The local effects of an innovation: Evidence from the French fish market[#]

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January 2020

Abstract

In this paper, we investigate the effects of the Danish seine which was introduced for a subsample of vessels on a single wholesale fish market in France. The goal was to mitigate the decrease in vessel profits due to the rise of gasoline prices. Estimations are conducted from transaction data over the 2009-2011 period during which the innovation was introduced. Using a difference-in-differences approach around the discontinuity, we find that the innovation has a large positive effect on quality, prices and profit of treated vessels. However, a shift in caught fish species is observed and new targeted species are fished very intensively. This suggests that quota management is needed to ensure the sustainability of fishing practices involving the new technology in the long run.

Keywords: fish, innovation, product quality, product prices, discontinuity, difference in differences

JEL Classification: L11, Q22

[#] We are indebted to two anonymous reviewers for their useful comments and suggestions on previous drafts. We also thank Luc Behaghel, Gabriel Fack and Thomas Piketty for their comments as well as participants to the Labour and Public Policy Seminar at the Paris School of Economics, IAAE Conference in Milan, TEPP Winter School in Aussois and seminars in Lyon, Saint-Etienne and Toulon. We are grateful to Laurent Baranger, Jean-François Bigot and Pierrick Olivier for giving us access to the data and for very helpful discussions.

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1. Introduction

Technology diffusion plays a major role in the production and gathering of food resources. It is thus crucial for the farming and fishing industries. Mechanisms underlying diffusion have been investigated (Foster and Rosenzweig, 2010), but the exact influence of new technologies on food markets is still subject to debate due to the scarcity of natural and controlled experiments for an adequate assessment of their effect as well as the lack of appropriate data.

In this paper, we evaluate the impact of a new fishing technology subsidized by local public authorities which was introduced to mitigate the decrease in vessel profits due to the rise of gasoline prices. This technology was supposed to increase the productivity of equipped vessels while reducing fishing costs. As the effect of the new fishing gear on profit and catches were not precisely known, public authorities authorized the new gear only for a restricted number of vessels.

Fishing offers an interesting context since producers are not attached to a location such as farmers. Vessels choose their fishing spots depending on expected profits and their catches affect the spatial distribution of fish stock and future fishing perspectives (Sanchirico and Wilen, 2009).[1] Even if gasoline prices limit fishing distances from the port, constrained choices are enough to alleviate the concern of unobserved heterogeneity. Nevertheless, each gear is associated with specific expected returns and risks, vessels can differ in their equipment, and the experience on gear choice and fishing spots can vary across captains and fishers (Eggert and Tveretas, 2004; Wolff et al., 2013). Moreover, the ability to obtain real-time information on the surrounding markets to determine the best place to land fish can differ across vessels and this information is crucial to sell all the catches at a good price (Jensen, 2007).

The new fishing gear, the Danish seine, was used to equip six vessels located on a single French fish market, Les Sables d'Olonne, because the profitability and impact of this technology on maritime resources were uncertain. It was expected to increase the quality and thus prices of catches, but also to target specific species in mid-water. A major concern was its high efficiency, and there were thus heated debates around its sustainability and unfair competitiveness (Hamon, 2015). We assess the effect of the new technology on fish quality, quantity, caught species and selling prices for treated vessels. The analysis is restricted to local fish markets on the Atlantic coast since they form a rather integrated market (Gobillon and Wolff, 2016). Our evaluation is made possible by the availability of panel data on fish transactions in which vessels are tracked. It thus departs from previous literature that relied on aggregate series of prices and fish stocks.[2]

[1] Latest models of renewal resource exploitation incorporate both inter-temporal dynamics and spatial movements (Sanchirico and Wilen, 1999). These models are of particular interest to address resource management questions such as reserve policies (Smith and Wilen, 2003). An application to reef-fish fishery is provided by Zhang and Smith (2012).

[2] See Gordon and Hannesson (2015) for a study on the effects of technological shocks on herring fishery.

We resort to a discontinuity approach coupled with difference in differences since data follow vessels in a continuous way across time. Our estimations show that the innovation had a large effect on treated vessels at the discontinuity when it was introduced, since it increased their proportion of high-quality fish by 29.2 percentage points and their prices by 23.2 percentage points. We also find that the composition of caught species was greatly affected, with a large increase in the quantity of fished mackerel, red mullet and whiting. The fact that the new technology is very intensive in some specific segments of the fish market suggests that fishing quotas are needed on all targeted species if the technology becomes widespread.[3] Finally, we provide evidence on costs, revenues and profits which shows that the introduction of the Danish seine was highly profitable for treated vessels.

The rest of the paper is organized as follows. Section 2 discusses the context in which the new technology was introduced and its expected effects. Section 3 presents our dataset and descriptive statistics. Section 4 explains our econometric approach and Section 5 discusses our estimation results. Section 6 reports evidence on costs, revenues and profits. Section 7 discusses additional results at the fish market level. Finally, Section 8 concludes.

2. Presentation of the policy and expected effects

2.1. Introduction of the new fishing gear

During the 2000s, the fishing industry in Europe was hit hard by a steep increase in gasoline price. This was particularly the case in France where prices increased by 120% between 2004 and 2007. Vessels needed to be adapted to the new market conditions and the European Community allowed for a temporary national support. A segment of the fishing fleet could benefit from public subsidies up to 55% of the costs incurred by the transformation of all or part of the vessels, as long as the energy spending represented at least 30% of production costs and the capacity of the fleet segment would be reduced by 30%. In France, such transformation was designed and conducted by public entities, since the fleet is heavily regulated to ensure the sustainability of maritime resources.

It is in this context that local authorities in the region of Pays de la Loire on the Atlantic coast decided to experiment with a new fishing technology, the Danish seine, which requires shorter travels and is expected to allow for catches of better quality. The effects of this technology were uncertain as it had never been used in France before and the Danish seine was thus introduced in 2010 on a single fish market, Les Sables d'Olonne, located on the Atlantic coast. This market was then ranked 14th among 40 when considering the volume of traded fish (4,900 tons), but 7th for the value (24.1 million euros). Fish is sold in ascending auction and the process involves both local bidders and remote internet bidders.

[3] The challenge for public authorities is then to reach an optimal management of marine resources with regulation while considering changes in fishing behavior along various margins (Smith, 2012).

Six trawlers were temporarily withdrawn from the local fleet to be equipped with the new technology, while six others were permanently withdrawn to reduce the size and cost of the fleet.[4] The fleet segment considered by local authorities to be partially transformed was that of trawlers which were at least 12 meters long. Indeed, these vessels were large enough to accommodate the new gear. The selection criteria for being equipped with the new technology were that vessels had to be built recently enough (to make the investment profitable over the years) and that the captain agreed to transform the ship. The selected vessels had a length between 18 and 25 meters with an average of 20.9 meters and were built between 1991 and 2005 (the average year of construction being 2001).

Equipping vessels with the Danish seine requires time and trawlers needed to stay on land between four and five months as shown by Figure 1. During the time vessels were stuck on land, the crew followed a short training period (two weeks) in Iceland where they boarded Icelandic seiners and fished with the crew. The Danish seine is a conical net with two long wings, a pocket in the middle to collect fish and buoys to maintain the seine close to the water surface. Seiners are thus expected to catch fish species living in mid-water that include whiting, mackerel or red mullet, rather than those at the bottom of the sea.[5] Still, the exact effects of the Danish seine on catches in France could not be anticipated in advance since fishermen needed to test alternative fishing spots to identify the places where the new gear would be the most efficient.

[Insert Figure 1]

2.2. Expected effects of the new technology

In our study, we quantify the effects of the introduction of the Danish seine for a crew who acquired the proper skills to use it thanks to a training period. This introduction is expected to have several effects on catches. Caught species should be different since seiners fish in mid-water rather than at the bottom of the sea, stay closer to the coast, and drag their net at a slower speed.[6] In fact, seiners mainly target slow species in mid-water such as whiting, mackerel or red mullet. The Danish seine is expected to increase the quantities of targeted species that are fished in the short run, but longer run effects are less obvious and fish quotas on all targeted species may be needed to avoid that the

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[4] Vessels permanently removed were chosen by local authorities because both the ship and the captain were old. Ships were built between 1986 and 1991 and they were between 14.4 and 20.8 meters long. Their withdrawal yielded a decrease of 31.6% in tank capacity for the fleet and a decrease of 36.7% in engine power.

[5] Two vessels equipped with the Danish seine keep using their previous gear during some specific time periods to catch mostly white tuna or Norway lobster. This behavior is ignored, but this simplification is innocuous since 97.3% of catches are made with the Danish seine after the vessels are equipped.

[6] A slower speed prevents to some extent the deformation of the net mesh. This ensures a better selection of fished species and it can lead to substantial fuel savings.

technology adoption exacerbates the commons problem and leads the depletion of the fish stock (Squires and Vestergaard, 2013).

