual management plan (WEST-MED) foresees a continuous decrease in the number of fishing days till 2025. In a context where the demand for seafood products is still affected by the pandemic, the negative supply shock resulting from the lower fishing effort should contribute to the decrease in sales revenue generated by the fisheries. Such trend is worrying insofar as the economic situation of fisheries has already deteriorated substantially since 2017 (Salladarré and Wolff, 2017) and trawlers tend to be pushed to the limit of their profitability. As overfishing is still a concern in the Mediterranean, it may be of interest to consider alternative management measures like those based on the extension of marine protected areas.

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Appendix A. Cooperation and sales revenue of trawlers

This appendix presents a theoretical framework to study the short-term effect of cooperation on trawlers' sales revenue in fish markets. Here, we do not consider the long-term consequences of cooperation on fish stocks as well as technological changes. We define cooperation as a mechanism leading to a reduction in the number of vessels catching fish. We leave aside the issue of costs and focus on sales revenue at the trawler level.

For the presentation, we consider a set of n identical trawlers. Let Q_i be the quantity of fish caught by the trawler i . There is no randomness in fish catches and each trawler sells the same quantity of fish. The total quantity is $Q_T = \sum_i Q_i = nQ_i$. Let $P(Q_T) = P(nQ_i)$ be the price function which is a decreasing function of the total quantity caught by all trawlers. We denote by R_i the revenue of trawler i such that $R_i = Q_i * P$. We study the effect of change in n on R_i in two different cases.

First, we assume that there is no congestion effect. This corresponds to a situation where the quantity Q_i of fish caught by each trawler does not depend on the number of trawlers n . Hence, the revenue function is $R_i = Q_i * P(nQ_i)$. By differentiating R_i with respect to n , we have $\frac{dR_i}{dn} = Q_i * \frac{dP(nQ_i)}{dn}$ from which we deduce $\frac{dR_i}{dn} = Q_i^2 * \frac{dP(Q_T)}{dQ_T}$. Since $\frac{dP(Q_T)}{dQ_T} < 0$, it follows that the derivative $\frac{dR_i}{dn}$ is negative.

Without any congestion effect, decreasing the number of trawlers reduces the total quantity of fish caught, which leads to an increase in fish price. As the quantity at the trawler level remains unchanged, the revenue per trawler is expected to be higher under cooperation due to a price effect.

Second, we assume that the quantity of fish caught by a given trawler is reduced when there are more trawlers fishing around (congestion effect). We now have $Q_i = Q_i(n)$ with $\frac{dQ_i}{dn} < 0$ and the revenue function is $R_i = Q_i(n) * P[n * Q_i(n)]$. By differentiating R_i with respect to n , it follows that

$\frac{dR_i}{dn} = \frac{dQ_i}{dn} P[n * Q_i(n)] + Q_i(n) * \frac{dP[n * Q_i(n)]}{dn}$. After some manipulations, the derivative $\frac{dR_i}{dn}$ can be

expressed as $\frac{dR_i}{dn} = \frac{dQ_i}{dn} P[n * Q_i(n)] + Q_i(n)^2 * \frac{dP(Q_T)}{dQ_T} (1 + e_{q_i,n})$ where $e_{q_i,n} = \frac{dQ_i}{dn} * \frac{n}{Q_i}$ is the

elasticity of the fish quantity with respect to the number of trawlers. On the one hand, the term

$\frac{dQ_i}{dn} P[n * Q_i(n)]$ is negative since $\frac{dQ_i}{dn} < 0$. On the other hand, the sign of the term $Q_i(n)^2 * \frac{dP(Q_T)}{dQ_T} (1 +$

$e_{q_i,n})$ can be either negative or positive. When the elasticity $e_{q_i,n}$ is comprised between -1 and 0,

$Q_i(n)^2 * \frac{dP(Q_T)}{dQ_T} (1 + e_{q_i,n})$ is negative and thus $\frac{dR_i}{dn} < 0$. Conversely, when $e_{q_i,n} < -1$, the derivative

$\frac{dR_i}{dn}$ cannot be signed since $\frac{dQ_i}{dn} P[n * Q_i(n)] < 0$ and $Q_i(n)^2 * \frac{dP(Q_T)}{dQ_T} (1 + e_{q_i,n}) > 0$.

So, in the general case allowing for congestion effect, reducing the number of trawlers can have a detrimental effect on each trawler's revenue. This would occur through a price effect. If a reduced number of trawlers catch too much fish overall, then prices can severely go down and the negative

price effect would offset the positive quantity effect. Nevertheless, such scenario seems very unlikely and demand conditions are important. Under the assumption that the elasticity of the congestion effect is inelastic, we expect instead that cooperation should increase the revenue per trawler with the positive effect on quantity per trawler dominating the negative effect on fish prices.

Appendix B. Sensitivity of daily sales revenues to number of trawlers

To study the sensitivity of daily sales revenue with respect to the number of trawlers, we begin by assuming that the number of trawlers n_{it} is exogenous. We estimate the following linear regression:

$$\ln R_{it} = \alpha_0 + \gamma * \ln n_{gt} + \alpha_C * \mathbb{C}_t + \theta_i + w_t + \varepsilon_{it} \quad (B1)$$

where γ is the elasticity of interest as we consider a log-log specification. In (B1), we introduce a dummy for the cooperation period as well as a trawler fixed effect. The fish market dummy \mathbb{G}_{it} is excluded because of the fixed effect θ_i , but the elasticity parameter γ remains identified because the number of trawlers n_{gt} varies on a daily basis in each fish market. We estimate the linear regression (B1) using different time windows and report estimates in panel A of Table B1.

