Evaluating the Law of One Price Using Micro Panel Data: The Case of the French Fish Market

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Abstract

This paper investigates spatial variations in product prices using an exhaustive micro dataset on fish transactions. The data includes all transactions between vessels and wholesalers that occurred within local fish markets in France during the year 2007. Spatial disparities in fish prices are sizable even after taking into account fish quality, time, and unobserved seller and buyer heterogeneity. The price difference between local fish markets can be explained to some extent by distance, but mostly by a coast effect related to separate locations on the Atlantic and Mediterranean coasts. We also propose a new approach for identifying groups of interconnected local fish markets based on the activity of sellers and buyers within these markets. We show that most markets on the Atlantic coast are well interconnected and that variation in prices across these markets is very small and in line with the law of one price.

Keywords: commodity price, disparities, fish, law of one price, local markets, nested fixed effects, panel, unobserved heterogeneity

JEL Classification: L11, Q22, R32

A long-standing question in economics is the validity of the law of one price (LOP) which states that, in an efficient market, all identical goods must have the same price. This law has been investigated by studies assessing whether prices in several cities or countries converge to a common value using co-integration techniques (Asche, Gordon and Hannesson 1996; Parsley and Wei 1996; Goldberg and Verboven 2005; Fan and Wei 2006). It has also been evaluated by articles assessing whether prices are significantly different for distant areas or when crossing an international border. Previous analyses have been carried out using either aggregate price indexes (Engel and Rogers 1996) or, more recently, micro data on prices for identical products (Broda and Weinstein 2008; Imbs et al. 2010).[1]

In this paper, we investigate the validity of the LOP over space for transactions in a microeconomic perspective using panel data techniques. In contrast to the existing literature, we are able to control for spatial differences in buyers' preferences and in production costs, which may influence spatial differences in prices, by modeling the unobserved heterogeneity of agents. We focus on the French fish market, for which we have an original exhaustive dataset of first-hand transactions; but our approach can be applied to any product, whether it is raw food (fruit, vegetable, wheat, cotton, etc.), transformed food (cereal boxes, cans, yoghurts, etc.) or even a specific manufactured good, as long as sellers and buyers participate within several local markets over time and panel data are available.

We assess whether significant spatial variations in fish prices can still be observed once the effects of observable fish characteristics and unobserved heterogeneity among agents have been netted out. As we compare the level of local prices, we are interested in making an assessment of the "absolute" LOP.[2] We also examine whether the net difference in prices between two fish markets is linked to distance and a coast effect, indicating a separate location on the Atlantic and Mediterranean coasts.

One original aspect of our work is that prices in the first-hand fish market are production prices, while other papers have focused instead on consumption prices for commodities sold at the retail level. Contrary to other studies, we are thus able to avoid the influence of marketing costs on prices – costs that are usually quite high and vary over space (Handbury and Weinstein 2014).

Interestingly, there is no inventory in fish markets and prices are set daily, depending on the size and composition of the daily catch. This lack of inventory restricts inter-temporal decisions of buyers who cannot infrequently purchase large quantities to avoid transportation costs (Miljkovic 1999; Chiang, Jonq-Ying and Brown 2001), and creates significant day-to-day variations in prices due to changes in demand and supply. Moreover, fish markets are spot markets, and most buyers within a local market have price information on all products sold locally, and sometimes price information on other markets, either through internet protocols (remote bidding) or simply by phoning distant representatives. However, buyers still have to choose a fish market within the territory where they buy fish and incur transportation costs in the case of a purchase. Because of these spatial frictions, the LOP is not guaranteed.

In our estimations, we use exhaustive data on the whole national territory, which is in contrast with other studies that consider unique locations such as the Marseille wholesale fish market in France (Härdle and Kirman 1995; Vignes and Etienne 2011), the Fulton fish Market in the USA (Graddy 1995) or the Ancona fish market in Italy (Gallegati et al. 2011). Our work builds on recent advances in economic geography that focus on spatial wage disparities and estimate wage equations, including both local fixed effects and individual fixed effects, in order to take into account worker heterogeneity (Combes, Duranton and Gobillon 2008). We also draw inspiration from the labor economics literature in which wage equations including both firm and worker fixed effects are estimated (Abowd, Kramarz and Margolis 1999). In the present article, we estimate fish price equations that include three types of fixed effects related to local markets, sellers and buyers.

