# The effect of innovation on quality and prices: Evidence from the French fish market[#]

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**February 2016**

**Abstract**

In this paper, we investigate the effect on quality and prices of an innovative fishing technique implemented on a subsample of vessels on a single wholesale fish market in France in March 2010. We quantify the treatment effect on the treated using a discontinuity analysis coupled with difference in differences. Estimations are conducted using transaction data from September 2009 to June 2011 period during which the innovation was introduced. We find that the innovation had a large effect on treated vessels within the two months after its introduction, since it increased their proportion of high-quality fish by 43.5 percentage points and their prices by 23.4 percentage points. We also quantify the treatment effect on the treated market from market data using a synthetic control approach and factor models. Our results show that, whereas the effect on market prices was small and not significant, the effect on market quality was sizable but smaller than the effect on the treated vessels. This suggests that non-treated vessels adapted their fishing practices to remain competitive.

**Keywords:** fish, innovation, product quality, product prices, discontinuity, difference in differences, synthetic controls, factor models

**JEL Classification:** L11, Q22

[#] We thank Laurent Baranger, Jean-François Bigot and Pierrick Olivier for very helpful discussions, as well as participants in seminars held in Toulon, Lyon and Aussois.

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## 1. Introduction

Technology diffusion plays a major role in the development of countries as it improves the productivity and well-being of population. Consequently, a large effort has been devoted to understanding the mechanisms underlying diffusion especially in the agricultural sector (Foster and Rosenzweig, 2010). At the same time, the exact influence of new technologies on the market is still subject to debate due to an absence 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 that has been introduced for some vessels on a French wholesale fish market. We assess its effects on fish quality and selling prices for these vessels, and more generally for the local market where it has been implemented. This evaluation is made possible by the availability of panel data on fish transactions in which vessels are tracked, and panel data reporting the aggregate activity on every local fish markets.

The use of a new technology is usually considered in the literature as an individual choice that depends on education, credit constraints, learning by doing and learning from others (Besley and Case, 1992; Foster and Rosenzweig, 1995; Bandiera and Rasul, 2006; Conley and Udry, 2010). Private entities and governments can influence adoption through extension agents that diffuse information on the new technology (Abdulai and Huffman, 2005, Genius *et al.*, 2014) or through subsidies to purchase equipment necessary to use the new technology. Here, we consider a natural experiment such that public authorities subsidized new gear for some specific vessels located in A single fish market to assess the extent to which it was able to improve the quality of fish catches. Indeed, the fishing gear often represents a significant investment but it is usually considered to have a significant effect on revenues.

The impact of a new technology on outcome and profit is usually difficult to assess in agriculture since there can be a selection of individuals deciding to adopt it that depends on production costs, expected returns and risk. In particular, land soil and climate have an effect on the harvest. Only a very few papers propose a convincing empirical strategy to establish a causal effect. Duflo et al., (2008) establish the rate of returns to fertilizers in Kenya using a controlled experiment with a random allocation of fertilizer use to farmers. Suri (2011) evaluates the distribution of returns to using hybrid maize in Kenya using extensive panel data technics.

Fishing offers a different context since producers are not attached to a location such as farmers cultivating fields. Vessels can fish everywhere at a reasonable distance from their port, and this alleviates the concern of unobserved heterogeneity. Still, vessels can differ in their equipment, and captain and sailors in their experience on where to fish and which fishing gear to choose as each gear is associated to specific expected return and risk (Eggert and Tveretas, 2004; Wolff et al., 2013). As panel data are available for our study, we are able to use several econometric methods to deal with very general forms of unobserved heterogeneity.

When assessing the effect of the innovation on fish quality and prices for newly equipped vessels, we resort to a discontinuity approach coupled with difference in differences since data follow vessels in a continuous way across time. More precisely, we contrast the change in fish quality at the time of technology adoption between vessels which benefited from the technology and similar vessels in the same local fish market which did not. This strategy provides estimators robust to the presence of vessel unobserved heterogeneity that remains constant around the date at which the innovation is introduced and unconstrained time effects.

At the aggregate level, the effect of the innovation on the treated local fish market is evaluated both with factor models and the synthetic control approach. These two approaches take into account heterogeneous time trends across markets. Factor models incorporate several vessel fixed effects interacted with time fixed effects in a linear panel specification (Bai, 2009; Gobillon and Magnac, 2016). The synthetic control approach estimates the treatment effect as the difference in outcome after treatment between the treated local fish market and an average of control local fish markets with similar characteristics and outcomes before treatment (Abadie and Gardeazabal, 2003; Abadie *et al.,* 2010 and 2015). The estimator is obtained by interpolation whereas factor models allow for extrapolation. Compared with the approach at the vessel level that exploits variations in outcome and treatment across vessels, the analysis at the aggregate level exploits variations across local fish markets.

We evaluate the treatment effect on fish quality for six vessels equipped with a new gear, the Danish seine, in March 2010 in Les Sables d'Olonne which is a local wholesale fish market located on the French Atlantic coast. Estimations are conducted on two datasets. The first one provides information on all transactions on fish lots occurring in Les Sables d'Olonne and three surrounding local fish markets from September 2009 to June 2011. The data report the day each transaction occurs, a vessel identifier such that vessels can be tracked across transactions, as well as details on fish lots. The second dataset provides aggregate monthly information for every local fish market in France from July 2009 to June 2011. The data give the proportion of high-quality fish and the fish distribution across species. The analysis is restricted to local fish markets on the Atlantic coast since they form a rather integrated market (Gobillon and Wolff, 2016).

Our estimations with transaction data show that the innovation had a large effect on treated vessels since it increased their proportion of high-quality fish by 43.5 percentage points and their prices by 23.4 points. The average effect over the whole post-treatment period was smaller for quality at 26.0 points but larger for prices at 27.9 points. We also quantify the treatment effect on the treated market using a synthetic control approach and factor models. Estimations conducted on market data show that, whereas the treatment effect on market prices was small and not significant, that on market quality was sizable but smaller than the effect on the treated vessels since it would have been in the 13.9-18.8 points range. It can be contrasted with the counterfactual effect obtained under the assumption that there is no spillover of the treated vessels on the non-treated, which is around 3% since treated vessels are involved in one sixth of transactions on the treated market. This suggests that non-treated vessels adapted their fishing practices to remain competitive.

The rest of the paper is organized as follows. Section 2 discusses the context in which the new technology was introduced as well as its expected effects. Section 3 presents our two datasets as well as descriptive statistics on our samples. Section 4 explains our econometric approach and Section 5 discusses the results. Finally, Section 6 provides our conclusions.

## 2. Presentation of the policy and expected effects

During the 2000s, the fishing industry in Europe was hit hard by a steep increase in gasoline price. This is particularly the case in France where prices increased by 120% over the 2004-2007 period. Vessel fleets needed to be adapted to the new market conditions and local authorities in the Vendée region 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.

This technology was introduced on the fish market located in Les Sables d'Olonne on the Atlantic coast in 2010 whereas it had not been used in France before. For that year, this market was ranked 14th among 40 when considering the volume of traded fish (4,900 tons), but ranked 7th for the value (24.1 million euros). 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.[1]

Vessels equipped with Danish seine are large since they are between 18 and 25 meter long,[2] and they were built rather recently with three of them dating from 2005. Equipping vessels with a new gear requires time and trawlers need to stay on land between four and five months. Figure 1 gives the exact time schedule for the six treated trawlers. The transformation of the fleet was conducted in two steps: whereas two vessels began to fish with Danish seine in March 2010, the four others were reintroduced in the fleet between the end of June and the mid of July 2010. Two treated vessels alternate their fishing gear between seine and other technics (trawl) during the summer because

[1] This reduction in the size of the fleet was imposed by the European Community which required a reduction of the fleet capacity by at least 30%. Vessels permanently removed were rather old since they were built between 1986 and 1991, and they had a size between 14.4 and 20.8 meters. Their suppression yielded a decrease of 31.6% in tank capacity for the fleet and a decrease of 36.7% in engine power.

[2] Lengths of treated vessels are the following: 18 meters for Manbrisa, 18 meters for Renaissance 2, 18.07 meters for Arundel, 22.89 meters for Anthineas Jounau, 23.30 meters for Black Pearl and 24.95 meters for Les Barges.

they have a specific license to fish white tuna as long as quotas are not exceeded. The crew of newly equipped vessels followed a training period in Island where they boarded seiners for two weeks.

[ Insert Figure 1 ]

The Danish seine is a conical net with two long wings and a pocket in the middle used to collect fish. There are long drag lines such that wings can embrace a large area. The seine is hauled thanks to a deck crane installed on the vessel, and the net is moved in a circle around the fish such that it is herded into the pocket. Buoys are used to maintain the seine close to the water surface and seiners usually target pelagic fish such as whiting, mackerel, sardine and anchovy. By contrast, trawlers drag large rectangular fish nets most often at the bottom of the sea. Whereas no species is specifically targeted when fishing at the bottom, species living in shoal are mostly caught in midwater.

The introduction of the Danish seine is expected to have several effects on catches. First, caught species should be different since seiners fish in midwater rather than at the bottom of the sea, stay closer to the coast, and the net is dragged at a slower speed.[3] In fact, seiners mainly target slow species that include round fish such as cod, whiting, mackerel or red mullet. Second, fish quality of a given species should improve since fish is caught alive and in good condition, rather than dead and spoiled. Indeed, fish is not dragged by a trawl net at the bottom of the sea. Moreover, most fishing trips are shorter when using the seine rather than other fishing techniques 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. For the treated vessels, prices should increase since quality increases. This effect can be mitigated in the medium run by non-treated vessels improving the quality of their catches as this would increase the supply of high-quality fish. Nevertheless, as more fish are caught close to the coasts, maritime resources and thus vessel supply may decrease over time. Finally, the reputation of treated vessels may improve over time with the diffusion of information on their fish quality and attract more buyers, in particular distance ones connected to Les Sables d'Olonne through electronic auctions. This can increase the demand and thus the prices on the market at equilibrium.

In this paper, we are interested in the effect of the innovation on fish quality and prices. 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: poor (B), average (A) and high (E which stands for Extra).

[3] A slower speed prevents to some extent the deformation of the net mesh, which ensures a better selection of fished species. It also gives the crew more time to retain specific fish and it can lead to substantial fuel savings.

## 3. Description of the data

*3.1. Description of the dataset at the micro level*

Information at the transaction level is available 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 in the same administrative unit (*département*). Data cover the period spanning from September 2009 to June 2011 and each transaction corresponds to a fish lot.[4]

The sample includes 812,112 transactions such that 50.9% of them occur in Les Sables d'Olonne, 20.6% in Noirmoutier, 17.7% in Saint-Gilles Croix-de-Vie and 10.8% in Ile d'Yeu. Fish quantities are distributed differently across fish markets as the corresponding proportions are respectively 45.5%, 14.6%, 30.2% and 9.7%. We have details on the exact day of the transaction, the identities of seller (i.e. vessel) and buyer, the price, the quantity, the fish species, the size (up to seven categories depending on species), the presentation (whole, gutted, in pieces, etc.) and the quality (poor, average or high).

As treated vessels have a length between 18 and 25 meters, we will consider a specific group of control vessels using techniques other than the Danish seine that are in the same length bracket. This group is restricted to vessels registered in Les Sables d'Olonne and operating fishing trawls, which is the technique used by seiners before their transformation. There are exactly six vessels verifying the three criteria related to location, size and fishing technique, and they are matched one by one with treated vessels in decreasing order of length.[5] In what follows, we label them as "matched control vessels". We will sometimes include all vessels landing fish in Les Sables d'Olonne or Vendée in our sample and we will then refer to vessels never using the Danish Seine as "control vessels". Over the whole period, there are 398,844 transactions in Les Sables d'Olonne such that 14.3% of them involve treated vessels and 15.8% of them involve matched control vessels. In terms of quantity, the contributions of treated vessels and matched control vessels were 16.8% and 18.0%, respectively.

We can 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 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.[6] For comparison, we construct a similar graph for matched control vessels. Transactions occurring during

[4] The six vessels removed from the fleet are not in the sample because their exit date was before September 2009.

[5] The length of treated vessels ranges from 18m to 24.95m, with an average of 20.87m and a standard deviation of 3.2m. The length of matched control vessels ranges 20.6m to 24.9m, with an average of 22.64m and a standard deviation of 1.8m. The null hypothesis of equal means for the treated and matched control groups is not rejected with a t-test.

[6] After the introduction of the Danish Seine, transactions involving fish caught with another gear are excluded from the computation since we are interested in the effect of the new technology.

the period when their paired treated vessels are landed to change gear are not taken into account.[7] On each graph, we represent non-parametric trends before and after the innovation.

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 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. Overall, the sharp contrast between treated and 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 control vessels increasing their fish quality over time after the new fishing equipment is introduced.[8]

[ Insert Figure 2 ]

We then construct a similar graph for each of the five main species fished by treated vessels, as well as a residual category labelled "others", to assess whether there is still a jump in the proportion of high-quality fish at the treatment date for treated vessels (but not for control vessels) once the composition effects have been taken into account.[9] Figure A1 in Appendix shows that it is the case for mackerel, red mullet, whiting and fish in the "others" category. By contrast, we do not observe any jump in the quality of cuttlefish and squid for treated vessels because these species can hardly be damaged and are already of high quality before treatment.

We finally consider similar graphs for prices per kilogram. Interestingly, Figure A2 shows that neither treated vessels nor matched control vessels experience a jump in prices at the treatment date. It is possible to check that this absence of jump is due to a composition effect. This can be shown by repeating the same exercise for the five main species fished by treated vessels and the "others" category. Indeed, we find for treated vessels that there is 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 A3. The jump is close to zero for cuttlefish and negative for the "others" category. When pooling all species, the negative and positive jumps cancel each other. By contrast, for control vessels, there is a positive jump for squid which is smaller than for treated vessels, and no jump for all the other species.

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[7] This restriction is made to avoid differences in quality between treated and matched control vessels that are related to fish at different period having different characteristics. It leads to the deletion of 15,016 transactions.

[8] Another possible interpretation considering the period covered by the four-month widows is that, after the innovation is introduced, winter is over and fish get closer to the coast. Hence, both treated and matched control vessels may make shorter trips after treatment and this could increase to some extent their fish quality.