The quality of a given fished species should improve since fish is caught alive and in good condition, rather than dead and squeezed. Indeed, fish is not dragged by a trawl net at the bottom of the sea. Moreover, most fishing trips are shorter when using the Danish seine rather than other fishing gears since they are made closer to the coast, so that fish can be brought back fresh without freezing it. There are also several expected effects on prices. Supply and demand differ according to fish characteristics and this leads to price variations among fish lots. In particular, prices vary across species, size, presentation and grade - an official summary of quality usually attributed when fish is landed on the market (Kristofersson and Rickertsen, 2004; Hammarlund, 2015; Gobillon et al., 2017). Fishing gear influences prices even when controlling for these fish characteristics (McConnel and Strand, 2001; Asche et al., 2015), suggesting that gears affect dimensions of quality not well captured by official grades. For treated vessels, the average selling price of a given species should increase since the average quality of caught species is expected to increase.

3. Description of the data

Data are available at the transaction level for the fish market in Les Sables d'Olonne as well as those in Saint-Gilles Croix-de-Vie, Noirmoutier and Ile d'Yeu, which are located at a short distance within the same administrative unit, the *département* of Vendée. They cover the period spanning from September 2009 to June 2011 and each transaction corresponds to a fish lot.[7] The sample includes 812,112 transactions, with 49.1% of them (398,844 transactions) occurring in Les Sables d'Olonne, 20.6% in Noirmoutier, 17.7% in Saint-Gilles Croix-de-Vie and 10.8% in Ile d'Yeu. We have details on the exact day of the transaction, the identities of seller (vessel) and buyer, price, quantity, fish species, size (up to seven categories depending on species), presentation (whole, gutted, in pieces, etc.) and quality.

In France, quality is graded following the European Community rule 2406/96 and workers grading fish who operate on fish markets are trained to ensure that grades are consistent over the whole territory. They are given reference documents which include pictures and detail multiple criteria on skin, eyes, gills, peritoneum and flesh, for specific groups of species such as white fish, blue fish and crustaceans. Quality evaluation is conducted using both touch and sight, and there are three grades that can be attributed: high (E which stands for Extra), average (A) and poor (B).

Effects at the discontinuity

[7] The six vessels removed from the fleet are not in the sample because their exits occurred before September 2009.

We assess to what extent the Danish seine has influenced fish quality with descriptive statistics at the discontinuity when the innovation was introduced. We plot on the same graph the daily proportion of high-quality fish (grade E) for every treated vessel during the two months before they are landed to get equipped with the new gear and during the two months after they are back to the sea.[8] For comparison, we construct the same graph for similar vessels not treated with the Danish seine.

Vessels are considered to be similar if they are within the same length bracket as treated ones, are registered in Les Sables d'Olonne and operate fishing trawls, which is the gear used by seiners before their transformation. There are exactly six vessels verifying these three criteria, so that we match them one by one with treated vessels in decreasing order of length. We label them as "matched control vessels".[9] Transactions occurring for a matched control vessel during the period when their paired treated vessels are landed to change gear are not taken into account. In each graph, we represent non-parametric trends before and after the innovation obtained from local polynomial regressions.

Figure 2 shows that for treated vessels, the daily proportion of high-quality fish is around 50% before the treatment date. There is then a very large positive jump of 30% at the treatment date and the proportion increases afterwards to reach 95%. For matched control vessels, the daily proportion of high-quality fish is around 45% before the treatment date and it experiences a negative jump of 15% at the treatment date before increasing to reach 60% after two months. We also investigated the complement of high-quality fish which can be decomposed into poor and average-quality fish. A comparison of the two-month periods before and after treatment shows that, for treated vessels, the proportion of average-quality fish decreased from 53.7% to 9.2%, and that of poor-quality fish from 4.7% to 0.1%. By contrast, for matched control vessels, the proportion of average-quality fish increased slightly from 47.7% to 54.2%, while that of poor-quality fish remained nearly unchanged (decreasing only very slightly from 4.2% to 3.5%).

Overall, the sharp contrast between treated and matched control vessels is highly suggestive of a large effect of the Danish seine on fish quality. It is also suggestive of a spillover effect with matched control vessels increasing their fish quality progressively after the new fishing gear is introduced.

[8] The construction of the graph is such that the time span during which vessels are on land to get equipped with the Danish seine (that includes the two-week training period) is not represented. The graph does not distinguish average-quality fish from poor-quality ones. This is because the amount of poor-quality fish is negligible (1.19% and 2.90% of transactions involve poor-quality fish for respectively treated and matched control vessels). After the introduction of the Danish seine, transactions involving fish caught with another gear by treated vessels are excluded from these computations since we are interested in the effect of the new technology. Sudden effects related to the introduction of the Danish seine cannot be confounded with effects related to exits of vessels removed from the fleet since these exits occurred before our time window around the discontinuity.

[9] They have a length between 20.6 and 24.9 meters with an average of 22.6 meters, and they were built between 1983 and 1990 with an average of 1987. In our dataset, 14.3% of transactions in Les Sables d'Olonne involve treated vessels and 15.8% of them involve matched control vessels.

Another possible mechanism is that, after the innovation is introduced, treated and matched control vessels turn to different fish species and this may affect their average quality. Indeed, winter is over and fish get closer to the coast so that both treated and matched control vessels may make shorter trips after treatment.

[Insert Figure 2]

To deal with composition effects, we construct a similar graph for each of the five main species fished by treated vessels, as well as a residual category labeled "others". We assess whether there is a jump in the proportion of high-quality fish at the treatment date for treated vessels (but not for matched control vessels) in the case of each species.[10] Figure A1 in Appendix shows that it is the case for mackerel, red mullet, whiting and fish classified in the "others" category. By contrast, we do not observe any jump in the quality of cuttlefish and squid for treated vessels. These species can hardly be damaged and are already of high quality before treatment.

We also consider similar graphs for prices per kilogram.[11] Figure A2 in Appendix shows that neither treated vessels nor matched control vessels experience a jump in prices at the treatment date. However, it is possible to check that this absence of jump is due to a composition effect by repeating the same exercise for the five main species fished by treated vessels and the "others" category. For treated vessels, we find a large positive jump of more than five euros for squids, and smaller positive jumps for mackerel, red mullet and whiting as shown by Figure Ap1 in Online Appendix. The jump is close to zero for cuttlefish and negative for the "others" category. When pooling all the species, the negative and positive jumps cancel each other. By contrast, for matched control vessels, there is a positive jump for squid which is smaller than for treated vessels, and no jump for all the other species.[12]

Effects over the whole period

We then assess whether there is a difference in the evolution of fish quality between treated and matched control vessels over the whole period spanning from March 2009 to June 2011. Panel A of

[10] The five selected species are those with the largest contribution to total quantity fished by treated vessels over the period. Albacore is excluded because tuna catches are highly seasonal and require specific permits.

[11] Here, we do not control for any fish characteristic or observed quality indicator. Consequently, prices per kilogram are likely to capture quality effects. We do not conduct a similar analysis for quantities as quantity is that involved in a given transaction and not the overall quantity fished by the vessel.

[12] It is possible to check that the concomitant jump of prices for treated and matched control vessels is related to price cycles for squids. Indeed, price series for the two groups of vessels reach their maximum around April two years in a row, are cyclic and highly correlated. In particular, prices are rather large just after treatment and rather small before treated vessels are landed to be equipped. Still, the price jump after treatment for treated vessels is larger than that for matched control ones (whereas it is not much the case for the jump of the proportion of high-quality squids). A possible explanation is that treated vessels bring back fresher squids after treatment because they make shorter trips at sea, and this would justify a higher sale price within the category of high-quality squids.

Table 1 reports, for both the treated and matched control vessels, the proportion of high-quality fish when pooling all species and when considering each species separately, before and after treatment. For treated vessels, the proportion of high-quality fish experiences a large increase of 44.3 percentage points after the introduction of the innovation. The difference in the evolution of this proportion between treated and matched control vessels is smaller as it takes a value of 27.7 percentage points. This can be explained by an overall improvement of fish quality over time for all vessels.

[Insert Table 1]

There is some heterogeneity in the evolution of quality across species since, for treated vessels, the increase in the proportion of high-quality fish is very large and above 50 percentage points for mackerel, whiting and the "others" category. It is smaller for red mullet and squid, and very small for cuttlefish. For every species, the difference in the evolution of quality between treated and matched control vessels is smaller than the evolution for treated vessels, and this points again at an overall increase in the quality of caught fish. This difference remains above 20 percentage points for mackerel, whiting and the "others" category, it is smaller for red mullet and close to zero for squid and cuttlefish.

Panel B of Table 1 reports descriptive statistics on the daily quantity of sold fish before and after the introduction of the innovation. The use of Danish seine is very intensive for mackerel, red mullet and whiting since, on average, less than 0.15 ton of each were fished daily before the introduction of the new technology but more than 1.2 tons are fished daily afterwards (even more than 1.9 tons for mackerel). There are also increases in the sales of these three species for matched control vessels but they are much smaller.