The model is estimated using a sample of one million transactions for seven fish and crustacean species in 2007. We first present some results for the species with the largest market share in our dataset – monkfish – and we then compare these results with those obtained for the six other species, which differ from or are substitutes for monkfish. For our preferred specification of monkfish, we find that space matters, as local market effects explain around 14% of the price variations. This result suggests that there is not a unique price in the fish market. In comparison, variables characterizing observable heterogeneity for fish explain as much as 40% of price variations, while unobserved heterogeneity among vessels and buyers explains only a small share (6% and 3.5%, respectively). Residual variations are sizable (around 20%) and capture features such as day-to-day changes in demand, supply and unobserved fish quality.

When replicating our approach for some other species, we find that our results vary greatly across species. In particular, local market effects explain 41% of price variations for hake. For squid, the corresponding proportion is 27.5%, whereas the explanatory characteristics of fish explain only 4.3% of price variations. Overall, results for a given product cannot be generalized to others, suggesting that products should always be considered separately in the analysis of prices.

We then regress the absolute price difference (net of composition effects) between two local fish markets on the logarithm of distance, a dummy capturing the location on the two different coasts and species dummies. Whereas distance only has a small effect, the coast effect is important. In fact, prices are 34% higher on the Mediterranean coast than on the Atlantic coast. The market segmentation between the two coasts can be explained by the prohibitive costs for boats to move from one coast to the other, which can be done only by going around Spain and through the Straits of Gibraltar. Results by species show that prices are significantly higher on the Mediterranean coast for five out of our seven selected species.

We also define groups of local fish markets such that, within each group, fish markets are well interconnected by mobile buyers and sellers. We consider that a group is well interconnected if, when restricting the estimation to transactions occurring within their group, the three types of fixed effects (buyers, sellers and local markets) in the price equation are all identified. We show that for every species, there is a main group that includes most local fish markets on the Atlantic coast. For this group, price variations are very small for almost all species. This suggests that markets on the Atlantic coast are integrated in line with the LOP, although it is not possible to rule out remaining biases related to selection effects for mobile buyers and sellers, as well as composition effects due to fish unobservables.

The rest of the paper is organized as follows. Section 2 presents our dataset along with some descriptive statistics on our sample. Section 3 explains our econometric approach, and Section 4 discusses the results. Finally, Section 5 provides our conclusions.

Data and descriptive statistics

We assess the validity of the LOP using transaction data from fish markets, which are organized as follows. After landing, the fish are weighted and then sorted by presentation (whole, gutted, cut into pieces), size and quality. The sorting is done either by the crew itself onboard or by the harbor staff. The rating of quality is based on an evaluation grid constructed from criteria at the European Union level. Staff in charge of rating fish have been trained and are under oath when giving a quality grade to each fish lot. Nevertheless, this does not completely rule out differences in rating practices between fish markets, because there can be local habits or a local agreement regarding the way ratings should be conducted. As emphasized by Kirman (2001, p. 157), the trading organization "varies from location to location, for little obvious reason". Most of the fish is auctioned in trading rooms or around fish boxes in the fish hall, where a mobile electronic auction clock is mounted on a battery-powered vehicle.[3] Only buyers and the auctioneer are present in the trading room.

In 2007, the year considered in our empirical analysis, 238,194 tons of fish valued at 705.5 million euros were landed and traded in 40 local fish markets scattered along the French coastline.[4] Figure 1 shows that most local fish markets are located along the Atlantic coast (including the Channel), and only a few are located along the Mediterranean coast. The three largest markets (Boulogne-sur-Mer along the Channel, Le Guilvinec and Lorient in Brittany) account for around one-third of the total sale value. Most of the largest fish markets are located on the north-west coast. By contrast, the fish markets located along the Mediterranean coast are rather small.

[Insert figure 1 here]

Our study of fish prices relies on a unique exhaustive dataset of transactions within the French fish market during the year 2007. In France, fish price data on every transaction are collected daily by the national bureau of seafood products (*France Agrimer*) from all fish markets, and they are processed in a data system called RIC (*Réseau Inter-Criées*). The dataset comprises only a few variables, but they provide an accurate description of each transaction.

The data include information on the fish market where each transaction takes place, as well as information on the vessel and the buyer involved in the transaction. There are three distinct identifiers associated with the local fish market, the vessel and the buyer. For the buyer, the dataset includes the buyer's license code, which is a market-specific account identifier. A buyer can have several accounts in one or several fish markets. To identify the buyers associated with the accounts, we rely on a complementary survey conducted by France Agrimer in 2008, which contains information on the official firm identifier for each account.[5]

When matching this information with our dataset, we are able to identify the buyers for 85.3% of the accounts.