[9] The five selected species are those with the largest contribution to total quantity fished by treated vessels over the period. By decreasing order of importance, these species are mackerel (340.3 tons), red mullet (268.1 tons), whiting (224.2 tons), squid (177.8 tons) and cuttlefish (140.8 tons). We exclude albacore (205.7 tons) because tuna catches are highly seasonal and require specific permits.

We then assess whether there is a difference in the evolution of fish quality between treated and control vessels over the whole period spanning from March 2009 to June 2011. Panel A of 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. The figures show for treated vessels that the proportion of high-quality fish experiences a large increase of 44.3 percentage points after the introduction of the innovation. The difference between treated and control vessels in the evolution of this proportion is smaller than the increase for treated vessels, as it takes a value of 27.7 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 points for mackerel (69.1%), whiting (59.5%) and the “others” category (53.1%). It is smaller for red mullet and squid at 28.2 and 9.8 points, respectively, and very small for cuttlefish at 3.7 points. For every species, the difference between treated and control vessels in the evolution of quality 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 points for mackerel (27.5%), whiting (47.7%) and the “others” category (31.6%), it is smaller at 17.7 points for red mullet, and it is close to zero for squid (4.3%) and cuttlefish (-2.0%).

As shown in Panel B of Table 1, the price per kilogram increases for the five main species fished by treated vessels. The increase is the largest for squid at 2.7 euros but it also reaches 1.4 euros for red mullet. It is smaller for cuttlefish (0.8 euros), mackerel (0.7 euros) and whiting (0.3 euros). For every species, the increase in prices for treated vessels is larger than the difference between treated and control vessels in the evolution of prices. By contrast, there is a slight decrease in prices for the “others” category that occurs for treated vessels and, to a lesser extent, for control vessels. This may be due to some changes in the composition of caught species within that category for treated vessels.

As shown in Panel C of Table 1, there are important changes in the composition of caught species for treated vessels after the innovation is introduced, whereas fish composition remains stable for control vessels. The difference in the proportion of red mullet between treated and control vessels increases by 17.1 percentage points, whereas the increase is 12.9 points for mackerel and 12.3 points for whiting. As changes in fish quality after treatment vary greatly across species, it is important to take composition effects into account when assessing the effect of the innovation.

### *3.2. Data at the aggregate level*

We also evaluate the overall effect of the innovation in Les Sables d'Olonne using an aggregate dataset that spans from July 2009 to June 2011, in which the observation unit is a fish market for a given month. In 2010, there were 40 fish markets in France among which 34 were localized on the Atlantic coast. As there are sizable differences in prices and species between the Atlantic and Mediterranean coasts (Gobillon and Wolff, 2016), we limit the sample to fish markets on the Atlantic coast. Specifically, we consider the 31 fish markets for which there are transactions every month for the five main species during the period and this sample includes the treated market of Les Sables d'Olonne. Data contain information on the overall fish quantity involved in transactions on the fish market, its market value, composition by species, and the proportion of high-quality fish. Fish price per kilo is computed as the ratio between quantity and value.

Figure 3 represents the proportions of high-quality fish for Les Sables d'Olonne and the other fish markets on the Atlantic Coast. These proportions are rather similar before the innovation is introduced: the gap in quality is for instance at most 5 percentage points between November 2009 and March 2010. By contrast, quality in the treated market becomes much larger after its introduction. There is a sizable difference in the proportion of high-quality fish with other markets every month over the period after treatment: from July to November 2010, this difference increases from 12 points to 25 points and then decreases to around 10 points. It then climbs again to reach 28 points in March 2011 and decreases again.

[ Insert Figure 3 ]

By contrast, Figure A4 in Appendix shows that neither Les Sables d'Olonne nor the other fish markets experience a change in the trend of average prices per kilogram after the innovation is introduced.

## 4. Empirical strategy

A discontinuity analysis is conducted using transaction data to identify the effect of treatment on the treated. It relies on the quantification of jumps in the proportion of high-quality fish and prices after treatment for treated vessels. An evaluation is also performed using market level data to identify the overall effect of treatment on the treated market. This effect is of interest because there can be spillover effects on non-treated vessels that affect their fish quality and prices. The evolution of fish quality on the treated market is compared with that on other markets while controlling for flexible forms of heterogeneity with a synthetic control approach and factor models.

### *4.1. Estimation strategy using micro data*

*Discontinuity Analysis*

At the micro level, 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 limit our attention to treated vessels and we investigate whether there is a jump in the probability of fish lots to be of high quality just after a newly equipped vessel uses the Danish seine. 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.

We denote by $E_i$ the dummy taking the value one if the fish lot corresponding to transaction $i$ is of high quality (and zero otherwise). We consider a linear probability model and our first specification is:

$$E_i = \delta_S \mathbb{1}_{\{t(i) \geq t_{j(i)}\}} \mathbb{1}_{\{S(i)=1\}} + \delta_O \mathbb{1}_{\{t(i) \geq t_{j(i)}\}} \mathbb{1}_{\{S(i)=0\}} + Z_i\theta + f_\theta\big(t(i)\big) + u_{j(i)} + \varepsilon_{it} \tag{1}$$

where $t(i)$ denotes the day at which transaction $i$ occurs, $j(i)$ is the vessel making that transaction, $t_j$ the first day at which vessel $j$ is able to use the Danish seine, $\mathbb{1}_{\{t(i) \geq t_{j(i)}\}}$ is a dummy variable taking the value one if the day of transaction occurs after the innovation is introduced (and zero otherwise), $S(i)$ is a dummy variable taking the value one if the Danish seine is used to catch the fish, and zero if another gear is used, $Z_i$ is a set of fish characteristics (species, size and presentation dummies, as well as the logarithm of quantity), $f_\theta(t)$ is a parametric function of time that we consider to be a cubic time trend,[10] and $u_j$ is a vessel fixed effect.

Our parameter of interested $\delta_S$ measures the effect of using the Danish Seine on the quality of fish. As some treated vessels have a mixed use of gears after treatment, we also introduced the parameter $\delta_O$ that measures the effect of using alternative fishing techniques. The effects of gears are measured as jumps around the cubic time trend. We expect the effect of Danish seine to be positive and larger than that of other fishing techniques that are still used by some treated vessels to catch specific species.

Identification relies on the fact that vessel unobserved 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 parametrized to be smoothed and the estimated effect of Danish seine is measured as a deviation from the time trend.

*Discontinuity Analysis coupled with difference in differences*

We assess the robustness of our results by coupling a difference in differences approach to our discontinuity analysis. We add to our sample the six matched control vessels that are similar to

[10] Time is measured as the number of days since the beginning of the four-month windows centered on the discontinuity for 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 within the week.

seiners and never use the Danish seine because they have not been equipped with this fishing technique. Remember that a control vessel is assigned to each treated vessel according to length. 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 then estimate the following specification:

$$E_i = \delta_S \mathbb{1}_{\{j(i)\in\Omega\}}\mathbb{1}_{\{t(i)\geq t_{j(i)}\}}\mathbb{1}_{\{S(i)=1\}} + \delta_O \mathbb{1}_{\{j(i)\in\Omega\}}\mathbb{1}_{\{t(i)\geq t_{j(i)}\}}\mathbb{1}_{\{S(i)=0\}} + \delta_C \mathbb{1}_{\{t(i)\geq t_{j(i)}\}} + Z_i\theta + f_\theta\big(t(i)\big) + u_{j(i)} + \varepsilon_{it} \quad (2)$$

where $\Omega$ 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 $\delta_C$ captures the average post-treatment time effect while simultaneously controlling for the cubic time trend.

The treatment effect is now recovered as the difference in evolution of fish quality between treated and control vessels when treated vessels use the Danish seine after treatment. Note that it is the treatment effect on the treated only if there are no spillovers of the treatment on control vessels. Otherwise it measures the difference in the effect of innovation on quality between treated and control vessels. As control vessels may decide 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.[11]

### *4.2. Estimation strategy using aggregate data*

We also quantify the overall effect of the introduction of the Danish seine on the fish market located in Les Sables d'Olonne by contrasting the evolution of quality on that market after the introduction of the innovation with that on other markets. We begin our analysis with a standard difference-in-differences approach that is valid under the assumption that the evolution for the treated in the absence of the technological innovation would be the same as the evolution for the non-treated. As this assumption might be violated, we then turn to more general specifications that allow for heterogeneity in time trends across markets and estimate factor models involving a dummy for treatment. Nevertheless, estimates are based on extrapolation when the characteristics of the treated market are not in the support of those of control markets. We therefore confront our results with those obtained by interpolation using the synthetic control method. We construct a synthetic market as a weighted average of control markets, and contrast the evolutions of quality after treatment between treated and control markets.

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

*Difference in differences*

We first present the difference-in-differences approach that will be used to obtain first estimates of the treatment effect. Our data consist in a balanced panel of $N = 31$ markets (including Les Sables d'Olonne) and $T = 31$ months. The proportion of high-quality fish in market $i$ at month $t$ is denoted $Y_{it}$ and the treated market is indexed by $i = 1$. The specification is given by:

$$Y_{it} = \theta \mathbb{1}_{\{i=1\}} \mathbb{1}_{\{t \geq \bar{t}\}} + X_{it}\beta + \delta_t + u_i + \varepsilon_{it} \tag{3}$$

where $\bar{t}$ is the month during which the new fishing technology is introduced (ie. March 2011), $\mathbb{1}_{\{i=1\}}$ is a dummy for Les Sables d'Olonne (ie. the treated market), $\mathbb{1}_{\{t \geq \bar{t}\}}$ is a dummy for the date being post treatment, $\theta$ is the treatment effect, $X_{it}$ are some explanatory variables (in practice, the shares of every fish species in total quantity sold on the market), $\delta_t$ is a month fixed effect, $u_i$ is a market fixed effect and $\varepsilon_{it}$ is a residual. This specification allows a correlation between market unobserved effects and treatment, and estimations are thus robust to the fact that the treated market is selected for treatment based on local quality or local prices. Nevertheless, selection may rather occur depending on local trends that can be heterogeneous across markets.

*Factor models*

It is possible to adopt a more general specification such that time effects are specific to markets in a very general way. Indeed, specification (3) can be augmented with interactions between time fixed effects and market fixed effects such that:

$$Y_{it} = \theta \mathbb{1}_{\{i=1\}} \mathbb{1}_{\{t \geq \bar{t}\}} + X_{it}\beta + \delta_t + u_i + F_t{}'\Lambda_i + \varepsilon_{it} \tag{4}$$

where $F_t$ is a $K \times 1$ vector of month fixed effects and $\Lambda_i$ is a $K \times 1$ vector of market fixed effects. This specification contains not only market fixed effects $u_i$, but also $K$ series of interactive terms involving market and month fixed effects which may be correlated with treatment. When rewriting the model in first difference, it can be seen that the specification allows for a heterogeneous impact of the evolutions of several unspecified time factors on the evolution of fish quality. Hence, market unobserved heterogeneity is taken into account in a very flexible way. Specification (4) can be estimated with least squares provided that some constraints are imposed on month and market fixed effects to ensure identification (Bai, 2009).

*Synthetic controls*

We also apply the synthetic controls method by computing the treatment effect as the difference in post-treatment quality between the treated market and a synthetic control market with similar characteristics and pre-treatment quality. This synthetic market is constructed as a weighted average of other markets that are used as control markets (Abadie and Gardeazabal, 2003; Abadie et al., 2010). Weights are comprised in the unit interval and the treatment effect is thus estimated by interpolation of control markets. In case of support issues, results obtained with synthetic controls can differ from those obtained with factor models (see Gobillon and Magnac, 2016, for a discussion).

More precisely, denote $Z_i = (Y_{i1}, \ldots, Y_{i\bar{t}-1}, X_{i1}, \ldots, X_{iT})'$ the set of pre-treatment quality, measured by the proportion of high-quality fish, and all the realizations of explanatory variables at all dates. The synthetic controls method consists in solving the following minimization program:

$$\min_{\omega_j | \omega_j \geq 0, \sum_{j=2}^{N} \omega_j = 1} \left(\sum_{j=2}^{N} \omega_j Z_j - Z_i\right)' W \left(\sum_{j=2}^{N} \omega_j Z_j - Z_i\right) \tag{5}$$

where $W$ is a symmetric positive matrix. This program leads to the choice of weights $\omega_j$ that should be attributed to control markets to obtain the synthetic control market (defined as the weighted average of control markets) similar to the treated market in terms of pre-treatment quality and realizations of explanatory variables at all dates. The matrix $W$ is used to fix the respective influence of pre-treatment quality and realizations of explanatory variables at all dates in determining the weights.[12] Denoting the estimated weights by $\widehat{\omega}_j$, an estimator of the treatment effect is given by:

$$\widehat{\theta} = \frac{1}{T-\bar{t}+1} \sum_{t=1}^{\bar{t}-1} \left(\sum_{j=2}^{N} \widehat{\omega}_j Y_{jt} - Y_{1t}\right) \tag{6}$$

A test of nullity of the treatment effect at finite distance can be computed from a Placebo experiment in which each market is alternatively considered to be the treated market (although in reality no treatment is applied) and the treatment effect for that market is computed using the synthetic control approach (see Abadie et al., 2010). This experiment provides a distribution of the treatment effect and one can assess whether the estimate obtained for Les Sables d'Olonne is in the upper right tail of this distribution.

[12] In our application, the vector $Z_i$ contains 8 values for the pre-treatment quality and 144 values for the proportions of our five main species and the "others" category at all dates. Hence, matrix $W$ is of dimensions 152 x 152. It is fixed such that pre-treatment quality and composition by species contribute respectively for 80% and 20% in determining the weights. It is thus the diagonal matrix with elements equal to .8/8=.1 for pre-treatment quality values and .2/144=.0014 for composition values. We will also apply the synthetic control approach while omitting composition effects. In that case, matrix $W$ is of dimensions 8 x 8 and it is fixed to be the identity matrix.