Finally, we assess to what extent fish caught by treated vessels are better valued on the market after the innovation is introduced. As shown in Panel C of Table 1, the price per kilogram increases for the five main species fished by treated vessels. For each of them, the increase in prices for treated vessels is larger than the change in prices for matched control vessels.[13]

4. Empirical strategy

We now present our methodology to quantify the effects of the introduction of the new technology. We assess whether the introduction of the Danish seine has a positive effect on quality and prices of fish lots. We present our approach for quality, but that for prices is similar. We first investigate

[13] When considering all species, price per kilogram decreases for both treated and matched control vessels, and the decrease is more important for treated vessels. This can be explained by a change in caught species. When holding the composition of species fixed to that before treatment, the price per kilogram for treated (resp. matched control) vessels experiences an increase of 1.040 euro (resp. 0.307 euro). In particular, the increase is larger for treated vessels.

whether there is an increase in the probability of fish lots to be of high quality just after treated vessels use the new technology. We consider only transactions occurring within two months before the vessels are landed to change their gear and within two months after they are back into water to fish.

Our setting is not a standard regression discontinuity design because the distribution of covariates is likely to be different before and after the introduction of the new technology. As the composition of fish in terms of species and characteristics varies over time at high frequency depending on daily conditions, it is not appropriate to use local polynomial regressions : the estimated treatment effect is biased when the expected values of covariates on both sides of the discontinuity are different (Imbens and Lemieux, 2008; Calonico et al., 2019). As a benchmark, we consider panel linear specifications involving a parametric time trend and fish characteristics to be estimated from the subsample of treated vessels. In order to better control for time effects, we then estimate difference-in-differences specifications at the discontinuity from the subsample of both treated and matched control vessels.

Discontinuity analysis using the subsample of treated vessels

We denote by E_{ijt} the dummy taking the value one if the fish lot i sold by vessel j at time t is of high quality (and zero otherwise). We consider the following linear probability model:

$$E_{ijt} = \delta \mathbb{1}_{\{t \geq \bar{t}_j\}} + X_i\theta + f_{\mu}(t) + u_j + \varepsilon_{ijt} \tag{1}$$

where $\bar{t}_j$ is the first day at which vessel j is able to use the Danish seine, $\mathbb{1}_{\{t \geq \bar{t}_j\}}$ is a dummy variable taking the value one if the day of transaction occurs after the innovation is introduced for the vessel making the transaction (and zero otherwise), X_i is a set of fish characteristics (species, size and presentation dummies), $f_{\mu}(t)$ is a parametric function of time that we consider to be a cubic time trend, and u_j is a vessel fixed effect.[14]

Our parameter of interest δ measures the effect of being equipped with the Danish seine on fish quality. This effect is measured as the jump around the cubic time trend. Identification relies on the fact that unobserved vessel effects do not vary around the discontinuity, which is credible since the boat engine, the captain, and the crew remain the same after boats equipped with the Danish seine are back into water. We also rely on a continuity argument since the effect of time on quality is

[14] Time is measured as the number of days since the beginning of the four-month window centered on the discontinuity which is specific to each vessel. When studying prices, we also include in the specification fixed effects for the days of the week since the demand for fish is expected to vary during the week.

parameterized to be smoothed and the estimated effect of Danish seine is measured as a deviation from the time trend.

Difference in differences at the discontinuity

We then control for time effects by using difference-in-differences at the discontinuity. We assess whether our results are robust when estimating the treatment effect as the difference in differences in the proportion of high-quality fish between treated and matched control vessels. For that purpose, we add to our sample the six matched control vessels that are similar to treated vessels and never use the Danish seine because they have not been equipped with this fishing gear.

We consider for a given control vessel that the period after innovation is exactly the same as the one of the treated vessel to which it is matched, even if it does not receive treatment. We estimate the following specification:

$$E_{ijt} = \delta \mathbb{1}_{\{j \in \Omega\}} \mathbb{1}_{\{t \geq \bar{t}_j\}} + \gamma \mathbb{1}_{\{t \geq \bar{t}_j\}} + X_i \theta + f_{\mu}(t) + u_j + \varepsilon_{ijt} \quad (2)$$

where Ω denotes the set of treated vessels and $\mathbb{1}_{\{j \in \Omega\}}$ is a dummy that takes the value one if vessel j is treated (and zero otherwise). Parameter γ captures the average post-treatment time effect while simultaneously controlling for the cubic time trend, and parameter δ now captures the difference in evolutions of fish quality between treated and matched control vessels when the innovation is introduced.

Our parameter of interest is the treatment effect on the treated only if there are no spillovers of the treatment on matched control vessels. Otherwise, it measures the difference in the effect of innovation on quality between treated and matched control vessels. As matched control vessels may try to increase their fish quality in the post-treatment period to remain competitive, the estimated effect is likely to be a lower bound on the treatment effect on the treated.[15]

Validity of control group and robustness checks

There are differences in the dates at which treated and matched control vessels were built. Age can change the profitability of vessels as it influences costs such as fuel consumption and need for repairs. However, there is no technical reason why age should change the fishing spot, species that are caught or the quality of catches for a boat of given length when considering a given gear. Quality mostly depends on the fishing gear and fishing locations. If vessels go far away from the coast, they have to freeze their catches and this lowers fish quality. Although the average power of vessels

[15] For instance, matched control vessels may try to improve the quality of their catches by making shorter fishing trips as this allows them to unload fresher fish.

equipped with the Danish seine is initially higher than that of the matched control vessels (465.7 kW versus 408 kW), both treated and non-treated vessels were fishing in nearly the same places in the Bay of Biscane before the introduction of the Danish seine. Turning to the fish quantity brought back to the port, it depends on storage capacities which are mainly determined by vessel length.

In robustness checks, we contrast the evolutions of outcomes for treated vessels with those for all non-treated vessels selling their fish in the same fish market or nearby. For that purpose, we re-estimate the treatment effect considering two alternative control groups which consist of all non-treated vessels landing fish in either Les Sables d'Olonne or the whole Vendée region. We will refer to them as "control vessels". Both groups are more heterogeneous with respect to vessel length, with an average of 14.1 meters for Les Sables d'Olonne and 12.2 meters for Vendée.

5. Results

5.1. The effect of the innovation on quality for treated vessels

We now discuss the results of our discontinuity analysis used to quantify the effect of the innovation on fish quality. We first focus on treated vessels only, the effect being identified as the jump in the proportion of high-quality fish when the innovation is introduced. As shown in panel A of Table 2, when only a cubic daily trend is introduced as a control, being equipped with the Danish Seine increases the proportion of high-quality fish by 35.2 percentage points for treated vessels (column 1). When additionally taking into account fish characteristics, the estimated effect remains rather stable at 33.3 percentage points (column 2). When also introducing vessel fixed effects, the estimated effect is slightly higher at 44.9 percentage points (column 3).

[Insert Table 2]

We then resort to difference in differences at the discontinuity. The treatment effect is now identified as the difference in jump in the proportions of high-quality fish between treated and matched control vessels. As shown in panel B of Table 2, the estimated treatment effect is of the same magnitude as when considering treated vessels only. It ranges from 42.9 percentage points when considering a cubic daily trend only in the set of control terms (column 1) to 29.2 percentage points when also including fish characteristics and vessel fixed effects (column 3). In column 2 where we control for both the cubic daily trend and fish characteristics, the dummy for being a treated vessel has an estimated effect which is small at -5.3 percentage points. Hence, the treated and matched control vessels would catch fish of rather similar quality in the absence of treatment, once time and composition effects have been taken into account.

To assess the effect of the new technology in the longer run, we then estimate the treatment effect over the whole period which spans from September 2009 to June 2011. Panel A of Table 3 shows that, when considering the subsample of treated vessels only, the estimated treatment effect is of the same order of magnitude as at the discontinuity and stable across specifications. It amounts to 40.6 percentage points when all control terms are included (column 3). As before, matched control vessels are then added to the sample and the treatment effect is re-estimated (panel B). This time, it turns out to be smaller than when considering treated vessels only, but it remains sizable and it amounts to 22.9 percentage points when all the control terms are included in the specification (column 3). Possible explanations for the decrease in the treatment effect two months after the introduction of the innovation are a decrease in fish stocks close to the coast which forces treated vessels to go further to catch fish and/or a change in the fishing behavior of matched control vessels that may fish closer to bring back fresher fish.

[Insert Table 3]

As a robustness check, we change the control group by considering alternatively all the non-treated vessels in Les Sables d’Olonne (panel C) and all the vessels in Vendée (panel D). We cannot impute a treatment date for control vessels that are not matched with treated vessels in the same way we did for matched ones. For those vessels, we choose to set that date to March 1, 2010 because the treated vessels which are the first to use the Danish seine do so in early March. When all the vessels in Les Sables d’Olonne are considered, the sample size more than triple but the estimated treatment effect remains sizable and even larger than before. It reaches 33.4 percentage points when all the control terms are included in the specification (column 3). When considering all the vessels in Vendée, the estimated treatment effect remains stable at 35.3 percentage points (column 3). For all the specifications that include a dummy for being a treated vessel, the estimated coefficient of that dummy is positive or negative and sometimes significant, but always very small. This means that the pre-treatment quality is similar for treated and matched control vessels.