Some information is also given for each transaction. We know the total price paid by the buyer along with the purchased quantity, from which we deduce the price per kilo. We also know the type of trading system used for the transaction (auction or direct sales). Some additional details are given on the characteristics of fish exchanged during the transaction, such as the fish species, size, presentation (whole, gutted, in pieces, etc.) and quality (ranging from extra – the best quality – to low). Finally, we know the month of transaction, but not the exact day.

The dataset includes 3,194,659 transactions when considering all species and all local fish markets. We restrict our sample in the following way. First, we only consider transactions corresponding to direct auctions between vessels and buyers in local fish markets. This eliminates 230,725 observations corresponding to direct sales to processors, whose price is bargained very differently across time and space. Second, we remove 14,970 observations because the account identifier is missing. Third, we focus on species characterized by a large number of transactions, in order to avoid fish and crustaceans, whose trade is limited to specific seasons or occurs only in a few local niche markets. More precisely, we restrict our analysis to the seven following species: monkfish, sole, langoustine, sea bass, hake, John Dory, and squid.[6] These selected species are involved in 1,009,788 transactions and represent about one-half of the total sales value.[7] On average, our selected species represent high-valued products. Transactions occur in 31 local markets along the Atlantic coast and 7 local markets along the Mediterranean coast.

We now present some descriptive statistics on fish prices, fish characteristics and local markets for the seven selected species. The average fish price per kilo varies considerably across species, as shown in column 2 of table 1. It is highest for sole (14 euros per kilo), and it ranges between 10 and 12 euros per kilo for John Dory, langoustine and sea bass. The lowest values are found for hake and monkfish (between 5 and 6 euros per kilo). Differences in average prices across species can reflect consumer tastes and differences in quality and supply. Fish species like sea bass, John Dory and sole are considered to be high-quality products and are bought by high-quality restaurants or consumers with high purchasing power.

[Insert table 1 here]

For a given species, column 3 of table 1 indicates that the variation in transaction prices can be quite large. This variation is expected to be strongly related to differences in size, quality and presentation. The coefficient of variation is the highest for hake and squid, with a value of around 0.5. It is the lowest for sole and John Dory, with a value of around 0.35.

As shown in column 4, fish species are all traded in more than 30 local markets (with a maximum of 37 markets for sole and sea bass), except for langoustine. This crustacean is found in only 17 local markets because there are a limited number of trawlers – located mostly near Lorient, Le Guilvinec, Oleron and Concarneau – that target langoustine under a specific license. By contrast, monkfish is caught all along the Atlantic and Mediterranean coasts by trawlers, dredgers and gillnetters, all of which target other species as well. As shown in Table A1 in the supplementary appendix online, only 0.4% of transactions occur on the Mediterranean coast for langoustine, compared to 10.5% for monkfish. The proportion of transactions on that coast is the highest for hake, at 28.1%. The average price varies considerably across local markets (column 5). The ratio between the maximum and minimum local prices is the highest for monkfish, with a value of around three, as shown in columns 6 and 7 (prices ranging from 4.3 to 13.4 euros). This ratio is the lowest for sole and hake (less than 2).

Table 2 gives some descriptive statistics on fish characteristics whose coding varies across species. For instance, there are five size categories for monkfish, but only three for sea bass. Concerning the presentation, all squid are traded whole, and langoustines are mostly sold alive (in 83% of transactions). Most monkfish transactions involve gutted fish, but monkfish is also sold whole or in pieces. Substantial differences in quality are observed across species. Most langoustines are characterized by the highest quality grade (extra grade), as well as sea bass and sole to a lesser extent, while most monkfish and John Dory are of medium quality (B-grade). Variations in fish characteristics may potentially explain variations in fish prices as long as the dispersion of fish across categories is large enough.

[Insert table 2 here]

Table 2 further describes market conditions in local fish markets. The yearly average number of transactions per local market ranges from 1,691 for the scarce John Dory to 6,648 for the more common sole. There is substantial variation in the number of landing vessels, with more than 2,400 vessels for sea bass, but fewer than 400 vessels for langoustine.