## 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, and the effect is identified as the jump in the proportion of high-quality fish for these vessels when the innovation is introduced. As shown in panel A of Table 2, when only a cubic daily trend is introduced as a control, the Danish Seine increases the proportion of high-quality fish by 35.8 percentage points for treated vessels. When additionally taking into account fish characteristics, the estimated effect remains stable at 35.6 points. When also introducing vessel fixed effects, the estimated effect is slightly higher at 41.8 points. By contrast, the same specification yields an estimated effect of the use of techniques other than the Danish seine on the proportion of high-quality fish in the post-treatment period which is 12.7 points lower.[13]

We then couple our discontinuity analysis with a difference in differences approach by including in our sample the transactions conducted by control vessels and by adding in the specification a dummy for treated vessel and a dummy for occurring after the treatment date. In that case, the treatment effect is identified as the difference in jump in the proportion of high-quality fish between treated and control vessels. As shown in panel B of Table 2, the estimated treatment effect is larger than when considering treated vessels only. It ranges from 54.7 points when considering a cubic daily trend only in the set of control terms to 43.5 points when also including fish characteristics and vessel fixed effects in the specification. Interestingly, when controlling for both the cubic daily trend and fish characteristics, the dummy for treated vessel has an estimated effect which is small at -4.7 points. Hence, the treated and control vessels would have a propensity to catch fish which are of rather similar quality in the absence of treatment, once time and composition effects have been taken into account.

[ Insert Table 2 ]

We then estimate the treatment effect over the whole period which spans from September 2009 to June 2011 using the same specifications, and results are reported in Table 3. When considering the subsample of treated vessels only (panel A), the estimated treatment effect is slightly larger than at the discontinuity, stable across specifications, and it amounts to 40.3 points when all control terms are included. As before, 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 26.0 points when all the control terms are included. The decrease in the treatment effect two months after the introduction of the innovation can be explained by a decrease in fish stocks close to the coast which forces vessels to go further to catch

[13] This can be explained by selection effects with other techniques being used to fish specific species far away from the coast and land frozen fish of lower quality.

fish and by a change in the fishing behavior of control vessels that may fish closer to bring back fresher fish.

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 chose to set it 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 included considered in the analysis, the sample size more than triple, but the estimated treatment effect remains sizable and even larger than before as it reaches 35.9 points when all the control terms are included in the specification. Including all the vessels in Vendée makes the sample more than six times larger than when considering only treated and matched control vessels. Nevertheless, the estimated treatment effect remains stable and it reaches 37.8 points. In all the specifications, the effect of the dummy for treated vessel is positive or negative and sometimes significant, but it is always very small.

[ Insert Table 3 ]

We also ran similar regressions similar to those reported in Table 3 for each main fish species separately. Results obtained when including all the control terms (cubic daily trend, fish characteristics and vessel fixed effects) in the specification are reported in Appendix Table A1 and they are consistent with descriptive statistics. When considering treated vessels only (panel A), the innovation has no significant effect for cuttlefish and squid, a medium effect for red mullet which is at 13.5 points, a large effect for whiting at 43.6 points, and very large effects for mackerel and the "others" category at 56.2 points and 56.5 points, respectively.

When adding matched control vessels to the sample and using a difference-in-differences approach, there are some quantitative differences in the results. They can be explained by time changes in quality after treatment on top of the continuous daily time trend as these changes are now taken into account thanks to the inclusion of control vessels in the sample. In particular, the estimated treatment effects are now around 40 points for mackerel (42.6%) and whiting (46.2%), and around 30 points for red mullet (30.5%) and the "others" category (30.7%). The effects for cuttlefish and squid are now significant but small and take the values of -5.4 points for cuttlefish and +4.2 points for squid. There are variations in the treatment effect again when including in the sample all the vessels in Les Sables d'Olonne (panel C) or all the vessels in Vendée (panel D).

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, for instance by shortening their trips to bring back fresher fish.[14]

### *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 effect of the treatment as the jump in the price per kilogram for treated vessels when the innovation is introduced, while controlling for a cubic daily trend, fixed effects for the day of the week and vessel fixed effects.

Results reported in Panel A of Table 4 show that the effect is large at 39.0 percentage points. Part of this effect is due to an increase in quality. When adding to the regression the observed quality, measured with a dummy for the fish to be of high quality, the treatment effect on prices decreases by 16.9% to reach a value 32.4 points. It is likely that this effect is at least partly explained by an increase in unobserved quality as there can be a significant heterogeneity in quality even among lots of high-quality fish. In particular, treated vessels may bring back fresher fish than non-treated ones if they fish closer to the shore and make shorter trips.[15] The unobserved quality is at least partly captured by the size of fish lots since more valuable fish are often sold in smaller lots. When introducing in the specification the fish quantity involved in the transaction, the treatment effect on the treated decreases again and reaches a value of 25.1 points.[16]

[ Insert Table 4 ]

We can also assess whether characteristics of the market can explain this effect. In particular, treated vessels may sell to buyers which 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, Wolff and Guillotreau, 2013, for details), the treatment effect on the treated decreases to 22.0 points. 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 the fish market of Les Sables d'Olonne. When adding these two variables to the specification, the treatment effect on the treated decreases to 20.1 points. Moreover, the market variables have the expected

[14] In our regressions, we take into account time-invariant unobserved vessel characteristics through vessel fixed effects, but not time variations in unobserved vessel characteristics that may occur because of changes in fishing practices. As a consequence, differences in time variations between treated and control vessels are captured by the treatment effect.

[15] This mechanism cannot be investigated since our dataset does not contain any information on the date and time at which vessels leave the harbor when they go to fish. Considering the difference between two successive transaction dates for a given vessel would lead to unreasonable approximations as vessels often do not go back to fish immediately after they have landed fish (since the crew may need a rest and weather conditions may be bad).

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

effect: while the total quantity of the day (ie. supply) decreases the price per kilogram on the market, the total number of buyers of the day (ie. demand) decreases it.

This remaining 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 by adding matched non-treated vessels to our sample and by including a dummy for the transaction to occur after the treatment date. In that case, the treatment effect on the treated when considering only a cubic daily trend, fixed effects for the day of the week and vessel fixed effects in the regression is only 23.4 percentage points compared to 39.0 points when considering only treated vessels in our sample. In the case of our full specification that also involves fish quantity of the lot, buyer-vessel match effects and market characteristics, the treatment effect on the treated in only 11.1 points compared to 20.1 points before. Hence, our results show that local conditions have changed significantly just after the innovation is introduced.

We then replicate the same exercise over the whole 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 42.9 points when the daily time trend, fixed effects for the day of the week and vessel fixed effects are introduced as control, and it drops to 23.9 points for the full specification. When adding matched control vessels to the sample (panel B), the treatment effect on the treated decreases to 27.9 points for our first specification and to 15.7 points for the full specification, which are slightly larger figures than at the discontinuity.

[ Insert Table 5 ]

### *5.3. The effect of the innovation on quality and prices for the treated market*

We now turn to the evaluation of the overall effect of treatment on the market where the innovation was introduced. Our goal is to assess whether there are externalities of the innovation on the non-treated vessels as they may try to improve their fish quality to remain competitive.

We first estimate the standard panel specification of the proportion of high-quality fish in which additive market month and month fixed effects are included together with a treatment dummy, which is defined as the interaction between a dummy for the treated market (Les Sables d'Olonne) and a dummy for the March 2010-June 2011 period. Panel A of Table 4 shows that, when fish composition is not taken into account, the estimated effect of the innovation is significant and sizable with a value of 16.5 percentage points. This effect can be explained by the evolution of quality for treated vessels, their significant market share, as well as incentives for control vessels to improve their quality. It is around two times lower than the jump in the proportion of high-quality fish for treated vessels which we measured to be as high as 37 points.

As the treated and control markets might be characterized by different trends in the evolution of quality, we conduct robustness checks by estimating specifications that also include interactive terms involving market and month fixed effects. The estimated treatment effect hardly changes since it varies between 15.9 and 16.6 points, depending on the number of interactive effects that are introduced (ranging from 1 to 3).[17]

Heterogeneous time trends can also be taken into account with the synthetic control approach in which the treated market is compared to a synthetic market, constructed as a weighted average of control markets such that pre-treatment quality is similar. In our case, the synthetic market mostly involves six control markets, the contributions of the two main ones being 38.9% (Loctudy) and 25.7% (Ile d'Oleron) as reported in Appendix Table A2. The evolution of the difference in quality between the treated and synthetic markets is represented in Figure A5. It shows that the synthetic market reproduces very well the quality in the treated market every month before treatment. We obtain an average estimated treatment effect very close to other estimates at 16.5 points. There are variations in the estimated treatment effect over time since it increases until December 2010 before fluctuating negatively or positively.

We also conduct a Placebo experiment in which every control market is successively considered fictitiously as treated. We can then assess whether the estimated treatment effect obtained for the treated market is larger than those for the control markets. As the synthetic market obtained for some of the control markets does not fit well quality before treatment, we only consider control markets for which the Root Mean Square Percentage Error (RMSPE) for quality before treatment is lower than five times that of the treated market.[18] The evolution of the difference in quality between each control market and its synthetic market is represented on part A of Figure A2. Overall, the estimated treatment effect is larger for the treated market than for control markets after treatment, except during the transition period when treated vessels are successively reintroduced in the vessel fleet with their new equipment.

We then take into account composition effects by using the proportions of the five species most fished by treated vessels and the "others" category as additional controls (panel B). The estimated treatment effect obtained with standard panel and factor model approaches are hardly affected. It is equal to 17.2 points when estimating the difference-in-differences specification and it oscillates

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[17] Even if there are procedures to determine the right number of factors to include in the specification (Bai and Ng, 2002, Moon and Weidner, 2015), they would be fragile (Onatski et al., 2013). As a consequence, we rather assessed the robustness of our results when varying the number of factors.

[18] The RMSPE is given by the formula $\sqrt{\sum_{t=1}^{\bar{t}-1}\sum_i\left(\frac{y_i-y_i^s}{y_i}\right)^2}$ where $y_i$ is the quality for control market $i$ and $y_i^s$ is the quality for its synthetic market.

between 15.7 and 18.8 points when estimating factor models. The synthetic fish market now involves nine control markets which are mostly different from those obtained when not taking into account the composition of species (see Table A2 in appendix). The estimated treatment effect obtained with the synthetic control method is a bit smaller than other estimates, at 13.9 points.[19] The likely reason for this discrepancy is that the quality slightly differs between the treated and control markets during some months before treatment as shown by Figure A2. This occurs because it is not possible to construct a synthetic market that is very similar to the treated market in the dimensions of both pre-treatment quality and composition of species.[20]

As before, we conduct a Placebo experiment and estimate the treatment effect for each control market by contrasting its post-treatment quality with that of a synthetic market as represented in part B of Figure A2. This time, we drop control markets for which the RMSPE for the quality before treatment is larger than two times that of the treated market. Indeed, the RMSPE for the treated market is now large due to the differences in quality before treatment between the treated and synthetic markets.[21] Nevertheless, the results are similar to those obtained when not taking into account the composition of species, since the estimated treatment effect is larger for the treated market than for control markets once the transition period during which treated vessels are reintroduced in the fleet with their new equipment has passed.

[ Insert Table 6 ]

Overall, our results suggest that the treatment effect on quality of the treated market would be comprised between 13.9 and 18.8 points. This effect can be contrasted with the treatment effect obtained under the assumption that there is no spillover from the treated vessels on the non-treated vessels. As the treatment effect on treated vessels is 26 points and 16.5% of transactions in Les Sables d'Olonnes are conducted by treated vessels, the treatment effect on the treated market were there no spillovers effect is around 3 points (as it ranges from 0.165*13.9=2.3 points to 0.165*18.8=3.1 points). This effect is smaller than the one we estimated from our market data, which suggests that spillover effects are significant.

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[19] Alternatively, we also experimented by considering for composition variables the proportions of the nine main species in the volume sold in the treated fish market (along with a residual category). The estimated treatment effect is very similar. It is 17.3 points when estimating the difference-in-differences specification, it ranges between 16.4 points and 19.6 points when estimating factors models, and it amounts to 13.1 points when using the synthetic control method.

[20] We replicated the same kind of exercise to study the treatment effect on the prices of the treated market. Results obtained when estimating a standard panel specification and factor models, and when conducting a synthetic control approach, whether or not fish composition and quality are taken into account, are reported in Table A3. The estimated treatment effect is always found to be non-significant. While it has a negative sign when estimating linear models, it has a positive sign when conducting a synthetic control approach. This difference comes from the inability to construct a synthetic market similar to the treated market with respect to prices before treatment.

[21] When fish composition is not taken into account, the RMSPE is equal to 0.0047 for the treated market of Les Sables d'Olonne. The maximal RMSPE which is allowed for the placebo analysis is thus 5*0.0047=0.0235. When taking the fish composition into account, the RMSPE for les Sables d'Olonne is 0.0439, meaning that we include in the placebo analysis fish markets which RMSPE is at most 2*0.0439=0.0878.

**6. Conclusion**

In this paper, we evaluated the effect of introducing an innovation on quality and prices using a natural experiment that occurred on a French fish market in March 2010. Some vessels could adopt a new fishing technique thanks to subsidies of local authorities while others kept using the same gear. We estimated the treatment effect on the treated vessels with a discontinuity approach coupled with difference and differences using transaction data covering the September 2009 – June 2011 period.

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 43.5 percentage points and their prices by 23.4 points. The average effect over the whole post-treatment period was smaller for quality but larger for prices.

We also evaluated the treatment effect on the treated market by estimating factor models and by implementing a synthetic control approach. We obtained an average effect on prices over the whole post-treatment period which is small and not significant, and an average effect on quality which is comprised between 13 and 20 points. This effect is larger than the counterfactual effect recovered under the assumption that there is no spillover of the treated vessels on the non-treated. This suggests market externalities such that non-treated vessels adapt their fishing practices to remain competitive.

Our analysis is a first step to evaluate the effects of an innovation on production. Further work could investigate whether the innovation increased the profit and well-being of fishermen, but additional data on cost are needed for that purpose. It would also be interesting to assess whether introducing an efficient fishing technique on the market can endanger some species and threaten the sustainability of maritime resources in the long run.

The questions addressed in this paper are similar to those of interest in the literature on developing countries that studies to what extent the introduction of new agricultural techniques, such as fertilizers, affects the productivity of farmers. In our case, we have very precise data that make it possible to assess the effect of an innovation in the context of a natural experiment. Whereas this kind of analyses is still scarce, it is likely that they will become more common when better-quality data become available.