When the control period is defined over the 25 following days, we find an estimated elasticity $\hat{\gamma} = -0.356$ (column 1), meaning that a one-percent decrease in the number of trawlers is associated to a 0.356 percent increase in daily sales revenue per trawler. The elasticity is lower when the comparison is made with the period before cooperation: -0.212 with the 25-days windows (column 2) and -0.234 with the 50-days windows (column 4). Also, the correlation between sales revenue and number of trawlers is not significant when considering the whole period from January to August (column 5). In fact, changes in the number of trawlers selling fish on a daily basis remain limited over the whole year, except at the beginning of the lockdown and during the cooperation period.

We use the scenario of cooperation as an instrument to account for the potential endogeneity of the number of trawlers in (B1). For instance, more trawlers may be tempted to catch fish when demand for fish products is high. The cooperation has induced substantial variation in the number of trawlers selling fish in the markets of Le Grau-du-Roi and Sète. Specifically, we turn to an instrumental variable two-stage fixed effect least squares estimator with the interaction term crossing Le Grau-du-Roi by the cooperation period as instrument. The daily sales revenue (in logarithm) is expressed as a function of the endogenous number of trawlers, cooperation period, day of week, time trend and a trawler fixed effect. We report both the first-stage and second-stage estimates of the IV fixed effect regressions in panel B of Table B1.

As expected, the instrument corresponding to the interaction of Le Grau-du-Roi by the cooperation period is strongly correlated with the number of trawlers¹⁸. The partial R^2 exceeds 0.7 when considering a control period of 25 days (either before or after the cooperation) and the F statistics associated to the test of excluded instruments is above 1,000 in each regression. When looking at

¹⁸ The first-stage results are not exactly comparable to those presented in Table 1 because the observation unit is different. In Table 1, each observation corresponds to a fish market observed a given day, while in Table 4 each observation corresponds to a trawler selling fish a given day.

changes around the cooperation period, we find very similar coefficients for the elasticity under exogeneity and with the IV specification. This was expected as this is the cooperation period which generates the changes in the number of trawlers selling fish each day between Le Grau-du-Roi and Sète. The only difference which is observed occurs when the sample is defined from January to August. The elasticity, which was -0.055 and insignificant under exogeneity, is around -0.4 with the IV strategy (panel B). Interestingly, this is very close to what is found with short time windows. This finding may be related to the fact that the IV estimate is a weighted average of local average treatment effects. The effect on daily sales revenue is mainly revealed for the subsample affected by the observed changes in the instrument, so around the cooperation period.

Table B1. Elasticity of sales revenue with respect to number of vessels

Variables	Rotation from May 5 to May 29, 2020					
	Treated period Control period	(1) 25 days after	(2) 25 days before	(3) 50 days After	(4) 50 days before	(5) January to August excluding cooperation
A. Fixed effect estimates – Fish markets = Grau du Roi and Sète – Year = 2020						
Number of trawlers (log)		-0.356*** (-6.69)	-0.212*** (-4.99)	-0.321*** (-7.37)	-0.234*** (-5.65)	-0.055 (-1.31)
Cooperation		-0.226*** (-2.89)	0.106* (1.79)	-0.267*** (-3.80)	0.081 (1.54)	0.107*** (4.76)
Day of the week + quartic daily trend		YES	YES	YES	YES	YES
Vessel fixed effects		YES	YES	YES	YES	YES
Number of observations		675	586	1,109	845	3,817
R ²		0.092	0.274	0.078	0.241	0.098
B. IV fixed effect estimates – Fish markets = Grau du Roi and Sète – Year = 2020						
<i>First-stage estimates</i>						
Instrument : Cooperation x Le Grau-du-Roi		-0.575*** (-39.25)	-0.716*** (-39.42)	-0.595*** (-44.12)	-0.755*** (-37.42)	-0.488*** (-34.49)
Partial R ² of excluded instrument		0.735	0.726	0.722	0.588	0.116
F statistic		1515.5	1525.6	1928.3	1383.0	1186.3
<i>Second-stage estimates</i>						
Number of trawlers (log)		-0.357*** (-5.28)	-0.222*** (-4.26)	-0.350*** (-6.67)	-0.198*** (-3.99)	-0.393*** (-6.71)
Cooperation		-0.226*** (-2.94)	0.104* (1.74)	-0.274*** (-3.94)	0.089* (1.69)	0.020 (0.77)
Day of the week + quartic daily trend		YES	YES	YES	YES	YES
Vessel fixed effects		YES	YES	YES	YES	YES
Number of observations		675	586	1,109	845	3,817
R ²		0.147	0.313	0.138	0.265	0.082

Source: authors' calculation, RIC data January 2019-August 2020.

Note : estimates from fixed effect regressions and IV fixed effect regressions, with robust standard errors. Significance levels for t-values in parentheses are 1% (*), 5% (**) and 10% (*).