There are also variations in the numbers of accounts and matched buyers, i.e. the buyers that we are able to match to at least one account. The average numbers of accounts and matched buyers are the lowest for langoustine (912 accounts and 538 matched buyers) because, as noted above, this product is sold in only a few fish markets. The figures are larger for sole and sea bass, with 1,900 accounts and 1,000 matched buyers per local market. The average number of transactions per buyer (ranging from 57 for John Dory to 195 for sole) is much higher than the number of transactions per account (respectively, 40 for John Dory and 129 for sole).

Overall, our descriptive statistics suggest that there are large variations in fish prices across local fish markets, and that many factors may influence price setting within these markets. We now propose an econometric approach to assess the extent to which fish prices are affected by fish characteristics, location of transactions or unobserved heterogeneity among sellers and buyers.

Empirical strategy

We now present the various steps of our econometric approach.

Specification

For a given fish species, we consider a transaction i of a given quantity of fish with specific characteristics X_i that is sold by a vessel $j(i)$ to a buyer $k(i)$ during month $t(i)$ in a local fish market $c(i)$. Characteristics include size, presentation (whole, gutted, in pieces, frozen, etc.) and quality. We want to explain the log of the price per kilo, or unit price, and we denote it by P_i. Our price specification is given by:

(1) $P_i = X_i\beta + \psi_{c(i)} + \gamma_{j(i)} + \delta_{k(i)} + \vartheta_{t(i)} + \varepsilon_i$

where γ_j is a vessel fixed effect, δ_k is a buyer fixed effect, ϑ_t is a month fixed effect, ψ_c is a local market fixed effect, and ε_i is a random error term not correlated with the observables and the various fixed effects. In particular, error terms capture idiosyncratic price variations, which include daily supply shocks due to specific weather conditions.

Our specification allows the quantification of spatial variations in prices after several composition effects have been taken into account. Spatial variations in net prices can differ from those in raw prices for several reasons. Fish characteristics can vary across markets, with some markets selling the best quality fish. There may also be some sorting of vessels across local fish markets according to production costs and fish quality, because fishing gear used by vessels varies over space. Moreover, there is some heterogeneity among wholesale buyers, as some of them supply high-quality restaurants that need high-valued seafood products and are ready to pay more than the average customer, whereas some others work for secondary processing plants and mostly purchase low-valued fish, for which they may bargain harder on prices. Some sorting of wholesale buyers may occur across local fish markets according to their willingness to pay, because of specific local downstream markets.

It is important to note that specification (1) includes non-nested terms, as there may be some mobility of buyers and vessels across local fish markets. While small vessels are always expected to land their catches in the same market, it is likely that some of the largest vessels sell their catches in various places, depending on their fishing location. Similarly, some fish buyers may purchase in only one fish market, while others may purchase in several places.

The literature puts particular emphasis on the necessary conditions for separately identifying two sets of non-nested fixed effects. In labor studies, the condition is that there is enough mobility of workers between firms for all firms to be interconnected by mobile workers (Abowd, Kramarz and Woodcock 2008, Andrews, Schank and Upward 2006). In our study, vessels are considered instead of firms, and they are interconnected through buyers purchasing fish from different sellers. As will be shown in the next section, there is a good interconnection of vessels for all fish species in the French market.

An additional difficulty in our study is that the specification also includes local market fixed effects that we want to identify separately from buyer and seller fixed effects. Some mobility of both sellers and buyers across local fish markets is necessary for identification. Sellers can be tracked across markets and may sell in several markets. This may occur if vessels believe that some buyers are more willing to pay for specific products in some places, or if skippers have several fishing zones and land their catches in the nearest fish market to reduce both transportation time and costs. When buyers are identified with their account number, which is specific to the market where they make their purchases, they cannot be tracked across markets. This implies that local market fixed effects cannot be distinguished from the local average of buyer fixed effects when using accounts. More formally, it is useful to rewrite equation (1) as:

(2) $\psi_c + E[\delta_{k(i)}|i \in c] = E[P_i - X_i\beta - \vartheta_{t(i)} - \gamma_{j(i)}|i \in c]$

To grant the identification of the model, we normalize the mean of buyer fixed effects in each local market to zero.

Assumption A1. $E[\delta_{k(i)}|i \in c] = 0$ *for each local fish market* c.

This implies that a local market fixed effect captures not only the local level of price, but also the local average composition of buyers. In that case, the fixed effect of a given local fish market is the average transaction price in that market, net the effects of fish, seller and time.