We also ran regressions similar to those reported in Table 3 for each of the five main fish species and the “others” category separately. Results obtained when including all the control terms (cubic daily trend, fish characteristics and vessel fixed effects) in the specification are reported in Table A1 in Appendix. When considering treated vessels only (panel A), the innovation has no effect for cuttlefish and squid, a medium effect for red mullet, a large effect for whiting and very large effects for mackerel and the “others” category. When adding matched control vessels to the sample and using a difference-in-differences approach, there are changes in the size of estimated treatment effects. These variations occur because we now contrast treated vessels with matched control ones, and there are time changes in quality after treatment for matched control vessels that can be due to spillovers from treated to matched control vessels on top of the continuous daily time trend. When including in the sample all the vessels in Les Sables d’Olonne (panel C) or all the vessels in Vendée (panel D), results remain qualitatively similar.

Overall, our results suggest that control vessels – in particular those matched with treated ones – may have changed their fishing practice after the introduction of the innovation to increase the quality of their fish lots.

5.2. The effect of the innovation on prices for treated vessels

We now present our estimation results when evaluating the effect of the innovation on prices. Using our discontinuity strategy, we first quantify the treatment effect as the jump in the price per kilogram for treated vessels when the innovation is introduced, while controlling for vessel fixed effects and a cubic daily trend, as well as fixed effects for the day of the week to take into account daily variations in supply and demand during the week.

Results reported in Panel A of Table 4 show that the effect is large at 100*[exp(0.389)-1]=47.6 percentage points (column 1).[16] Part of this effect is due to an increase in quality. When adding a dummy for high-quality fish, the estimated treatment effect on prices decreases by 23.4% to reach 38.3 percentage points (column 2). This remaining effect can be explained to some extent by an increase in unobserved quality for treated vessels since there are only three grades for quality and the high-quality category remains broad. In particular, some high-quality fish lots sold by treated and non-treated vessels may differ in unobserved quality because treated vessels may bring back fresher fish as they fish closer to the shore and make shorter trips than non-treated ones. Some dimensions of unobserved quality are partly captured by the size of fish lots since more valuable fish are often sold in smaller lots. When introducing the fish quantity involved in the transaction, the treatment effect on the treated decreases again to reach 28.5 percentage points (column 3).[17]

[Insert Table 4]

We can assess whether characteristics of the market can explain this effect. In particular, treated vessels may sell to buyers whose propensity to pay for very fine fish is larger than that of buyers involved in transactions with non-treated vessels. When replacing vessel fixed effects with buyer-seller fixed effects to control for specific matches between sellers and buyers (see Gobillon et al., 2017), the treatment effect on the treated decreases to 24.7 percentage points (column 4). Other market characteristics include the local supply and demand that we proxy respectively with total fish quantity and total number of buyers involved in transactions during the day in Les Sables d'Olonne.

[16] Subsequent figures are computed using the same formula. Note that the significant effect of the new technology on prices contrasts with the absence of average price effect for all species reported in Table 1 and Figure A2. This is because we hold the composition of species constant in the regressions with the use of dummies for species. We thus control for the fact that newly equipped vessels capture species that are sold on average at a lower price, and we now only quantify the price effect within species which is shown to be positive.

[17] As expected, the fish quantity involved in the transaction has a negative estimated effect on prices, which means that larger lots are sold for a lower price per kilogram.

When adding these two variables, the treatment effect on the treated decreases to 22.9 percentage points (column 5). Moreover, the market variables have the expected effect since the price per kilogram on the market decreases with the total quantity of the day (ie. supply), but it increases with the total number of buyers of the day (ie. demand).

The remaining treatment effect could be due to changes in unobserved local conditions after treatment, whether they concern fish quality or market structure, as these changes would be captured by the dummy for fishing with Danish seine after the innovation is introduced. To take them into account, we couple again our discontinuity analysis with a difference-in-differences approach conducted on the subsample including both the treated and matched control vessels. Panel B of Table 4 shows that the treatment effect on the treated when considering a cubic daily trend, fixed effects for the day of the week and vessel fixed effects in the specification is only 23.2 percentage points (column 1) compared to 47.6 in our discontinuity analysis involving only the treated vessels. In the case of our full specification that also involves a dummy for high quality, fish quantity of the lot, buyer-vessel match effects and market characteristics, the treatment effect on the treated is only 11.7 percentage points compared to 22.9 percentage points before (column 5). Hence, our results suggest that local conditions have changed significantly just after the innovation was introduced.

We then replicate the same exercise over the September 2009 - June 2011 period using the same specifications, and results are reported in Table 5. When considering the subsample of treated vessels only (panel A), the estimated treatment effect is slightly larger than at the discontinuity. It amounts to 53.6 percentage points when the daily time trend, fixed effects for the day of the week and vessel fixed effects are introduced as controls (column 1), and it drops to 27.0 percentage points for the full specification (column 5). When adding matched control vessels to the sample (panel B), the treatment effect on the treated decreases to 30.9 percentage points for our first specification (column 1) and to 16.0 percentage points for the full specification (column 5). Again, these are slightly larger figures than at the discontinuity.

An explanation is the progressive diffusion of information over time on the quality of fish landed by seiners. This progressive improvement of the reputation should attract new buyers looking for high-quality products (and presumably with a high willingness-to-pay) on the fish market of Les Sables d'Olonne and increase the demand for fish sold by treated vessels.

[Insert Table 5]

6. Cost – benefit analysis

We finally provide evidence on costs and revenues for some of the vessels involved in this study for the years 2009 and 2011. Information on these quantities is available for our six treated vessels and two control vessels only. We choose to exclude the two treated vessels with a specific license to fish white tuna. Indeed, their maintenance and reparation costs are very large compared to other treated vessels, but we are not able to separate costs related to tuna fishing activities from costs related to the Danish seine activities. As data on costs and revenues for each vessel are confidential, we can only report aggregate statistics separately for our restricted treated and control groups (see Table 6).

[Insert Table 6]

The main motivation for equipping vessels with the Danish seine is to increase revenues through the sale of better-quality fish, while keeping expenditures under control though a decrease in gasoline consumption. Treated vessels largely increased their sale revenues (+120.1%) between 2009 and 2011, while there was also a rise for control vessels but to a lesser extent (+54.3%). Treated vessels incurred a large fixed cost for being equipped with the Danish seine. Subsidies to pay that cost were also large and covered on average 49.5% of the fixed cost. Variable costs of treated vessels increased to a large extent (+77.1%) between 2009 and 2011. This rise is smaller for control vessels (+54.3%).

Consistently with the purposes of Danish seine, treated vessels decreased their gasoline consumption by making shorter trips at sea when being equipped with their new gear. Indeed, the average duration of their trips decreased from 61 to 16 hours, and their average gasoline consumption decreased (-23.6%). However, their average gasoline spending increased (+43.9%) because of the large rise in gasoline prices. Still, this rise is substantially lower than that for control vessels (+63.3%).

Conversely, variable costs related to gear and repairs significantly increased for treated vessels (+74.1%). A possible explanation is that repair costs increase with time spent at sea and vessels are used more intensively after they are equipped with the new gear. Moreover, repairs are made irregularly over time and the first refit after the gear change could have taken place after one year. Variable costs for control vessels also increased moderately (+15.3%), and the wage bill increased much more for treated vessels (+135.3%) than for non-treated ones (+52.3%). This is not surprising since sales increased and related revenues are shared with the crew. Moreover, new seiners needed additional crew. Indeed, their trips are shorter and occur daily, which leads to a more intensive pace of work at sea. As a consequence, one additional crew member was hired per vessel to allow for a more regular rotation of staff on board.

Overall, the Danish seine is very profitable. The gross operating profit (computed as the difference between sales revenues and variable costs) increased a lot (+651.5%) between 2009 and 2011. This means in particular that only three years are needed to recover the fixed cost for being equipped with the Danish even without taking subsidies into account. There was also a large rise of profits for control vessels (+212.7%), but it is nonetheless three times lower than that for treated vessels.

7. Discussion

The new technology may affect non-treated vessels as they may react to changes in competitors. We discuss here some mechanisms at stake and propose additional results on the aggregate effects of the new technology on the treated market.

First, we note that non-treated vessels were not able to adopt the new technology as no additional license was issued on top of those for treated vessels.[18] Still, they could change their practices to provide higher-quality fish to remain competitive on the market. For instance, they may make shorter trips to bring back fresher fish even if they keep targeting the same fish species. The new technology may thus increase quality on the treated market to a larger extent than what is expected from the effect on treated vessels.

The effect of the new technology on aggregate quantity is difficult to assess. Indeed, some species are fished more intensively by treated vessels, but quantity brought back to the port depends on maritime resources close to the coast. Moreover, even if the frequency at which vessels go back to the port increases, some of them may decide to return even if their hold is not full so that they can sell fresher fish. Finally, some vessels may choose fishing spots close to the coast even if available maritime stocks in these spots are rather low because this will allow them to sell fresh fish of higher quality. Species other than the ones targeted by treated vessels may be fished less although their demand may increase if customers are attracted by the treated fishing market due to a higher average quality and non-treated vessels react by fishing these species more extensively.