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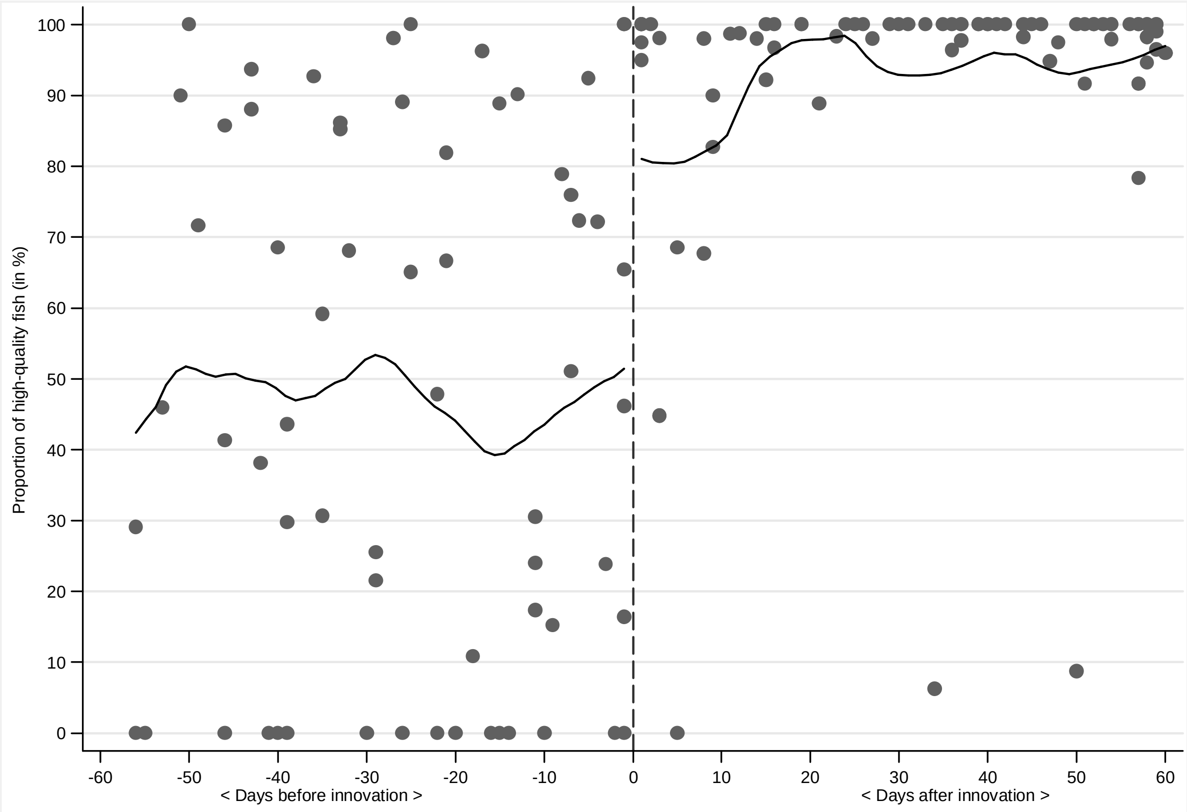
**Figure 1. Calendar on fishing techniques used by vessels equipped with Danish seine**

| | 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 techniques / 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 techniques / 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 techniques / 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 techniques / 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 techniques / 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 techniques / starting date of Danish seine | | | | | | | | 16/03 | | | 19/07 | | | | | | | | | | | |

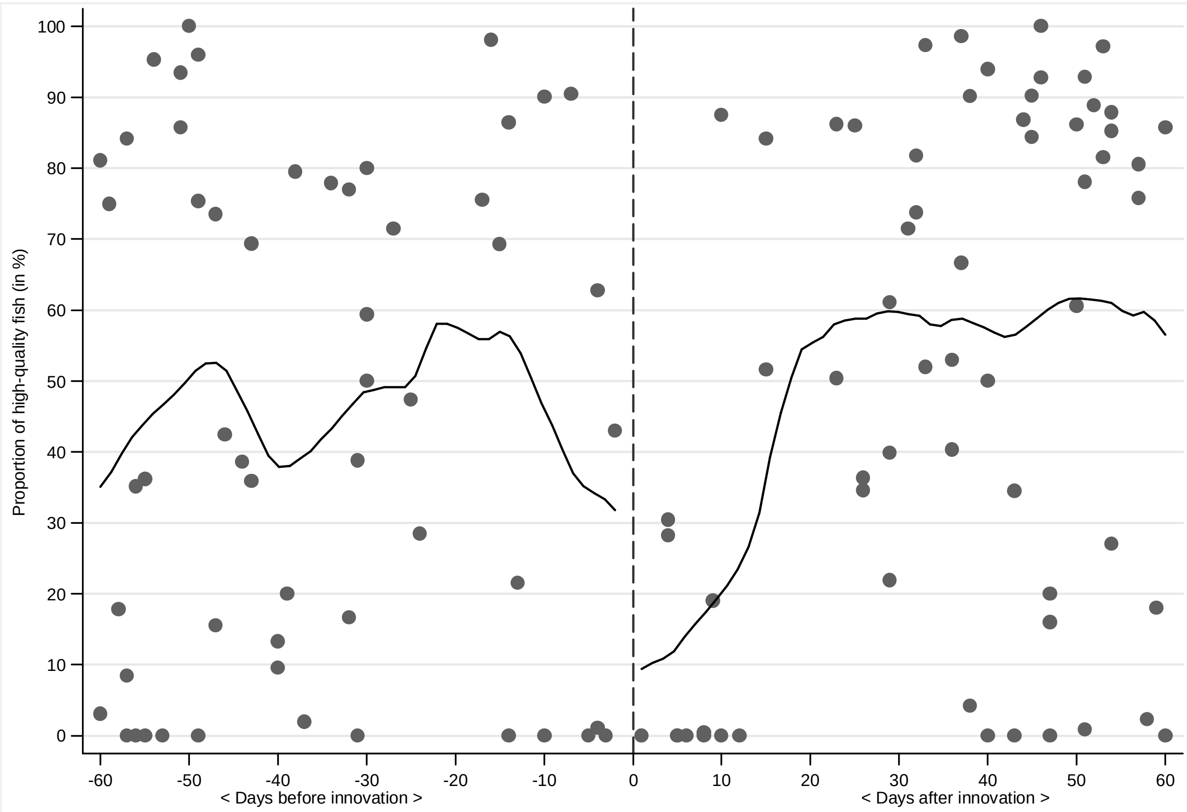
Source: authors' calculations.
Legend: **S** Danish seine, **O** other fishing techniques, **M** mix between Danish seine and other techniques.

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

***A. Danish seiners***



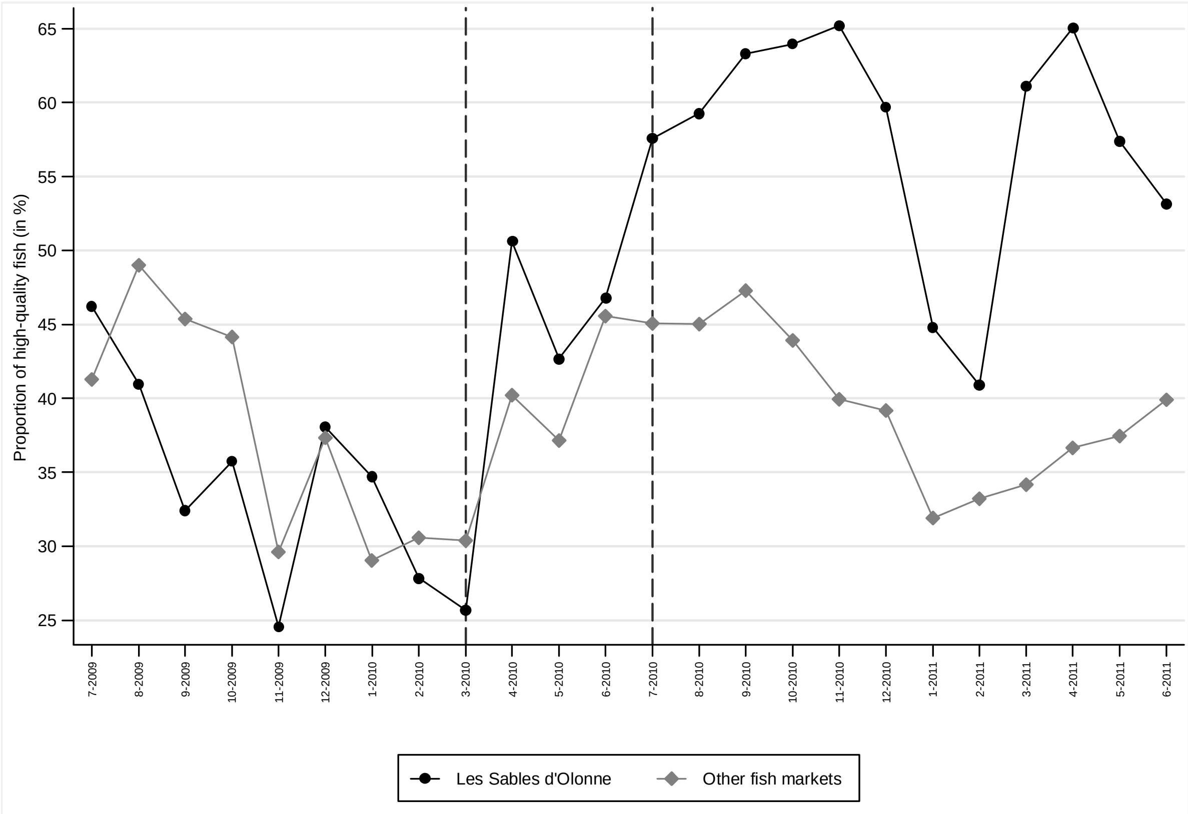

***B. Control vessels***




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

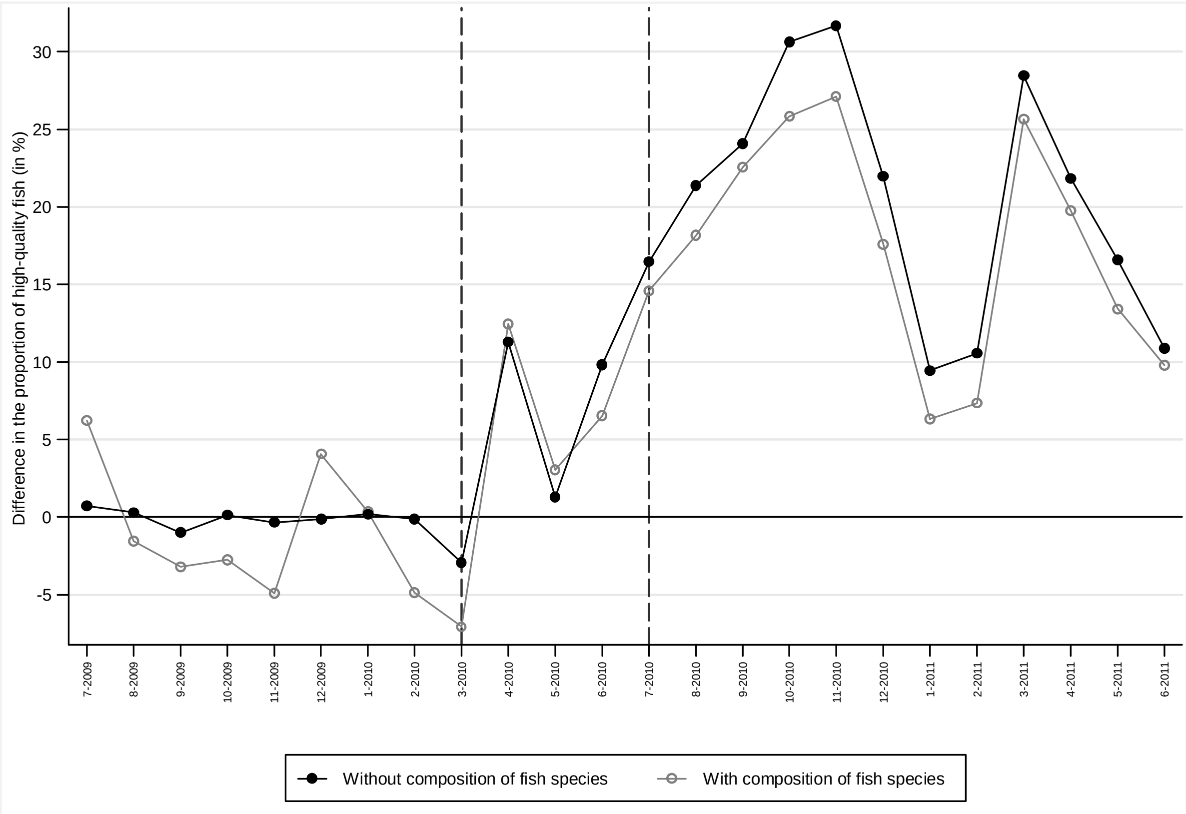
Note: each dot corresponds to the set of transactions of one vessel on a specific day.

**Figure 3. Proportion of high-quality fish and prices: Les Sables d'Olonne versus other fish markets**
**A. Proportion of high quality fish**




Source: authors' calculations, RIC data.
Note: fish markets located on the Mediterranean Sea are excluded.

**Figure 4. Proportion of high-quality fish: Les Sables d'Olonne versus synthetic markets, without and with fish composition**




Source: authors' calculations, RIC data.

Note: monthly proportion of high-quality fish from July 2009 to February 2010 are used as predictor variables for the synthetic control estimator without fish composition. With fish composition, the predictor variables used for the synthetic control estimator also include the proportion of fish species (5 most important species – mackerel, red mullet, whiting, squid, cuttlefish – and a residual category). Fish markets located on the Mediterranean Sea are excluded.