We need an empirical strategy to estimate our model that includes four sets of fixed effects under the empirical counterpart of Assumption A1, stating that the local averages of buyer fixed effects are normalized to zero. For that purpose, we center observations with respect to their local market average. This transformation makes the local market fixed effects disappear, and we obtain:

(3) $\Delta P_i = \Delta X_i\beta + \Delta\vartheta_{t(i)} + \Delta\gamma_{j(i)} + \delta_{k(i)} + \Delta\varepsilon_i$

where Δ denotes the operator centering variables with respect to their local market average. As there are only 12 months in a year, month fixed effects can easily be taken into account with month dummies. We still need to deal with the two series of buyers' and sellers' fixed effects, whose number is larger than a thousand for most species (see Table 2). The model is first projected in the within-buyer dimension and estimated using OLS. This step allows the estimation of the effects of fish characteristics as well as seller and time fixed effects. The fixed effect of any given buyer k can then be recovered as the average of $\Delta P_i - \Delta X_i\hat{\beta} - \Delta\hat{\vartheta}_{t(i)} - \Delta\hat{\gamma}_{j(i)}$, computed on the subset of transactions involving the buyer. The local market fixed effects ψ_c are finally recovered as the empirical counterpart of the right-hand side of equation (2).

So far, accounts that are specific to fish markets have been used to determine who purchases fish. We now resort to buyer identifiers, which allow the tracking of buyers across markets. We consider that fish markets are well interconnected if there is enough mobility of sellers and buyers across fish markets for seller, buyer and local market fixed effects to be all identified (provided one fixed effect of each series is fixed to zero as a normalization). For a group of well interconnected fish markets, it is possible to test the absolute LOP while taking into account the unobserved heterogeneity of buyers and sellers without any restriction on sorting across local markets.

Groups of well interconnected fish markets are determined as follows. First, we consider buyers and sellers. We define a group as a set of buyers and sellers such that all the buyers purchased fish at least once from a vessel in that set, and all the vessels sold fish at least once to a buyer in that set. A second group is introduced when there are buyers and sellers such that no buyer in the first group has ever purchased fish from a vessel in that second group, and no vessel in the first group has ever sold fish to a buyer in the second group. Drawing on graph theory, Abowd, Creecy and Kramarz (2002) propose a simple algorithm to identify mutually exclusive groups, and we implement it using the Stata procedure developed by Andrews, Schank and Upward (2006).

Now consider our three series of fixed effects, i.e. buyer, seller and local market fixed effects. We identify three different types of groups: groups of connected buyers and sellers, groups of connected buyers and local markets, and groups of connected sellers and local markets. We then combine these groups to define groups of interconnected buyers, sellers and local markets. Each tri-dimensional group is defined by a unique combination of buyer-seller group, buyer-local market group and seller-local market group. For the various species, we find that there is one group that includes most of the transactions.

Estimations are restricted to the main group, but otherwise the estimation procedure is very similar to the one in which the mobility of buyers is not considered. The model is first projected in the within-buyer dimension and estimated using ordinary least squares. This step allows estimating not only the effects of fish variables and seller and time fixed effects, but also of local market fixed effects. The fixed effect of any given buyer k can then be recovered as the average of $P_i - X_i\hat{\beta} - \hat{\psi}_{c(i)} - \hat{\vartheta}_{t(i)} - \hat{\gamma}_{j(i)}$, which is computed on the subset of transactions involving that buyer.

A limit to our approach is that mobile sellers and buyers, who grant the identification of market fixed effects, may be particularly responsive to daily conditions in local markets (for instance, those related to weather conditions), and this may lead to estimation biases. For instance, mobile buyers could be the wholesalers who are best informed on a daily basis about where the fish harvest is good (in terms of quantity purchased) and the prices are low. In that case, spatial disparities are measured using mostly low-price markets and are probably understated. Moreover, market fixed effects could also capture some remaining heterogeneity in unobserved fish quality, since our quality variables are rather coarse and the fixed effects of mobile sellers capture the average unobserved quality in several markets rather than a single one, which makes them imperfect proxies. In that case, net price dispersion can be underestimated or overestimated.

The role of spatial frictions in explaining spatial variations in prices

As a final step, we assess to what extent spatial frictions explain differences in local price fixed effects. For that purpose, we consider the following bilateral framework. Let $\psi_{c,s}$ denote the fixed effect for local market c of species s (where subscript s has been reintroduced).