Finally, even if fish prices may increase in the short run due to higher quality, this effect may be mitigated in the medium run if non-treated vessels improve the quality of their catches, as this would increase the supply of high-quality fish of a given species and thus imply a decrease in prices on the corresponding segment of the market. Nevertheless, as more fish are caught close to the coasts, maritime resources and thus vessel supply may decrease in the medium or long run. This would put an upward pressure on prices. Finally, the reputation of treated vessels may improve over time with the diffusion of information on their fish quality and this could attract more buyers, in particular distant ones connected with internet to Les Sables d'Olonne where there are electronic auctions. This can increase the demand and thus prices on the market for fish of given species and quality at equilibrium. However, the price effects described above might remain small since both treated and non-treated vessels are expected to have a limited influence on the market which has become national due to distant auctions (Guillotreau and Jimenez-Toribo, 2011).[19]

[18] It is impossible to cheat with the license system since using the Danish seine first necessitates vessels to be landed for around four months to get equipped, and this is not discrete. Moreover, it is obvious from the look of equipped vessels which ones are seiners and which ones are not.

[19] For instance, most whitefish now compete in the same market in France (Asche et al., 2004) and there even exists a global market for whitefish to which France participates.

We quantify the effects of the innovation on the treated market from aggregate data over the July 2009-June 2011 period, in which the observation unit is a fish market in a given month (see Online Appendix B). We use various approaches such as difference in differences, but also factor models and synthetic controls that allow for heterogeneous unobserved trends for fish markets (see Abadie and Gardeazabal, 2003; Abadie et al., 2010 and 2015; Gobillon and Magnac, 2016).

We find that the treatment effect on the treated market is sizable and comprised within the 13.5-18.2 percentage points interval. This range can be contrasted with the counterfactual treatment effect obtained from transaction data under the assumption that there is no spillover of the treated vessels on the non-treated ones, which is found to be lower (5.5 percentage points). This suggests that non-treated vessels adapted their fishing practices to remain competitive, for instance by fishing closer to the coast to bring back fresher fish. Conversely, the estimated treatment effects on market prices and quantity are found to be small and not significant.

8. Conclusion

In this paper, we evaluated the effects of introducing an innovation on quality, quantity and prices using a natural experiment that occurred on a French wholesale fish market. Some vessels could adopt a new fishing gear thanks to subsidies of local authorities while others kept using the same gear. We find that the innovation had a large effect on treated vessels just after its introduction, since it increased their proportion of high-quality fish by 29.2 percentage points and their prices by 23.2 percentage points. The use of the new technology also induced a shift in targeted species and new targeted species were fished very intensively. Suggestive evidence on revenues and costs shows that the introduction of the Danish seine was highly profitable for treated vessels.

The intensity with which targeted species are fished is of primary importance in a world where capacity-enhancing subsidies represent the largest share of subsidies and lead to overcapacity and overfishing as discussed in Sumaila et al. (2019). In fact, due to concerns about sustainability and unfair competitiveness, newly equipped vessels have been forbidden to fish around the coasts of three surrounding regions: Bretagne, Aquitaine and Poitou-Charentes (Hamon, 2015). Moreover, there are currently discussions on the opportunity to reduce the net size of the new gear to limit its efficiency in the same way it was done in Norway where this technology is also used.

Alternatively, control on catches without imposing a limit on productivity may be achieved by using a more efficient regulation of catches (Asche and Smith, 2018). A possibility is individual fishing quotas after total allowable catches (TAC) have been introduced to protect the fish stock. Provided that an efficient regulation system is put in place, a more widespread introduction of the Danish seine could in fact improve sustainability through a better targeting of species and the avoidance of catches of under-sized fish. It may also improve the welfare of fishermen thanks to lower fuel spendings and shorter journeys at sea.

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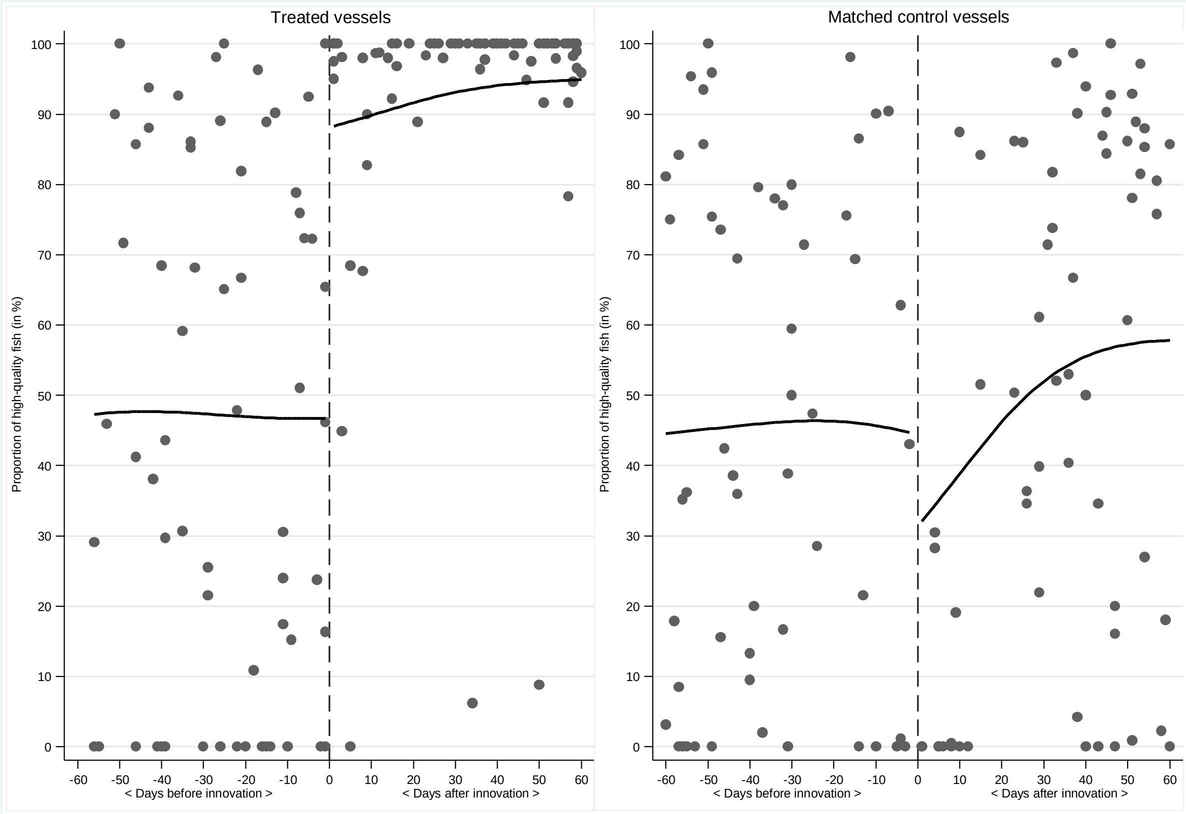
Figure 1. Calendar on fishing gears used by vessels equipped with Danish seine

	2009				2010												2011					
	S	*O*	*N*	*D*	*J*	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*	*J*	*F*	*M*	*A*	*M*	*J*
ANTHINEAS	**O**						**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
end date of other gears / starting date of Danish seine	17/09						15/03															
MANBRISA	**O**	**O**					**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
end date of other gears / starting date of Danish seine		10/05					04/03															
RENAISSANCE II	**O**	**O**	**O**	**O**	**O**					**S**	**M**	**M**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
end date of other gears / starting date of Danish seine					21/01					21/06												
ARUNDEL	**O**	**O**	**O**	**O**	**O**						**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
end date of other gears / starting date of Danish seine					11/01						05/07											
BLACK PEARL	**O**	**O**	**O**			**O**	**O**	**O**			**M**	**O**	**M**	**S**	**S**	**S**			**S**	**S**	**S**	**S**
end date of other gears / starting date of Danish seine								09/04			19/07											
LES BARGES	**O**	**O**	**O**			**O**	**O**	**O**			**M**	**O**	**M**	**S**	**S**			**S**	**S**	**S**	**S**	**S**
end date of other gears / starting date of Danish seine								16/03			19/07											

Source: authors' calculations, transaction data from Les Sables d'Olonne.
Legend: **S** Danish seine, **O** other fishing gears, **M** mix between Danish seine and other gears.

Figure 2. Discontinuity analysis: daily proportion of high-quality fish (window: four months)



Source: authors' calculations, transaction data from Les Sables d'Olonne.
Note: each dot corresponds to the set of transactions of one vessel on a specific day. Data are smoothed using a kernel-weighted local polynomial regression with a Gaussian kernel.