**Table 1. Descriptive statistics for treated and matched control vessels**

**A. Proportion of high-quality fish**

| Variables | Treated vessels | | | Matched control vessels | | | Difference in differences |
|---|---|---|---|---|---|---|---|
| | Before | After | Difference | Before | After | Difference | |
| Mackerel | 0.284<br>[N=67] | 0.974<br>[N=4260] | 0.691 | 0.399<br>[N=138] | 0.815<br>[N=2089] | 0.416 | 0.275 |
| Red mullet | 0.503<br>[N=304] | 0.785<br>[N=10819] | 0.282 | 0.356<br>[N=519] | 0.461<br>[N=1091] | 0.105 | 0.177 |
| Whiting | 0.260<br>[N=196] | 0.856<br>[N=8274] | 0.595 | 0.410<br>[N=478] | 0.528<br>[N=2120] | 0.118 | 0.477 |
| Squid | 0.857<br>[N=652] | 0.955<br>[N=4003] | 0.098 | 0.766<br>[N=1293] | 0.820<br>[N=2542] | 0.055 | 0.043 |
| Cuttlefish | 0.916<br>[N=937] | 0.953<br>[N=2515] | 0.037 | 0.840<br>[N=1410] | 0.897<br>[N=3018] | 0.057 | -0.020 |
| Other species | 0.248<br>[N=5635] | 0.779<br>[N=19583] | 0.531 | 0.299<br>[N=10604] | 0.514<br>[N=37734] | 0.215 | 0.316 |
| All species | 0.390<br>[N=7791] | 0.833<br>[N=49454] | 0.443 | 0.401<br>[N=14442] | 0.566<br>[N=48594] | 0.166 | 0.277 |

**B. Price**

| Variables | Treated vessels | | | Mathced control vessels | | | Difference in differences |
|---|---|---|---|---|---|---|---|
| | Before | After | Difference | Before | After | Difference | |
| Mackerel | 0,596<br>[N=67] | 1,280<br>[N=4260] | 0,683 | 1,004<br>[N=138] | 0,972<br>[N=2089] | -0,032 | 0,716 |
| Red mullet | 6,675<br>[N=304] | 8,079<br>[N=10819] | 1,405 | 6,373<br>[N=519] | 6,450<br>[N=1091] | 0,077 | 1,327 |
| Whiting | 1,623<br>[N=196] | 1,931<br>[N=8274] | 0,308 | 1,745<br>[N=478] | 1,341<br>[N=2120] | -0,404 | 0,712 |
| Squid | 4,023<br>[N=652] | 6,738<br>[N=4003] | 2,715 | 4,136<br>[N=1293] | 4,823<br>[N=2542] | 0,687 | 2,027 |
| Cuttlefish | 3,157<br>[N=937] | 3,975<br>[N=2515] | 0,818 | 2,920<br>[N=1410] | 3,442<br>[N=3018] | 0,522 | 0,296 |
| Other species | 6,238<br>[N=5635] | 5,755<br>[N=19583] | -0,483 | 5,272<br>[N=10604] | 5,217<br>[N=37734] | -0,055 | -0,427 |
| All species | 5,534<br>[N=7791] | 5,227<br>[N=49454] | -0,307 | 4,823<br>[N=14442] | 4,762<br>[N=48594] | -0,061 | -0,246 |

**C. Proportion of fish species**

| Variables | Treated vessels | | | Matched control vessels | | | Difference in differences |
|---|---|---|---|---|---|---|---|
| | Before | After | Difference | Before | After | Difference | |
| Mackerel | 0.008<br>[Q=2.1] | 0.225<br>[Q=338.0] | 0.217 | 0.011<br>[Q=3.8] | 0.099<br>[Q=129.1] | 0.088 | 0.129 |
| Red mullet | 0.016<br>[Q=4.4] | 0.176<br>[Q=263.7] | 0.160 | 0.022<br>[Q=7.9] | 0.011<br>[Q=14.8] | -0.011 | 0.171 |
| Whiting | 0.013<br>[Q=3.5] | 0.147<br>[Q=220.4] | 0.134 | 0.023<br>[Q=8.3] | 0.034<br>[Q=43.9] | 0.011 | 0.123 |
| Squid | 0.075<br>[Q=20.5] | 0.105<br>[Q=157.3] | 0.030 | 0.100<br>[Q=35.7] | 0.062<br>[Q=81.3] | -0.038 | 0.068 |
| Cuttlefish | 0.147<br>[Q=40.0] | 0.067<br>[Q=100.7] | -0.080 | 0.172<br>[Q=61.7] | 0.103<br>[Q=134.0] | -0.069 | -0.011 |
| Other species | 0.741<br>[Q=201.9] | 0.281<br>[Q=421.3] | -0.460 | 0.672<br>[Q=240.6] | 0.690<br>[Q=897.9] | 0.018 | -0.478 |
| All species | 1.000<br>[Q=272.5] | 1.000<br>[Q=1501.4] | | 1.000<br>[Q=358.0] | 1.000<br>[Q=1301.1] | | |

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. The number of transactions N is in brackets below the average proportion of high-quality fish in panel A. The total quantity in tons Q is in bracket below the proportion of each fish species in panel B.

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

| Variables | (1) | (2) | (3) |
|---|---|---|---|
| *Panel A. Transactions of treated vessels in Les Sables d'Olonne* | | | |
| After innovation x Danish seine | 0.358*** | 0.356*** | 0.418*** |
| | (0.022) | (0.021) | (0.017) |
| After innovation x Other technique | -0.201*** | -0.130*** | -0.127*** |
| | (0.026) | (0.031) | (0.028) |
| Cubic daily trend | YES | YES | YES |
| Fish characteristics | NO | YES | YES |
| Vessel fixed effects | NO | NO | YES |
| Number of observations | 10124 | 10124 | 10124 |
| $R^2$ | 0.288 | 0.544 | 0.583 |
| *Panel B. Transactions of Danish seiners and matched control vessels in Les Sables d'Olonne* | | | |
| Treated vessels | -0.057*** | -0.047*** | |
| | (0.012) | (0.010) | |
| After innovation | -0.300*** | -0.151*** | -0.052*** |
| | (0.019) | (0.017) | (0.017) |
| Treated vessels x After innovation x Danish seine | 0.547*** | 0.472*** | 0.435*** |
| | (0.014) | (0.014) | (0.013) |
| Treated vessels x After innovation x Other technique | -0.022 | -0.094*** | -0.109*** |
| | (0.019) | (0.020) | (0.019) |
| Cubic daily trend | YES | YES | YES |
| Fish characteristics | NO | YES | YES |
| Vessel fixed effects | NO | NO | YES |
| Number of observations | 19715 | 19715 | 19715 |
| $R^2$ | 0.189 | 0.409 | 0.477 |

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 (transaction data)**

| Variables | (1) | (2) | (3) |
|---|---|---|---|
| *Panel A. Transactions of Danish seiners in Les Sables d'Olonne* | | | |
| Treated vessels x After innovation x Danish seine | 0.387*** | 0.406*** | 0.403*** |
| | (0.010) | (0.010) | (0.009) |
| Treated vessels x After innovation x Other technique | -0.159*** | -0.101*** | -0.045*** |
| | (0.016) | (0.020) | (0.017) |
| Cubic daily trend | YES | YES | YES |
| Fish characteristics | NO | YES | YES |
| Vessel fixed effects | NO | NO | YES |
| Number of observations | 57245 | 57245 | 57245 |
| $R^2$ | 0.240 | 0.343 | 0.369 |
| *Panel B. Transactions of Danish seiners and matched control vessels in Les Sables d'Olonne* | | | |
| Treated vessels | -0.043*** | -0.036*** | |
| | (0.007) | (0.006) | |
| After innovation | 0.028*** | 0.057*** | 0.062*** |
| | (0.008) | (0.008) | (0.007) |
| Treated vessels x After innovation x Danish seine | 0.329*** | 0.286*** | 0.260*** |
| | (0.007) | (0.007) | (0.007) |
| Treated vessels x After innovation x Other technique | -0.155*** | -0.189*** | -0.193*** |
| | (0.015) | (0.013) | (0.015) |
| Cubic daily trend | YES | YES | YES |
| Fish characteristics | NO | YES | YES |
| Vessel fixed effects | NO | NO | YES |
| Number of observations | 120281 | 120281 | 120281 |
| $R^2$ | 0.146 | 0.274 | 0.313 |
| *Panel C. All transactions in Les Sables d'Olonne* | | | |
| Treated vessels | -0.013** | 0.006 | |
| | (0.006) | (0.005) | |
| After innovation | 0.173*** | 0.122*** | -0.011*** |
| | (0.004) | (0.003) | (0.003) |
| Treated vessels x After innovation x Danish seine | 0.308*** | 0.269*** | 0.359*** |
| | (0.006) | (0.005) | (0.004) |
| Treated vessels x After innovation x Other technique | -0.190*** | -0.119*** | -0.040*** |
| | (0.015) | (0.009) | (0.010) |
| Cubic daily trend | YES | YES | YES |
| Fish characteristics | NO | YES | YES |
| Vessel fixed effects | NO | NO | YES |
| Number of observations | 399844 | 399844 | 399844 |
| $R^2$ | 0.064 | 0.353 | 0.585 |
| *Panel D. All transactions in Vendée* | | | |
| Treated vessels | -0.047*** | -0.015*** | |
| | (0.006) | (0.005) | |
| After | 0.176*** | 0.102*** | 0.017*** |
| | (0.003) | (0.002) | (0.002) |
| Treated vessels x After innovation x Danish seine | 0.357*** | 0.348*** | 0.378*** |
| | (0.006) | (0.005) | (0.004) |
| Treated vessels x After innovation x Other technique | -0.168*** | -0.094*** | -0.035*** |
| | (0.015) | (0.009) | (0.009) |
| 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 | 797096 | 797096 | 797096 |
| $R^2$ | 0.231 | 0.480 | 0.640 |

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 (transaction data – windows: four months)**

| Variables | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| *Panel A. Transactions of Danish seiners in Les Sables d'Olonne* | | | | | |
| Treated vessels x After innovation x Danish seine | 0.390*** | 0.324*** | 0.251*** | 0.220*** | 0.201*** |
| | (0.022) | (0.023) | (0.022) | (0.022) | (0.022) |
| Treated vessels x After innovation x Other technique | 0.400*** | 0.431*** | 0.344*** | 0.330*** | 0.322*** |
| | (0.035) | (0.035) | (0.034) | (0.034) | (0.034) |
| High-quality fish | | 0.164*** | 0.154*** | 0.130*** | 0.134*** |
| | | (0.013) | (0.012) | (0.012) | (0.012) |
| Quantity of the transaction (log) | | | -0.146*** | -0.125*** | -0.123*** |
| | | | (0.006) | (0.006) | (0.006) |
| Total quantity of the day (log) | | | | | -0.035*** |
| | | | | | (0.012) |
| Total number of buyers of the day (log) | | | | | 0.025* |
| | | | | | (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 | 10124 | 10124 | 10124 | 10124 | 10124 |
| $R^2$ | 0.814 | 0.817 | 0.828 | 0.858 | 0.858 |
| *Panel B. Transactions of Danish seiners and matched control vessels in Les Sables d'Olonne* | | | | | |
| After innovation | 0.073*** | 0.077*** | 0.084*** | 0.076*** | 0.064*** |
| | (0.020) | (0.020) | (0.019) | (0.019) | (0.019) |
| Treated vessels x After innovation x Danish seine | 0.234*** | 0.194*** | 0.159*** | 0.134*** | 0.111*** |
| | (0.016) | (0.016) | (0.016) | (0.016) | (0.016) |
| Treated vessels x After innovation x Other technique | 0.135*** | 0.148*** | 0.121*** | 0.114*** | 0.111*** |
| | (0.022) | (0.021) | (0.021) | (0.022) | (0.022) |
| High-quality fish | | 0.091*** | 0.084*** | 0.056*** | 0.067*** |
| | | (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) | | | | | -0.082*** |
| | | | | | (0.009) |
| Total number of buyers of the day (log) | | | | | 0.023** |
| | | | | | (0.012) |
| 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 | 19363 | 19363 | 19363 | 19363 | 19363 |
| $R^2$ | 0.787 | 0.788 | 0.799 | 0.835 | 0.836 |

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 (transaction data)**

| Variables | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| *Panel A. Transactions of Danish seiners in Les Sables d'Olonne* | | | | | |
| Treated vessels x After innovation x Danish seine | 0.429*** | 0.383*** | 0.296*** | 0.282*** | 0.239*** |
| | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) |
| Treated vessels x After innovation x Other technique | 0.497*** | 0.507*** | 0.405*** | 0.412*** | 0.317*** |
| | (0.021) | (0.021) | (0.021) | (0.020) | (0.021) |
| High-quality fish | | 0.126*** | 0.122*** | 0.095*** | 0.104*** |
| | | (0.006) | (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) | | | | | -0.180*** |
| | | | | | (0.005) |
| Total number of buyers of the day (log) | | | | | 0.303*** |
| | | | | | (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 | 57245 | 57245 | 57245 | 57245 | 57245 |
| $R^2$ | 0.785 | 0.787 | 0.800 | 0.822 | 0.827 |
| *Panel B. Transactions of Danish seiners and matched control vessels in Les Sables d'Olonne* | | | | | |
| After innovation | 0.135*** | 0.129*** | 0.105*** | 0.114*** | 0.084*** |
| | (0.008) | (0.008) | (0.008) | (0.008) | (0.008) |
| Treated vessels x After innovation x Danish seine | 0.279*** | 0.255*** | 0.232*** | 0.197*** | 0.157*** |
| | (0.008) | (0.008) | (0.008) | (0.008) | (0.008) |
| Treated vessels x After innovation x Other technique | 0.131*** | 0.148*** | 0.120*** | 0.114*** | 0.030* |
| | (0.017) | (0.017) | (0.016) | (0.016) | (0.016) |
| High-quality fish | | 0.097*** | 0.097*** | 0.073*** | 0.078*** |
| | | (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) | | | | | -0.178*** |
| | | | | | (0.003) |
| Total number of buyers of the day (log) | | | | | 0.246*** |
| | | | | | (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 | 120281 | 120281 | 120281 | 120281 | 120281 |
| $R^2$ | 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. Estimates for the proportion of high-quality fish (aggregate market data)**