Following the literature on LOP, we want to explain the squared price difference $\left(\Delta\psi_{cc',s}\right)^2$, with $\Delta\psi_{cc',s} = \psi_{c,s} - \psi_{c',s}$ as a function of distance between local markets and a parameter capturing the fact that two markets are located on two different coasts, i.e. the Atlantic and the Mediterranean.[8] Indeed, the Atlantic and the Mediterranean are two disconnected areas for the French fishing fleet, since the only maritime passage between them is via the Straits of Gibraltar. We consider the following linear model:

(4) $\left(\Delta\psi_{cc',s}\right)^2 = \alpha + \beta \ln d_{cc'} + \omega B_{cc'} + \mu_s + \varepsilon_{cc',s}$

where $d_{cc'}$ is the distance in kilometers between fish markets c and c', β is the elasticity of price difference with respect to distance, $B_{cc'}$ is a dummy equal to one when one of the local markets c or c' is located along the Atlantic coast and the other market is located along the Mediterranean (zero otherwise), ω is a parameter measuring the magnitude of the coast effect, α is a constant, μ_s is a species fixed effect, and $\varepsilon_{cc',s}$ is an error term.[9]

Model (4) is estimated by weighted least squares after the left-hand side variable has been replaced by $\left(\Delta\hat{\psi}_{cc',s}\right)^2$, where $\hat{\psi}_{cc',s}$ is the first-stage estimator. The weight is given by $min(N_c, N_{c'})$, where N_c and $N_{c'}$ are the numbers of transactions occurring in fish markets c and c', respectively. The intuition for using this weight is that $\left(\Delta\psi_{cc',s}\right)^2$ is estimated with less accuracy when one of the local fixed effects is estimated with less precision. This occurs when there are only a small number of transactions in the corresponding market. We take the minimum number of transactions in the two markets, as it should be the market with the smallest number of transactions that limits precision. Note, however, that results are qualitatively very close to those obtained when not using any weight.[10] Standard errors and significance levels are bootstrapped by using 100 random samples of transactions drawn from the full sample of transactions and by re-estimating in two steps equations (1) and (4) from each sample.

Empirical results

We now assess whether price differences exist between local fish markets once the heterogeneity among fish, sellers, buyers and months is netted out. As there is a lot of heterogeneity across species, we choose to present results by species; but those for pooled species are available in table A2 in the supplementary appendix online. We begin with the case of the monkfish species, which was ranked first in France in 2007 in terms of sales value, and present the results for the specifications developed in the previous section. We then discuss the results obtained when considering other fish species.

Spatial variations in prices for monkfish

Results when regressing fish prices only on fish market fixed effects are reported in column 1 of table 3. They show large spatial variations in prices, as the R^2 measuring the explanatory power of local fixed effects is large, with a value of 46%. We then assess to what extent these spatial variations in prices are due to spatial differences in fish characteristics.

For that purpose, we add fish characteristics and month fixed effects as controls in our specification. Inclusion of these additional terms scales down the variance of estimated local market fixed effects by more than three, from 0.053 (column 1) to 0.015 (column 3). An explanation of this decrease is the positive correlation between fish quality effects and local market fixed effects, which is equal to 0.36 for monkfish, indicating that higher quality products are often sold in more expensive markets.

There are also variations in quality within local fish markets, as the R^2 increases substantially to 74%. This increase is due to the inclusion of fish characteristics rather than month fixed effects, since the increase in R^2 when adding month fixed effects to the specification including only local fixed effects (see columns 1 and 2 of table 3) is much smaller than when additionally adding fish characteristics (see columns 2 and 3). The estimated coefficients of fish characteristics have the expected sign. The lowest quality fish is much cheaper, at a price per kilo that is approximately 60% lower than the highest quality fish. Also, fish sold in pieces (with cut-off heads) is significantly more expensive than whole fish, as raw inedible parts have been removed.[11]

[Insert table 3 here]

Next, we introduce account and seller fixed effects by following equation (1). Results reported in column 4 of table 3 are very similar to those reported previously, in particular for the variance of local market fixed effects. This suggests that the choice of fish market where vessels land catches does not depend on the expected local price. It may rather depend on the location of the fishing zone, as landing fish close to this zone reduces transport costs. At the same time, the introduction of buyer and seller fixed effects leads to a significant increase in the R^2 value, from 0.74 to 0.80.