Table 1. Descriptive statistics for treated and matched control vessels

Variables	Treated vessels			Matched control vessels			Difference in differences
	Before	After	Difference	Before	After	Difference	
Panel A. Proportion of high-quality fish							
Mackerel	0.284	0.974	0.691	0.399	0.815	0.416	0.275
Red mullet	0.503	0.785	0.282	0.356	0.461	0.105	0.177
Whiting	0.260	0.856	0.595	0.410	0.528	0.118	0.477
Squid	0.857	0.955	0.098	0.766	0.820	0.055	0.043
Cuttlefish	0.916	0.953	0.037	0.840	0.897	0.057	-0.020
Other species	0.248	0.779	0.531	0.299	0.514	0.215	0.316
All species	0.390	0.833	0.443	0.401	0.566	0.166	0.277
Panel B. Quantity in tons per day							
Mackerel	0.060	1.920	1.860	0.046	0.916	0.870	0.990
Red mullet	0.126	1.498	1.372	0.096	0.105	0.009	1.363
Whiting	0.100	1.252	1.152	0.101	0.311	0.210	0.942
Squid	0.586	0.894	0.308	0.435	0.577	0.142	0.166
Cuttlefish	1.143	0.572	-0.571	0.752	0.950	0.198	-0.769
Other species	5.769	2.394	-3.375	2.934	6.368	3.434	-6.809
All species	7.786	8.531	0.745	4.366	9.228	4.862	-4.117
Panel C. Price							
Mackerel	0.596	1.280	0.683	1.004	0.972	-0.032	0.716
Red mullet	6.675	8.079	1.405	6.373	6.450	0.077	1.327
Whiting	1.623	1.931	0.308	1.745	1.341	-0.404	0.712
Squid	4.023	6.738	2.715	4.136	4.823	0.687	2.027
Cuttlefish	3.157	3.975	0.818	2.920	3.442	0.522	0.296
Other species	6.238	5.755	-0.483	5.272	5.217	-0.055	-0.427
All species	5.534	5.227	-0.307	4.823	4.762	-0.061	-0.246

Source: authors' calculations, transaction data for Les Sables d'Olonne.

Note: the sample includes all transactions of treated and control vessels observed between September 2009 and June 2011.

Table 2. Estimates for the probability for fish involved in a transaction to be of high quality, discontinuity analysis (windows: four months)

Variables	(1)	(2)	(3)
Panel A. Transactions of treated vessels in Les Sables d'Olonne			
After innovation	0.352***	0.333***	0.449***
	(0.023)	(0.021)	(0.018)
Cubic daily trend	YES	YES	YES
Fish characteristics	NO	YES	YES
Vessel fixed effects	NO	NO	YES
Number of observations	10,124	10,124	10,124
R^2	0.155	0.513	0.554
Panel B. Transactions of treated and matched control vessels in Les Sables d'Olonne			
Treated vessels x After innovation	0.429***	0.356***	0.292***
	(0.014)	(0.014)	(0.013)
Treated vessels	-0.058***	-0.053***	
	(0.012)	(0.010)	
After innovation	-0.238***	-0.099***	0.049***
	(0.020)	(0.017)	(0.017)
Cubic daily trend	YES	YES	YES
Fish characteristics	NO	YES	YES
Vessel fixed effects	NO	NO	YES
Number of observations	19,715	19,715	19,715
R^2	0.122	0.377	0.454

Source: authors' calculations, transaction data for Les Sables d'Olonne.

Note: (1) and (2) are estimates from linear probability models with robust Hubert-White standard errors and (3) are estimates from fixed effects linear probability models. Significance levels are respectively 1% (***), 5% (**) and 10% (*). Fish characteristics include fish species, size and presentation.

Table 3. Estimates for the probability for fished involved in a transaction to be of high quality (whole period)

Variables	(1)	(2)	(3)
Panel A. Transactions of treated vessels in Les Sables d'Olonne			
After innovation	0.298***	0.416***	0.406***
	(0.010)	(0.010)	(0.009)
Cubic daily trend	YES	YES	YES
Fish characteristics	NO	YES	YES
Vessel fixed effects	NO	NO	YES
Number of observations	57,245	57,245	57,245
R^2	0.205	0.328	0.357
Panel B. Transactions of treated and matched control vessels in Les Sables d'Olonne			
Treated vessels x After innovation	0.319***	0.258***	0.229***
	(0.007)	(0.007)	(0.007)
Treated vessels	-0.045***	-0.023***	
	(0.007)	(0.006)	
After innovation	-0.008	0.054***	0.059***
	(0.008)	(0.008)	(0.007)
Cubic daily trend	YES	YES	YES
Fish characteristics	NO	YES	YES
Vessel fixed effects	NO	NO	YES
Number of observations	120,281	120,281	120,281
R^2	0.136	0.267	0.307
Panel C. All transactions in Les Sables d'Olonne			
Treated vessels x After innovation	0.295***	0.251***	0.334***
	(0.006)	(0.005)	(0.004)
Treated vessels	-0.014**	0.011**	
	(0.006)	(0.005)	
After innovation	0.162***	0.118***	-0.014***
	(0.004)	(0.003)	(0.003)
Cubic daily trend	YES	YES	YES
Fish characteristics	NO	YES	YES
Vessel fixed effects	NO	NO	YES
Number of observations	399,844	399,844	399,844
R^2	0.061	0.351	0.584
Panel D. All transactions in Vendée			
Treated vessels x After innovation	0.344***	0.329***	0.353***
	(0.006)	(0.005)	(0.004)
Treated vessels	-0.047***	-0.009*	
	(0.006)	(0.005)	
After innovation	0.170***	0.099***	0.015***
	(0.003)	(0.002)	(0.002)
Cubic daily trend	YES	YES	YES
Fish market fixed effects	YES	YES	YES
Fish characteristics	NO	YES	YES
Vessel fixed effects	NO	NO	YES
Number of observations	797,096	797,096	797,096
R^2	0.230	0.479	0.242

Source: authors' calculations, transaction data for Vendée.

Note: (1) and (2) are estimates from linear probability models with robust Hubert-White standard errors and (3) are estimates from fixed effects linear probability models. Significance levels are respectively 1% (***), 5% (**) and 10% (*). Fish characteristics include fish species, size and presentation.

Table 4. Estimates for the log price of a transaction, discontinuity analysis (windows: four months)

Variables	(1)	(2)	(3)	(4)	(5)
Panel A. Transactions of treated vessels in Les Sables d'Olonne					
After innovation	0.389***	0.324***	0.251***	0.221***	0.206***
	(0.022)	(0.023)	(0.022)	(0.022)	(0.022)
High-quality fish		0.150***	0.141***	0.117***	0.120***
		(0.012)	(0.012)	(0.012)	(0.012)
Quantity of the transaction (log)			-0.146***	-0.124***	-0.123***
			(0.006)	(0.006)	(0.006)
Total quantity of the day (log)					-0.029**
					(0.011)
Total number of buyers of the day (log)					0.020
					(0.014)
Cubic daily trend + day of week	YES	YES	YES	YES	YES
Fish species + size + presentation	YES	YES	YES	YES	YES
Vessel fixed effects	YES	YES	YES	NO	NO
Buyer-vessel matched fixed effects	NO	NO	NO	YES	YES
Number of observations	10,124	10,124	10,124	10,124	10,124
R^2	0.814	0.817	0.828	0.858	0.858
Panel B. Transactions of treated and matched control vessels in Les Sables d'Olonne					
Treated vessels x After innovation	0.209***	0.183***	0.150***	0.131***	0.111***
	(0.015)	(0.015)	(0.014)	(0.015)	(0.015)
After innovation	0.091***	0.086***	0.090***	0.079***	0.066***
	(0.019)	(0.019)	(0.019)	(0.018)	(0.019)
High-quality fish		0.096***	0.089***	0.058***	0.068***
		(0.008)	(0.008)	(0.008)	(0.008)
Quantity of the transaction (log)			-0.136***	-0.124***	-0.121***
			(0.004)	(0.004)	(0.004)
Total quantity of the day (log)					-0.080***
					(0.009)
Total number of buyers of the day (log)					0.036***
					(0.011)
Cubic daily trend + day of week	YES	YES	YES	YES	YES
Fish species + size + presentation	YES	YES	YES	YES	YES
Vessel fixed effects	YES	YES	YES	NO	NO
Buyer-vessel match fixed effects	NO	NO	NO	YES	YES
Number of observations	19,715	19,715	19,715	19,715	19,715
R^2	0.789	0.791	0.801	0.837	0.838

Source: authors' calculations, RIC data.

Note: estimates from fixed effects linear probability models. Significance levels are respectively 1% (***), 5% (**) and 10% (*).