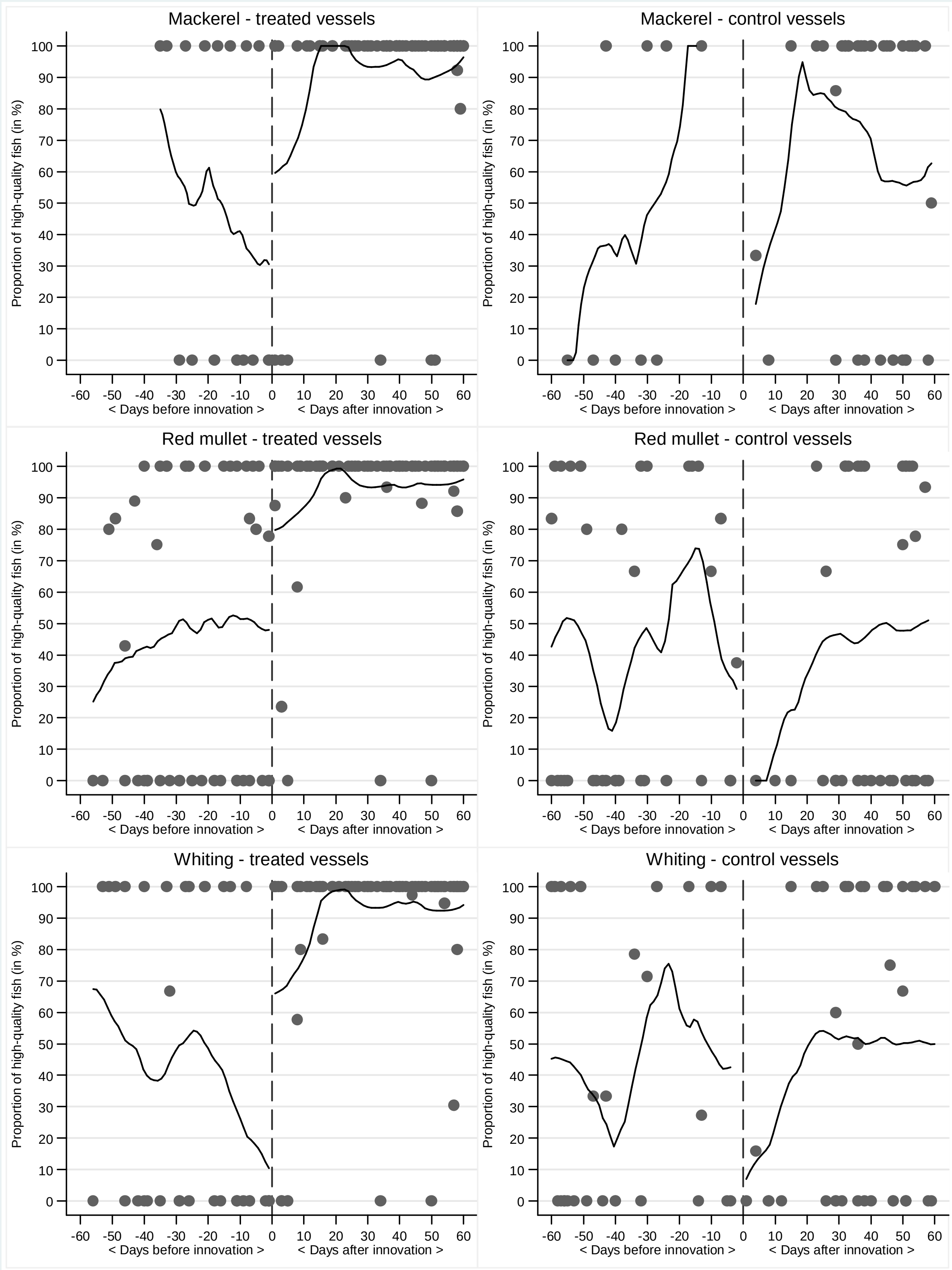
| Variables | (1) DID FE | (2) Additive and interactive FE | | | (3) Synthetic control |
|---|---|---|---|---|---|
| | | 1 factor | 2 factors | 3 factors | |
| *Panel A. Without fish composition* | | | | | |
| Les Sables d'Olonne x (March 2010-June 2011) | 0.165** | 0.161*** | 0.166*** | 0.159*** | 0.165 |
| | (0.065) | (0.034) | (0.029) | (0.026) | |
| Proportions of fish species | NO | NO | NO | NO | |
| Month fixed effects | YES | YES | YES | YES | |
| Fish market fixed effects | YES | YES | YES | YES | |
| Number of observations | 744 | 744 | 744 | 744 | 744 |
| $R^2$ | 0.826 | | | | |
| *Panel B. With fish composition* | | | | | |
| Les Sables d'Olonne x (March 2010- June 2011) | 0.172*** | 0.157*** | 0.188*** | 0.177*** | 0.139 |
| | (0.057) | (0.034) | (0.030) | (0.027) | |
| Proportions of fish species | YES | YES | YES | YES | |
| Month fixed effects | YES | YES | YES | YES | |
| Fish market fixed effects | YES | YES | YES | YES | |
| Number of observations | 744 | 744 | 744 | 744 | 744 |
| $R^2$ | 0.871 | | | | |

Source: authors' calculations, RIC data.

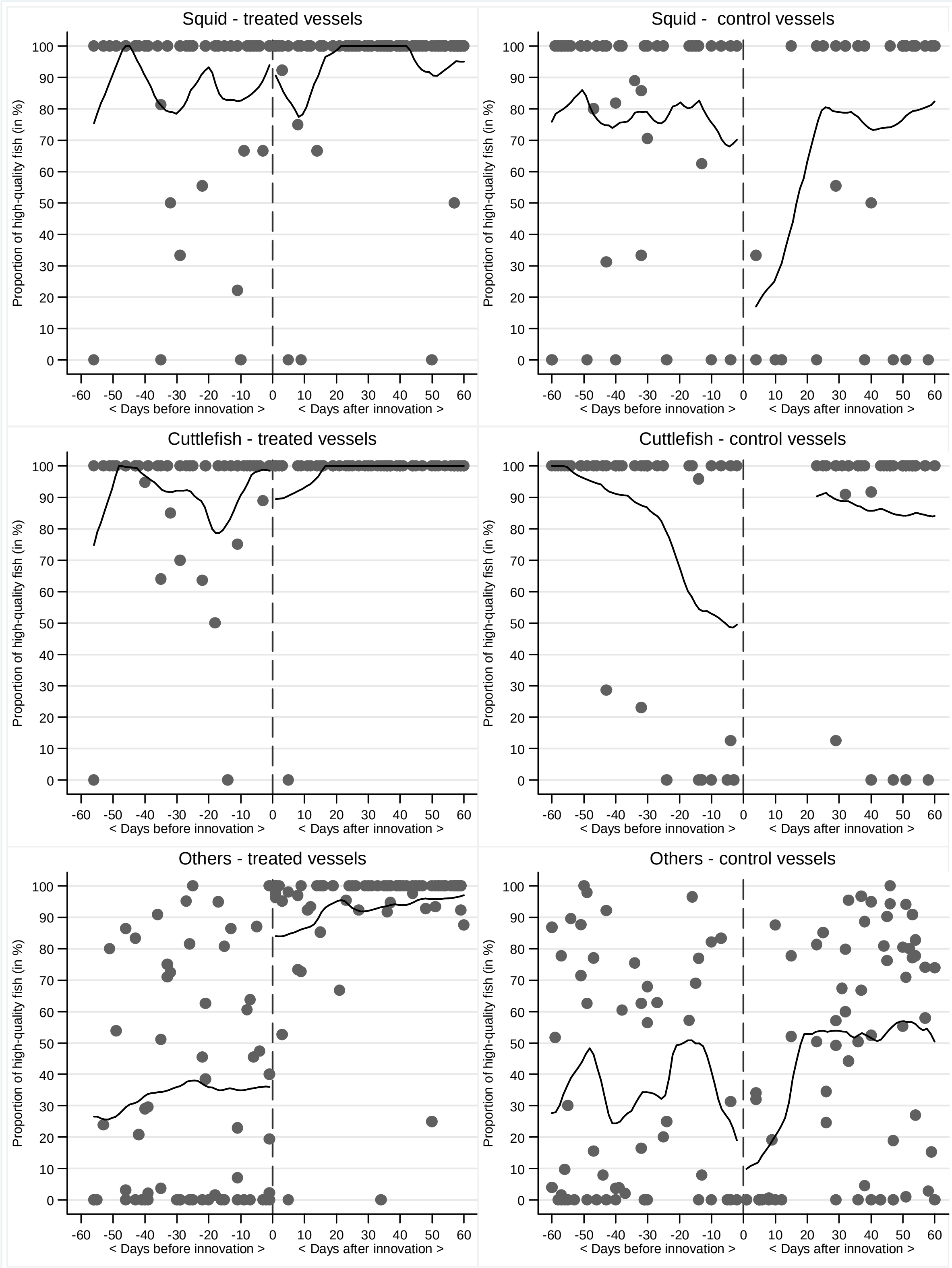
Note: DID stands for difference-in-differences, FE for fixed effects. Significance levels are respectively 1% (***), 5% (**) and 10% (*). In panel A, monthly proportions of fish of extra quality from July 2009 to February 2010 are used to determine the synthetic market. In panel B, variables used to determine the synthetic market also include the monthly proportion of fish species (5 most important species – cuttlefish, squid, red mullet, mackerel, whiting – and the residual category) for all months. Fish markets located on the Mediterranean Sea are excluded.

# Appendix

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



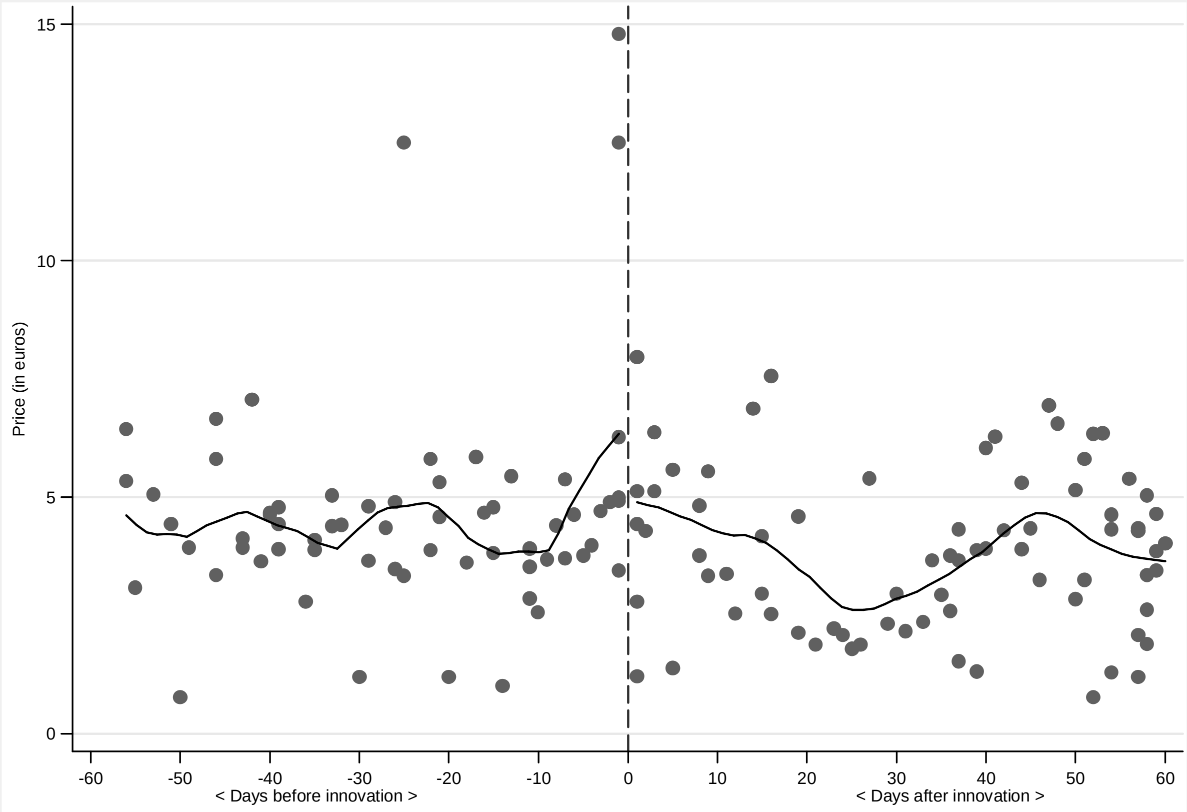

[continued below]



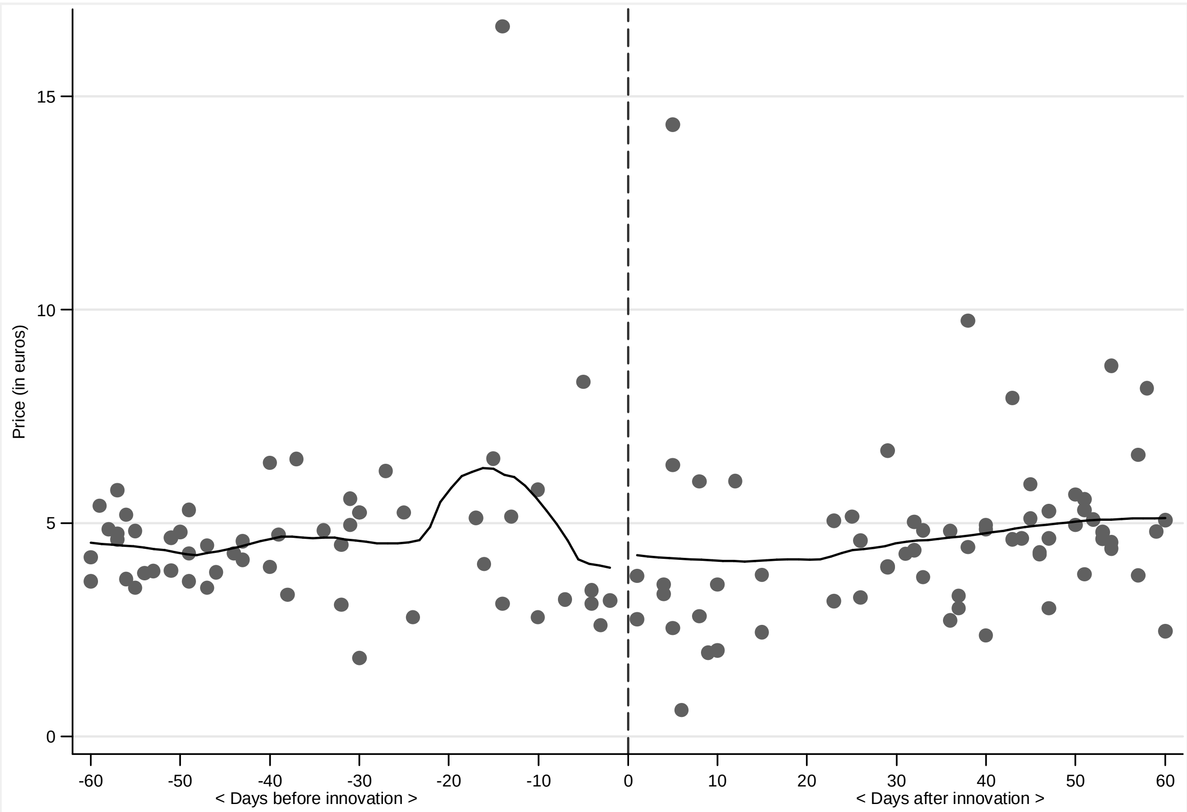

Source: authors' calculations, transaction data.