To assess the importance of factors in explaining fish price variations, we perform a variance decomposition for equation (1). Results reported in table 4 show that space plays an important role for monkfish, as the variance of estimated local market fixed effects accounts for 13.8% of price variations. There is thus not a unique price in the fish market for monkfish and spatial frictions may occur. Fish characteristics are still the most important determinant of price variations. Size, presentation and quality account for 41.5% of price variations. Time, seller and account fixed effects play a lesser role, explaining 6.4%, 5.7% and 3.5% of price variations, respectively. Vessel unobserved heterogeneity does not matter much, although it captures to some extent unobserved fish quality that is related to fishing gear and onboard fish storage.

[Insert table 4 here]

Spatial variations in prices for other species

We also conduct a variance decomposition of prices for each fish species using the estimates obtained for the most complete price specification, which are reported in table A3 in the supplementary appendix online. Results of this variance decomposition are given in table 4. They suggest that local markets play a major role for some species. In particular, space is a major determinant of prices for hake, as local market fixed effects explain as much as 41% of price variations. The corresponding figure is also large for squid, with a value of 27.5%. By contrast, local markets play a minor role for sole, sea bass, and John Dory, as they explain less than 10% of price variations (5.9%, 7.6% and 8.0%, respectively).

Fish characteristics play an important role, except for squid, for which they explain only 4.3% of price variations. This is not really surprising, as there is not much variation in presentation or size for this species. Among fish characteristics, size is always an important determinant of the price per kilo. A lower price is usually associated with a smaller fish, although there are exceptions. For species like monkfish and sole, fish in the second largest size category is more expensive than fish in the first size category, because it better fits certain market requirements (the size of portions). Whereas monkfish is more expensive in pieces than when it is whole (as the non-edible raw material has been discarded), this is not the case for langoustine, for which cut-off pieces are mostly frozen tails whose value is lower than that of a whole, live langoustine.

The importance of time effects also varies a lot across species, mainly because some species are seasonal whereas others are not. Month fixed effects account for as much as 25.4% of price variations for squid, for which catches vary greatly over the year (they are largest in October and January). Month effects also have a large explanatory power for langoustine, as they explain around 17.2% of price variations. The price is low between May and July, when langoustines are abundant, but it increases sharply in December as langoustines are scarcer, and demand rises sharply at Christmas and New Year.

Finally, vessel and buyer unobserved heterogeneity explains a sizable share of price variations, but their explanatory power is never very large. Seller fixed effects account for 14.1% of price variations for hake, but the corresponding value is lower for other species and never exceeds 8%.[12] Buyer fixed effects account for 11.4% of price variations for John Dory, but the corresponding value is 10% at most for other species, and even below 4% for monkfish and langoustine.

Overall, our results show that there are still large spatial disparities in fish prices after taking into account composition effects regarding fish characteristics and buyer and seller heterogeneity. These disparities may remain because of spatial frictions due to distance, which to some extent create a spatial fragmentation of demand and supply; or they may be due to spatial sorting of buyers on unobservables, as Assumption A1 implies that their local average is confounded with the local fixed effect (which, so far, makes it difficult to conclude whether LOP is verified or not).[13]

The role of distance and coast effects

We now assess to what extent spatial differences in fish prices, net of composition effects, are related to distances between local markets and the location on the Atlantic or Mediterranean coast. We first pool data for the seven species and regress the squared price difference between estimated local fixed effects on fish dummies to establish a benchmark. The R^2 is 14%, as shown by the results reported in column 1 of table 5.

[Insert table 5 here]

We then introduce the logarithm of Euclidean distance between markets as an additional regressor. As shown in column 2, the distance is found to have a significant positive effect and a sizable explanatory power as the R^2 increases by 6% (from 14% to 20%). Adding a dummy indicating whether markets are located on different coasts substantially decreases the marginal effect of distance, which nonetheless remains positive and significant (column 3). The effect of the coast dummy is also found to be positive and significant, suggesting that markets on the two coasts are not integrated. Again, the R^2 increases and amounts to 25.4%. This finding points to a sizable explanatory power of the coast effect even when the influence of geographic distance is netted out.

When only distance is introduced into the specification as well as fish dummies, its coefficient is 0.037 (column 2). Adding one standard deviation (260.1 kilometers) to the average distance between two fish markets (386.5 kilometers) leads to a variation of 1.3% in the price ratio between fish markets.[14] This effect is sizable, but not large. Furthermore, it decreases significantly when the coast dummy is introduced in the regression, since the coefficient of distance falls to 0.008. In that case, adding one standard deviation to the average distance between fish markets leads to a variation in the price ratio between fish markets that is twice lower (0.6%).