Table 5. Estimates for the log price of a transaction (whole period)

Variables	(1)	(2)	(3)	(4)	(5)
Panel A. Transactions of treated vessels in Les Sables d'Olonne					
After innovation	0.429***	0.385***	0.298***	0.284***	0.239***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
High-quality fish		0.121***	0.118***	0.090***	0.101***
		(0.005)	(0.005)	(0.005)	(0.005)
Quantity of the transaction (log)			-0.159***	-0.144***	-0.131***
			(0.003)	(0.003)	(0.003)
Total quantity of the day (log)					-0.181***
					(0.005)
Total number of buyers of the day (log)					0.310***
					(0.017)
Cubic daily trend + day of week	YES	YES	YES	YES	YES
Fish species + size + presentation	YES	YES	YES	YES	YES
Vessel fixed effect	YES	YES	YES	NO	NO
Buyer-vessel matched fixed effect	NO	NO	NO	YES	YES
Number of observations	57,245	57,245	57,245	57,245	57,245
R^2	0.785	0.787	0.800	0.822	0.827
Panel B. Transactions of treated and matched control vessels in Les Sables d'Olonne					
Treated vessels x After innovation	0.269***	0.247***	0.224***	0.190***	0.148***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
After innovation	0.133***	0.128***	0.105***	0.113***	0.084***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
High-quality fish		0.099***	0.099***	0.074***	0.080***
		(0.003)	(0.003)	(0.003)	(0.003)
Quantity of the transaction (log)			-0.146***	-0.139***	-0.130***
			(0.002)	(0.002)	(0.002)
Total quantity of the day (log)					-0.176***
					(0.003)
Total number of buyers of the day (log)					0.240***
					(0.012)
Cubic daily trend + day of week	YES	YES	YES	YES	YES
Fish species + size + presentation	YES	YES	YES	YES	YES
Vessel fixed effect	YES	YES	YES	NO	NO
Buyer-vessel match fixed effect	NO	NO	NO	YES	YES
Number of observations	120,281	120,281	120,281	120,281	120,281
R^2	0.765	0.766	0.779	0.803	0.808

Source: authors' calculations, RIC data.

Note: estimates from fixed effects linear probability models. Significance levels are respectively 1% (***), 5% (**) and 10% (*).

Table 6. Average costs and revenues for restricted samples of treated and control groups

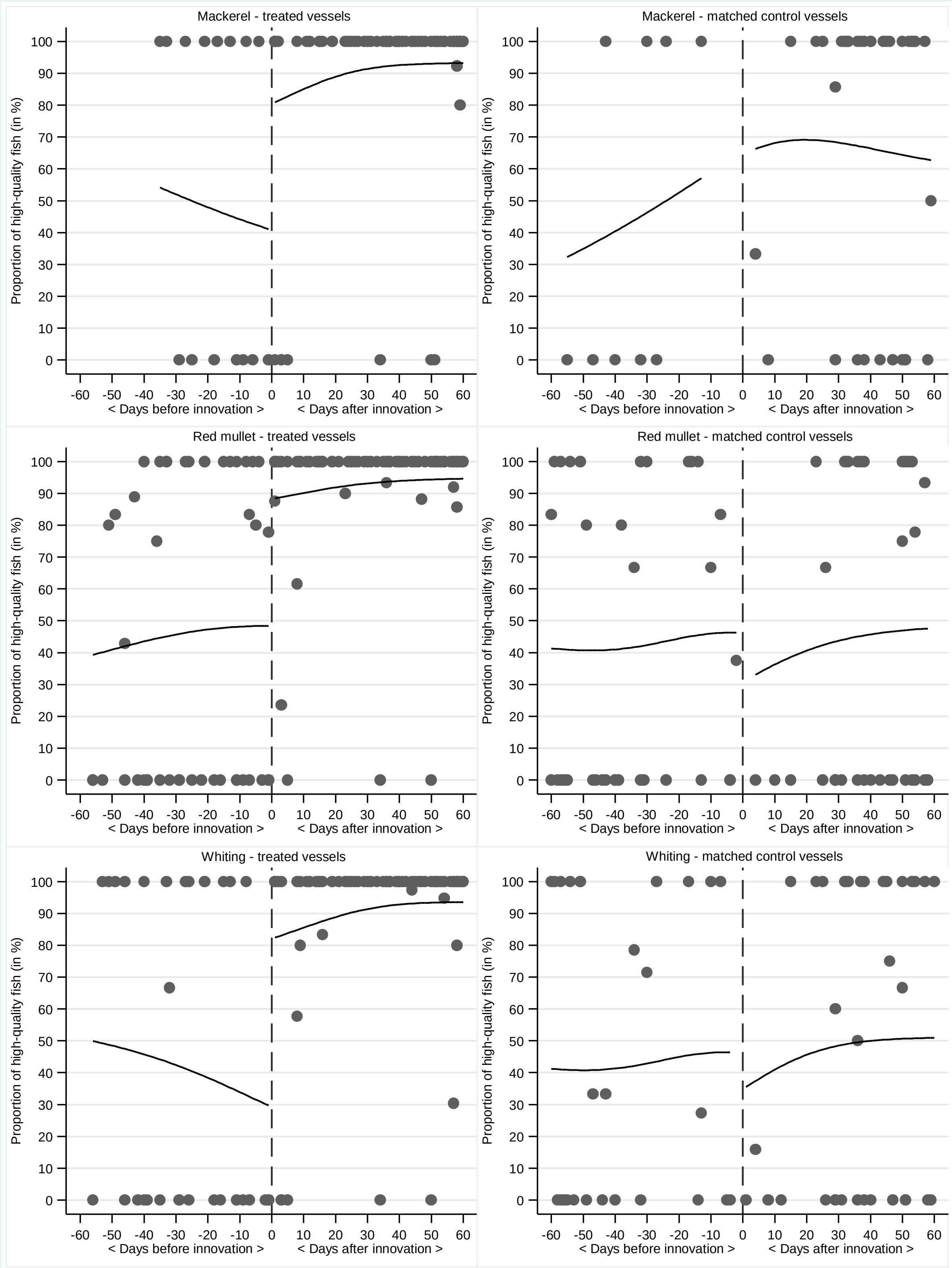
	Restricted treated group			Restricted control group		
	2009	2011	Difference (in %)	2009	2011	Difference (in %)
Average duration of trips (in hours)	61.0	16.0	-73.9	84.0	72.0	-14.3
Gasoline (in thousand liters)	382.5	292.2	-23.6	515.0	515.0	0
Sale revenues (in thousand €)	537.6	1,183.2	+120.1	756.2	1,166.5	+54.3
Variable costs (in thousand €)	497.5	881.2	+77.1	699.5	989.2	+42.7
Gasoline	130.4	187.7	+43.9	204.7	334.3	+63.3
Gear and repairs	93.5	162.9	+74.1	131.4	151.4	+15.3
Wages	154.5	363.6	+135.3	210.1	328.3	+53.8
Others (taxes, insurance, food, etc.)	119.1	167.0	+40.2	153.3	175.2	+14.3
Gross operating profit (in thousand €)	40.1	302.0	+651.5	56.7	173.3	+212.7

Source: authors' calculations, vessel data.

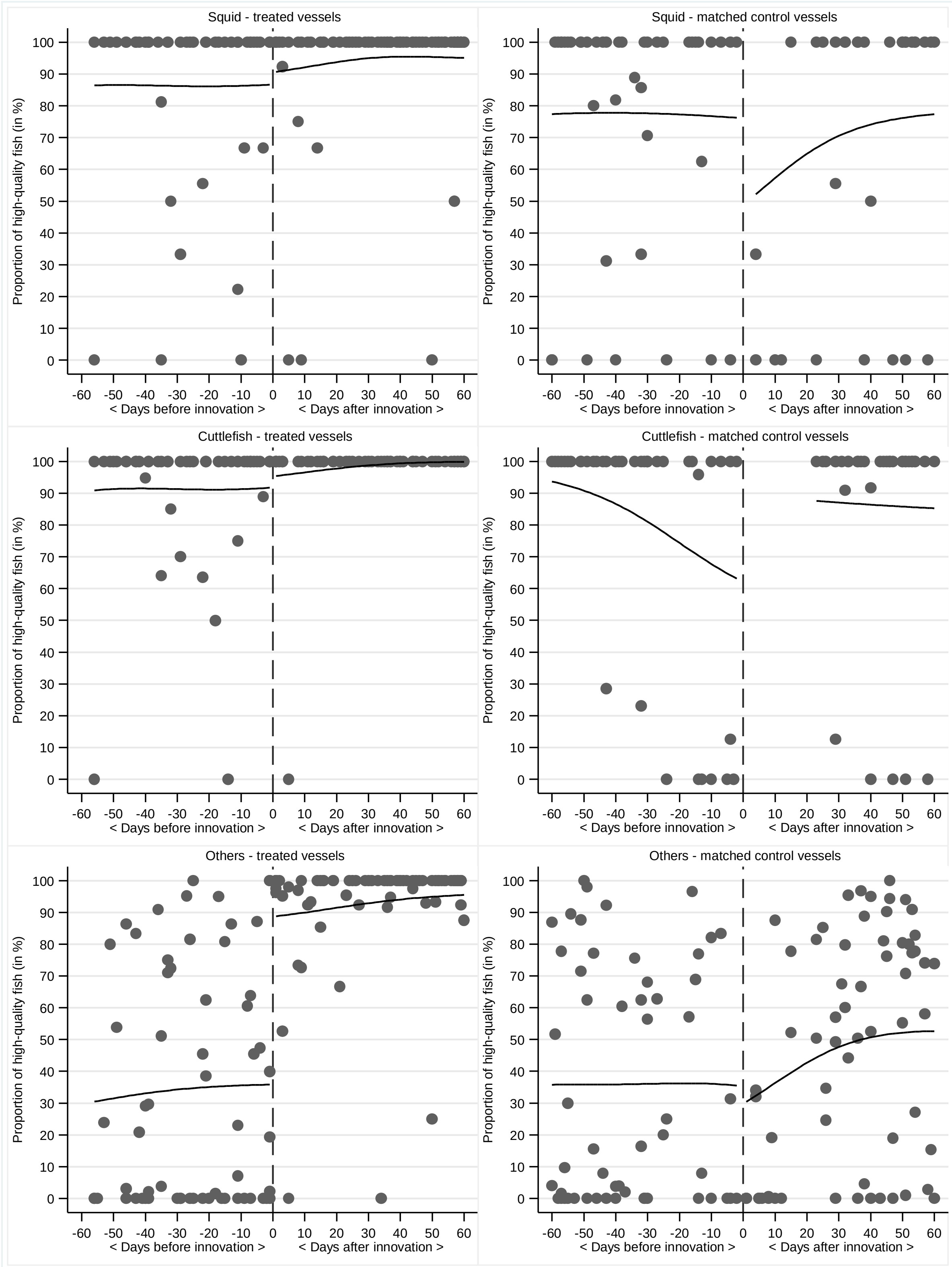
Note: the restricted treated group contains four vessels: Anthineas, Manbrisa, Arundel and Renaissance II. The restricted control group contains only two vessels: Eden Roc II and Saint Clair. The difference (in %) is given as the difference in values between 2011 and 2009 divided by the value in 2009 (x100).