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

***A. Danish seiners***

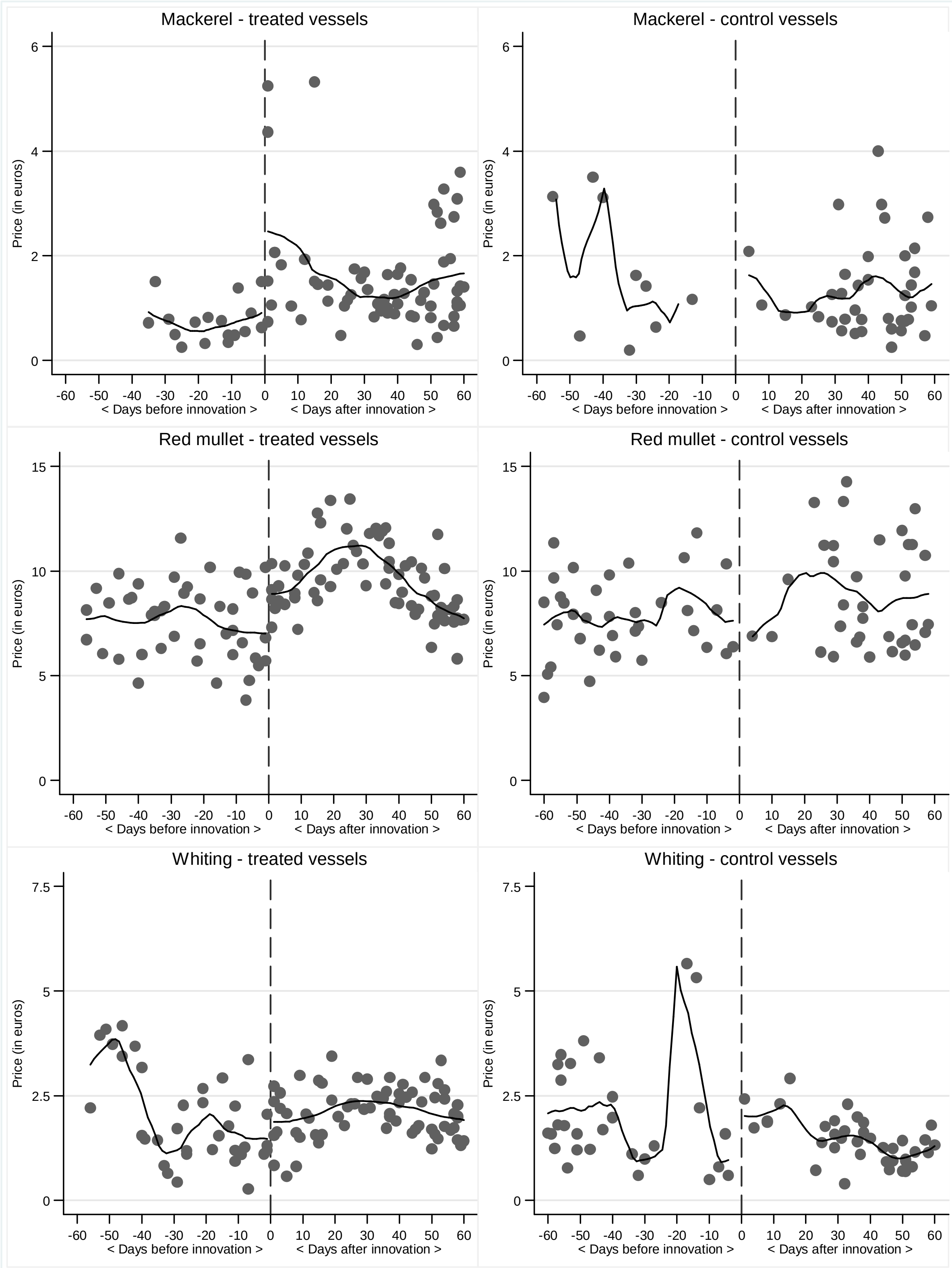



***B. Control vessels***

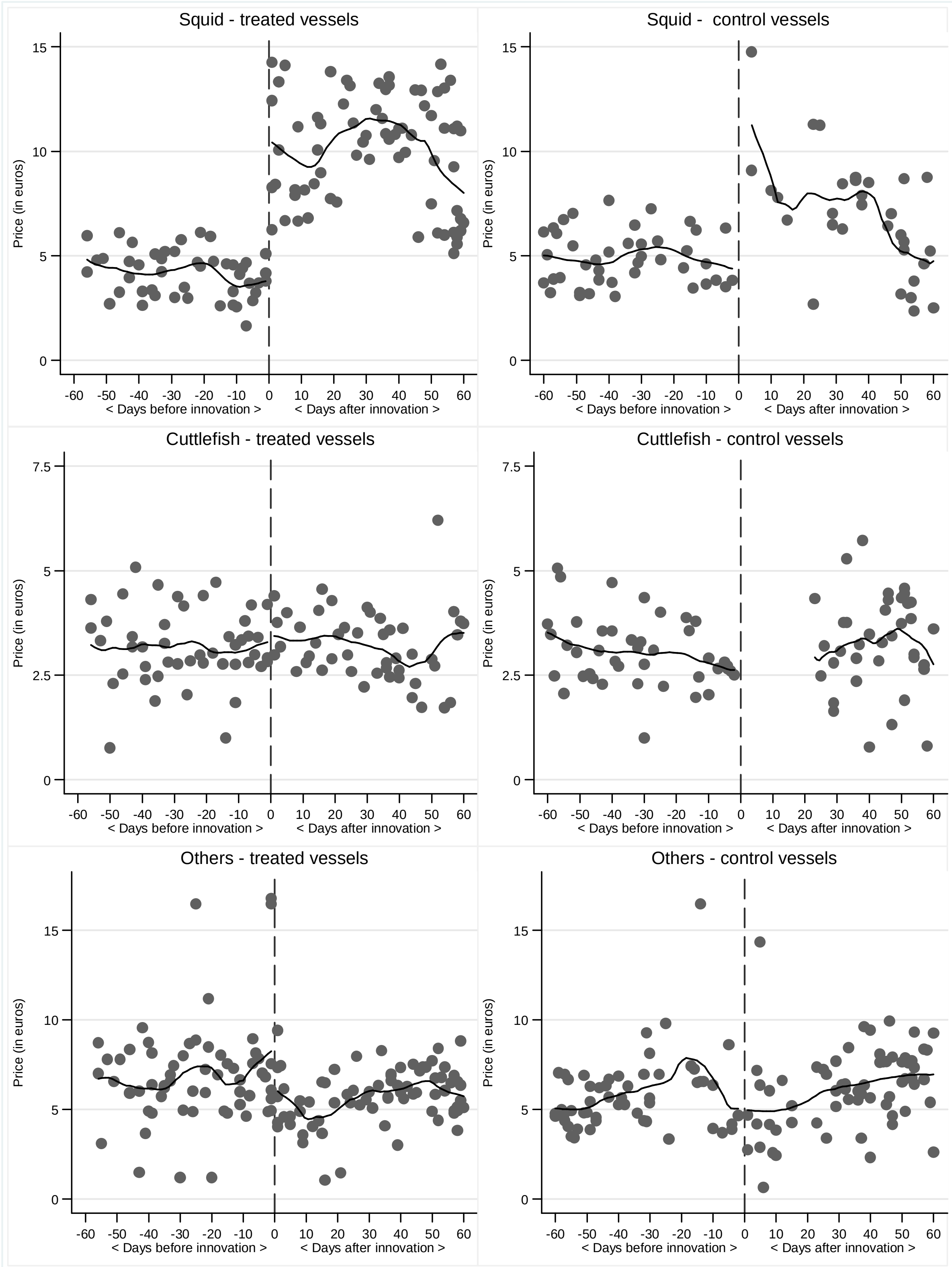



Source: authors' calculations, transaction data from Les Sables d'Olonne.
Note: each dot corresponds to the set of transactions of one vessel on a specific day.

**Figure A3. Discontinuity analysis: daily fish price per kilogram, by fish species (window: four months)**

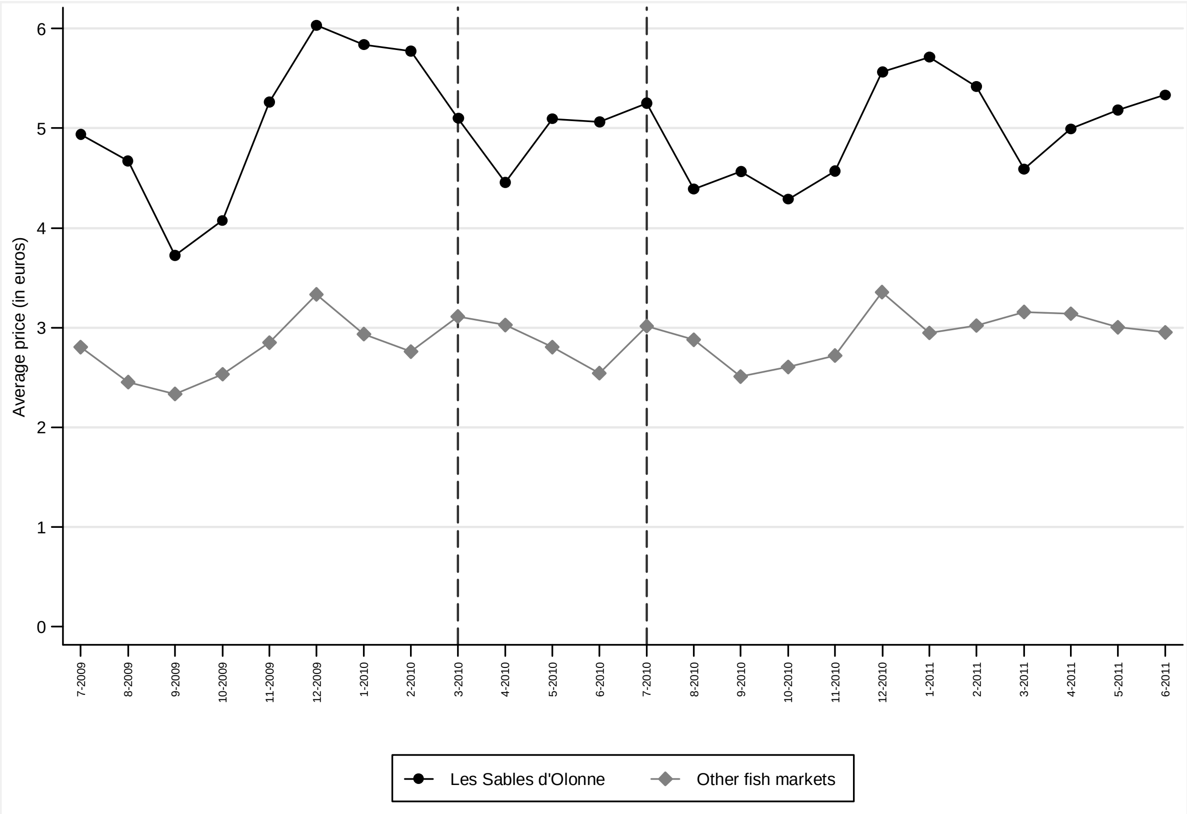



[continued below]



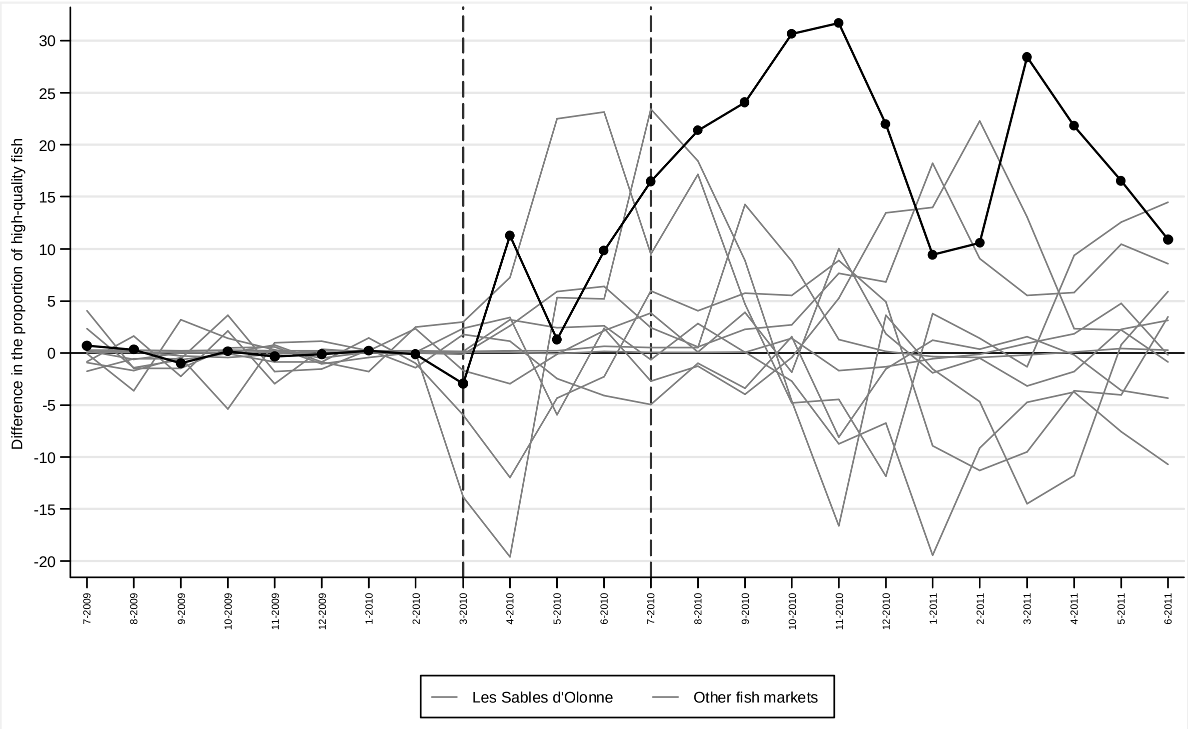

Source: authors' calculations, transaction data.