Appendix

Figure A1. Discontinuity analysis: daily proportion of high-quality fish for treated and matched control vessels, by fish species (window: four months)

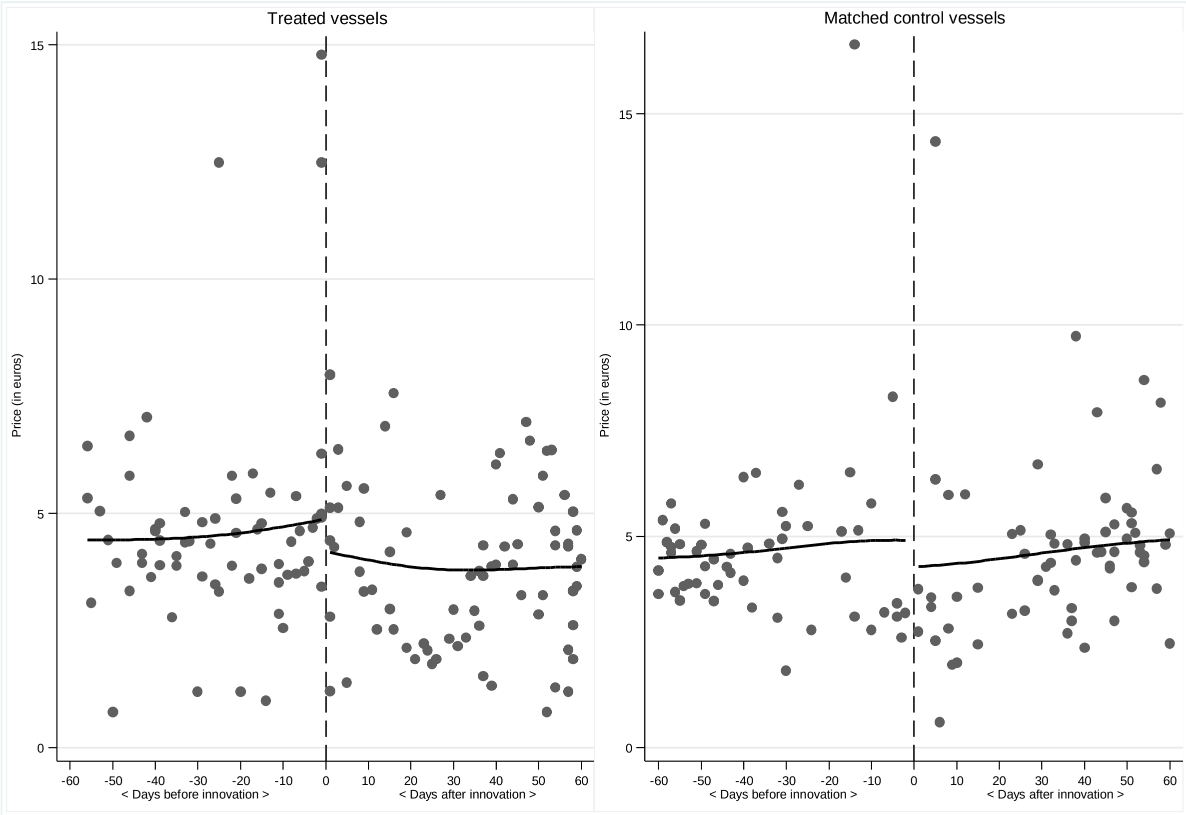


[continued below]



Source: authors' calculations, transaction data.
Note: each dot corresponds to the proportion of high-quality fish for the set of transactions of one vessel on a specific day. Data are smoothed using a kernel-weighted local polynomial regression with a Gaussian kernel.

Figure A2. Discontinuity analysis: daily fish price per kilogram (window: four months)



Source: authors' calculations, transaction data from Les Sables d'Olonne.

Note: each dot corresponds to the average price per kilogram for the set of transactions of one vessel on a specific day. Data are smoothed using a kernel-weighted local polynomial regression with a Gaussian kernel.

Table A1. Estimates for the probability for fish involved in a transaction to be of high quality (transaction data)

Variables	(1) Mackerel	(2) Red mullet	(3) Whiting	(4) Squid	(5) Cuttlefish	(6) Others
Panel A. Transactions of treated vessels in Les Sables d'Olonne						
After innovation	0.566***	0.133***	0.435***	-0.012	-0.003	0.533***
	(0.030)	(0.041)	(0.041)	(0.022)	(0.023)	(0.012)
Cubic daily trend	YES	YES	YES	YES	YES	YES
Fish characteristics	YES	YES	YES	YES	YES	YES
Vessel fixed effects	YES	YES	YES	YES	YES	YES
Number of observations	4,327	11,123	8,470	4,655	3,452	25,218
R^2	0.226	0.212	0.205	0.114	0.044	0.435
Panel B. Transactions of treated and matched control vessels in Les Sables d'Olonne						
Treated vessels x After innovation	0.424***	0.305***	0.462***	0.071***	-0.032*	0.254***
	(0.045)	(0.034)	(0.033)	(0.018)	(0.017)	(0.009)
After innovation	0.005	-0.083**	-0.118***	-0.057**	0.043**	0.094***
	(0.042)	(0.038)	(0.033)	(0.022)	(0.018)	(0.009)
Cubic daily trend	YES	YES	YES	YES	YES	YES
Fish characteristics	YES	YES	YES	YES	YES	YES
Vessel fixed effects	YES	YES	YES	YES	YES	YES
Number of observations	6,554	12,733	11,068	8,490	7,880	73,556
R^2	0.218	0.235	0.266	0.145	0.103	0.284
Panel C. All transactions in Les Sables d'Olonne						
Treated vessels x After innovation	0.652***	0.214***	0.458***	0.067***	-0.036***	0.389***
	(0.042)	(0.028)	(0.026)	(0.014)	(0.013)	(0.005)
After innovation	-0.196***	0.043*	-0.040***	-0.008	0.025***	-0.016***
	(0.026)	(0.023)	(0.013)	(0.012)	(0.009)	(0.003)
Cubic daily trend	YES	YES	YES	YES	YES	YES
Fish characteristics	YES	YES	YES	YES	YES	YES
Vessel fixed effects	YES	YES	YES	YES	YES	YES
Number of observations	12,444	18,281	22,213	19,892	25,242	301,772
R^2	0.325	0.253	0.522	0.139	0.342	0.599
Panel D. All transactions in Vendée						
Treated vessels x After innovation	0.691***	0.248***	0.527***	0.081***	-0.014	0.422***
	(0.028)	(0.023)	(0.021)	(0.011)	(0.012)	(0.005)
After innovation	-0.126***	0.074***	-0.014*	-0.004	-0.035***	0.010***
	(0.013)	(0.016)	(0.008)	(0.009)	(0.008)	(0.002)
Cubic daily trend	YES	YES	YES	YES	YES	YES
Fish market fixed effects	YES	YES	YES	YES	YES	YES
Fish characteristics	YES	YES	YES	YES	YES	YES
Vessel fixed effects	YES	YES	YES	YES	YES	YES
Number of observations	27,392	30,559	38,110	28,776	32,135	640,124
R^2	0.821	0.346	0.690	0.713	0.460	0.657

Source: authors' calculations, transaction data from Vendée.

Note: estimates from fixed effects linear probability models. Significance levels are respectively 1% (***), 5% (**) and 10% (*). Fish characteristics include fish species (only in column 6), size and presentation.