**Figure A4. Average prices per kilogram: Les Sables d'Olonne versus other fish markets**

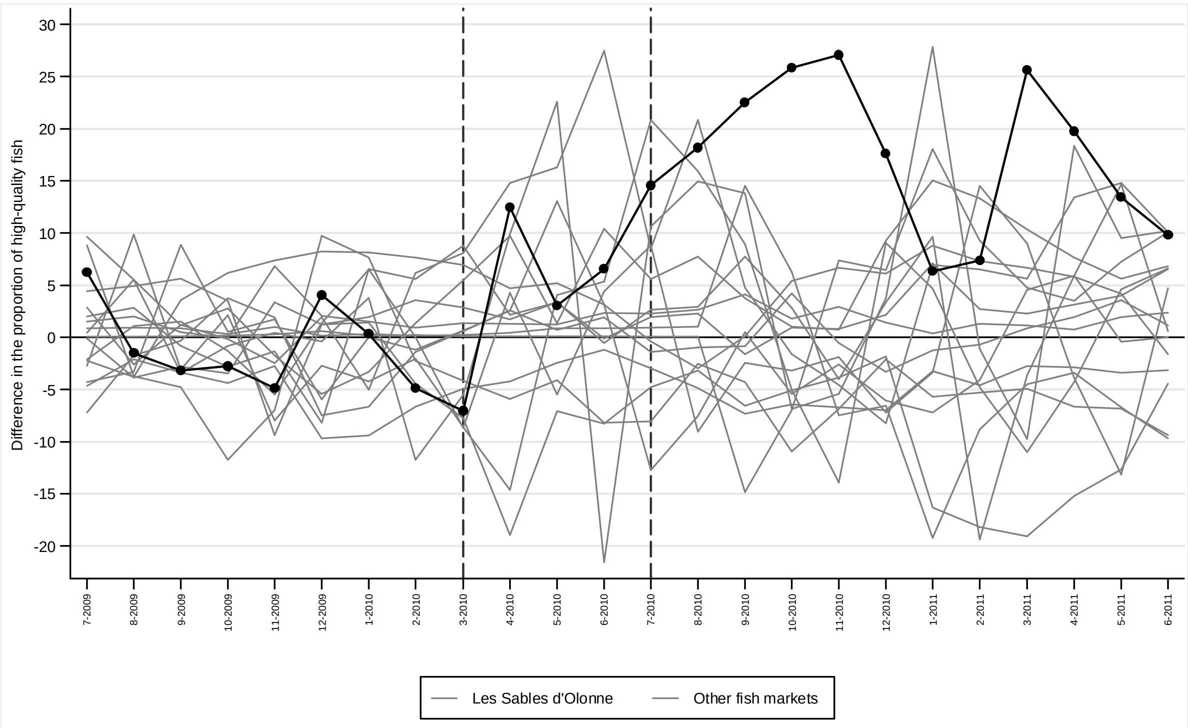



Source: authors' calculations, RIC data.
Note: fish markets located on the Mediterranean Sea are excluded.

**Figure A5. Proportion of high-quality fish: Les Sables d'Olonne versus synthetic hall market, placebo analysis**
**A. Without composition of fish species**




**B. With composition of fish species**




Source: authors' calculations, RIC data.

Note: when not taking into account fish composition, monthly proportions of fish of extra quality from July 2009 to February 2010 are used to determine the synthetic market. When taking into account fish composition, variables used to determine the synthetic market also include the monthly proportion of fish species (5 most important species – cuttlefish, squid, red mullet, mackerel, whiting – and the residual category) for all months. Markets whose Root Mean Square Percentage Error is more than five times (respectively two times) higher than that of Les Sables d'Olonne are excluded for the case without (respectively with) fish species.

**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 Danish seiners in Les Sables d'Olonne* | | | | | | |
| Treated vessels x After innovation x Danish seine | 0.562*** | 0.135*** | 0.436*** | -0.006 | -0.010 | 0.565*** |
| | (0.030) | (0.041) | (0.041) | (0.022) | (0.023) | (0.012) |
| Treated vessels x After innovation x Other technique | 0.614*** | -0.604 | 0.347*** | -0.212*** | 0.052 | -0.002 |
| | (0.049) | (0.371) | (0.115) | (0.069) | (0.040) | (0.020) |
| 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 | 4327 | 11123 | 8470 | 4655 | 3452 | 25218 |
| $R^2$ | 0.226 | 0.212 | 0.206 | 0.115 | 0.044 | 0.460 |
| *Panel B. Transactions of Danish seiners and matched control vessels in Les Sables d'Olonne* | | | | | | |
| After innovation | 0.001 | -0.082** | -0.118*** | -0.054** | 0.042** | 0.102*** |
| | (0.042) | (0.038) | (0.033) | (0.023) | (0.018) | (0.009) |
| Treated vessels x After innovation x Danish seine | 0.426*** | 0.305*** | 0.462*** | 0.072*** | -0.033** | 0.307*** |
| | (0.045) | (0.033) | (0.033) | (0.018) | (0.017) | (0.009) |
| Treated vessels x After innovation x Other technique | 0.526*** | -0.460 | 0.388*** | -0.149 | -0.006 | -0.199*** |
| | (0.081) | (0.389) | (0.126) | (0.093) | (0.046) | (0.017) |
| 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 | 6554 | 12733 | 11068 | 8490 | 7880 | 73556 |
| $R^2$ | 0.218 | 0.236 | 0.266 | 0.146 | 0.103 | 0.294 |
| *Panel C. All transactions in Les Sables d'Olonne* | | | | | | |
| After innovation | -0.198*** | 0.043* | -0.040*** | -0.007 | 0.025*** | -0.012*** |
| | (0.026) | (0.023) | (0.013) | (0.012) | (0.009) | (0.003) |
| Treated vessels x After innovation x Danish seine | 0.652*** | 0.214*** | 0.459*** | 0.068*** | -0.039*** | 0.437*** |
| | (0.042) | (0.028) | (0.026) | (0.014) | (0.013) | (0.005) |
| Treated vessels x After innovation x Other technique | 0.762*** | -0.538 | 0.390*** | -0.145* | 0.031 | -0.005 |
| | (0.087) | (0.402) | (0.116) | (0.083) | (0.040) | (0.011) |
| 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 | 12444 | 18281 | 22213 | 19892 | 25242 | 301772 |
| $R^2$ | 0.325 | 0.253 | 0.522 | 0.139 | 0.342 | 0.602 |
| *Panel D. All transactions in Vendée* | | | | | | |
| After innovation | -0.127*** | 0.075*** | -0.013* | -0.003 | -0.035*** | 0.013*** |
| | (0.013) | (0.016) | (0.008) | (0.009) | (0.008) | (0.002) |
| Treated vessels x After innovation x Danish seine | 0.691*** | 0.248*** | 0.527*** | 0.082*** | -0.017 | 0.471*** |
| | (0.028) | (0.023) | (0.021) | (0.011) | (0.012) | (0.005) |
| Treated vessels x After innovation x Other technique | 0.759*** | -0.522 | 0.416*** | -0.138** | 0.068* | 0.003 |
| | (0.060) | (0.353) | (0.095) | (0.069) | (0.037) | (0.010) |
| 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 | 27392 | 30559 | 38110 | 28776 | 32135 | 640124 |
| $R^2$ | 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.

**Table A2. Characterization of the synthetic fish market of Les Sables d'Olonne**

| Code | Fish markets | Proportion of fish of extra quality | Total quantity (log) | Distance from Les Sables d'Olonne (in kms) | Weight in the synthetic control | |
|---|---|---|---|---|---|---|
| | | | | | Without composition of fish species | With composition of fish species |
| AC | Arcachon | 0.047 | 15.160 | 209.9 | 0.000 | 0.000 |
| AD | Audierne | 0.918 | 14.413 | 268.9 | 0.000 | 0.000 |
| BL | Boulogne | 0.041 | 17.994 | 532.7 | 0.000 | 0.127 |
| BT | Brest | 0.434 | 14.971 | 293.0 | 0.000 | 0.000 |
| CC | Concarneau | 0.554 | 16.464 | 222.9 | 0.000 | 0.000 |
| CH | Cherbourg | 0.284 | 16.214 | 349.7 | 0.000 | 0.045 |
| CR | Le Croisic | 0.965 | 14.976 | 104.8 | 0.000 | 0.030 |
| DK | Dunkerque | 0.969 | 14.400 | 590.4 | 0.000 | 0.000 |
| DP | Dieppe | 0.396 | 15.623 | 436.1 | 0.000 | 0.000 |
| DZ | Douarnenez | 0.989 | 16.355 | 262.1 | 0.000 | 0.000 |
| EQ | Erquy | 0.361 | 16.854 | 242.7 | 0.000 | 0.000 |
| GD | Grandcamp | 0.670 | 15.036 | 326.3 | 0.001 | 0.000 |
| GL | Saint-Gilles Croix-de-Vie | 0.308 | 15.879 | 24.7 | 0.051 | 0.117 |
| GR | Granville | 0.778 | 16.921 | 261.0 | 0.000 | 0.000 |
| GV | Le Guilvinec | 0.065 | 17.297 | 238.5 | 0.000 | 0.000 |
| IO | Ile d'Oléron | 0.746 | 16.164 | 71.4 | 0.257 | 0.247 |
| LC | Loctudy | 0.132 | 15.651 | 233.9 | 0.389 | 0.000 |
| LO | Lorient | 0.148 | 17.390 | 183.6 | 0.000 | 0.000 |
| LR | La Rochelle | 0.154 | 15.230 | 61.3 | 0.000 | 0.247 |
| NO | Noirmoutier | 0.966 | 15.061 | 66.9 | 0.000 | 0.000 |
| PO | Port en Bessin | 1.000 | 14.444 | 326.2 | 0.000 | 0.000 |
| QB | Quiberon | 0.996 | 14.622 | 149.2 | 0.000 | 0.000 |
| RO | Roscoff | 0.241 | 16.379 | 297.9 | 0.111 | 0.000 |
| RY | Royan | 0.518 | 14.273 | 112.8 | 0.075 | 0.000 |
| SG | Saint-Guénolé | 0.545 | 17.085 | 242.5 | 0.000 | 0.000 |
| SJ | Saint-Jean de Luz | 0.330 | 15.762 | 345.5 | 0.108 | 0.067 |
| SM | Saint-Malo | 0.582 | 14.864 | 238.4 | 0.000 | 0.000 |
| SQ | Saint-Quay Portrieux | 0.623 | 16.841 | 252.4 | 0.000 | 0.000 |
| TB | La Turballe | 0.651 | 16.231 | 109.8 | 0.000 | 0.028 |
| YE | Ile d'Yeu | 0.415 | 14.632 | 48.0 | 0.009 | 0.092 |
| LS | Les Sables d'Olonne | 0.474 | 16.161 | | | |

Source: authors' calculations, RIC data.

Note: monthly proportion of fish of extra quality and fish quantity from July 2009 to February 2010 are used as predictor variables for the synthetic control estimator without fish composition. The predictor variables used for the synthetic control estimator with fish composition also include the monthly proportions of fish species (5 most important species – cuttlefish, squid, red mullet, mackerel, whiting – and one residual category) for all months.

**Table A3. Estimates for the logarithm of price (aggregate market data)**

| Variables | (1) DID FE | (2) Additive and interactive FE | | | (3) Synthetic control |
|---|---|---|---|---|---|
| | | 1 factor | 2 factors | 3 factors | |
| *Panel A. Without fish composition and quality* | | | | | |
| Les Sables d'Olonne x (March 2010-June 2011) | -0.026 | -0.140 | -0.111 | -0.124 | 0.012 |
| | (0.095) | (0.091) | (0.101) | (0.110) | |
| Log of quantity | YES | YES | YES | YES | |
| Proportions of fish species | NO | NO | NO | NO | |
| Proportion of high-quality fish | NO | NO | NO | NO | |
| Month fixed effects | YES | YES | YES | YES | |
| Fish market fixed effects | YES | YES | YES | YES | |
| Number of observations | 744 | 744 | 744 | 744 | 744 |
| $R^2$ | 0.826 | | | | |
| *Panel B. With fish composition, without quality* | | | | | |
| Les Sables d'Olonne x (March 2010- June 2011) | -0.022 | -0.052 | -0.067 | -0.102 | 0.084 |
| | (0.094) | (0.085) | (0.083) | (0.104) | |
| Proportions of fish species | YES | YES | YES | YES | |
| Proportion of high-quality fish | NO | NO | NO | NO | |
| Month fixed effects | YES | YES | YES | YES | |
| Fish market fixed effects | YES | YES | YES | YES | |
| Number of observations | 744 | 744 | 744 | 744 | 744 |
| $R^2$ | 0.881 | | | | |
| *Panel C. With fish composition and quality* | | | | | |
| Les Sables d'Olonne x (March 2010- June 2011) | -0.016 | -0.010 | -0.073 | -0.097 | 0.055 |
| | (0.094) | (0.087) | (0.084) | (0.103) | |
| Proportions of fish species | YES | YES | YES | YES | |
| Proportion of high-quality fish | YES | YES | YES | YES | |
| Month fixed effects | YES | YES | YES | YES | |
| Fish market fixed effects | YES | YES | YES | YES | |
| Number of observations | 744 | 744 | 744 | 744 | 744 |
| $R^2$ | 0.881 | | | | |

Source: authors' calculations, RIC data.

Note: DID stands for difference-in-differences, FE for fixed effects. Significance levels are respectively 1% (***), 5% (**) and 10% (*). In panel A, prices from July 2009 to February 2010 and quantity over all the period are used to determine the synthetic market. In panel B, variables used to determine the synthetic market also include the proportions of fish species (5 most important species – mackerel, red mullet, whiting, squid, cuttlefish – and a residual category) for all months. In panel C, they also include the proportion of high-quality fish for all months. Fish markets located on the Mediterranean Sea are excluded.