In fact, the coast effect itself is very large, at 0.102, which corresponds to a variation in the price ratio as large as 37.6% ($= 100 * \left(\exp\left(\sqrt{0.102}\right) - 1\right)$). Price differences between coasts can also be assessed by running a linear regression of the local fixed effects on a Mediterranean coast dummy and species dummies. As shown in table A6 in the supplementary appendix online, we obtain a coefficient of 0.294 for the coast effect, meaning that prices are 34% higher ($= 100 * (\exp(0.294) - 1)$) on the Mediterranean coast than on the Atlantic coast. This difference is due to the geographic separation of the Atlantic and Mediterranean coasts. Vessels based in a port on one coast never make a trip to the other coast, because costs are far too high.

We also experiment with indicators that capture the difference in market structure between two fish markets, and we assess the extent to which they are able to explain residual price differences. In particular, we consider the squared difference in market share of the fish species (normalized by its standard deviation) as an indicator of the difference in local scarcity of the species. Column 4 of table 5 shows that its effect is significant at the 10% level only, and that its explanatory power measured by the increase in R^2 is negligible. Moreover, the estimated coefficients of distance and coast dummy are barely affected.

In an alternative specification, we also add an interaction between our scarcity indicator and a coast dummy to assess whether a distant separation on two different coasts makes the price difference more sensitive to the difference in scarcity. Results reported in column 5 show that, as expected, the estimated coefficient associated with the interaction term is significantly positive. However, the explanatory power of this term is rather small, and estimated coefficients of distance and coast dummy are only marginally affected.[15]

We report in table 6 the results obtained by species for a specification that includes distance and a coast dummy. Results differ across species, with the distance coefficient varying from a significant negative value of -0.008 for hake to a significant positive value of 0.039 for langoustine. However, even for langoustine, adding one standard deviation (236.5 kilometers) to the average distance between two fish markets (297.2 kilometers) leads to a variation in the price ratio between fish markets of only 1.6%. This suggests that distance effects (net of the coast effect) are small.

[Insert table 6 here]

We also find substantial differences for the coast effect, which varies from a non-significant value of 0.004 for sole to a significant value of 0.501 for langoustine. In fact, the coast effect is important for four species, which are, in decreasing order of magnitude: langoustine, hake, squid and monkfish. The very large coefficient found for langoustine can be related to the scarcity of catches in the Mediterranean and the high selling prices of Mediterranean langoustines in high-quality restaurants.

The determination and characterization of integrated markets

We finally assess to what extent local fish markets are integrated. We determine the main group of local fish markets that are well interconnected by flows, not only of sellers, but also of buyers, who are now tracked across fish markets using the buyer identifier instead of the account identifier. Composition effects in terms of buyer heterogeneity are thus fully taken into account. For the main group of local fish markets, we test the validity of the absolute LOP.

For monkfish, we are able to identify the buyer for 87.1% of the 144,436 transactions. The remaining observations are dropped from our sample. As shown in table 2, each buyer is related to an average of 27.1 vessels during the year, which is larger than for accounts, for which the average is 18.2 vessels. This comes from the aggregation of several accounts for a given buyer, with an average of 1.8 accounts per buyer. Note that this leads to a mechanical decrease in the number of buyer fixed effects. The percentage of mobile buyers purchasing monkfish in at least two local markets reaches 23.4%, which is higher than the percentage of mobile vessels (16.5%).

Table 7 shows for various species that there are several groups of well interconnected fish markets. For monkfish, there are exactly seven groups (column 1). The largest group, defined as the group where the largest number of transactions takes place, includes 87.9% of transactions in 21 fish markets, whereas monkfish is sold in 33 fish markets in the full sample. Interestingly, most fish markets on the Atlantic coast are in this group, while fish markets on the Mediterranean coast are all in other groups. This reinforces our claim that Mediterranean markets and Atlantic markets are separated.

[Insert table 7 here]

We then assess to what extent significant price variations remain after the different sources of heterogeneity have been taken into account. We define a dispersion indicator as the ratio between the standard deviation of local market fixed effects (weighted by the number of transactions) and the average log-price. This indicator is much like a coefficient of variation and takes into account scale effects related to differences in the average valuation of species by consumers. It can thus be compared across species. We consider that net price variations across markets are negligible if our indicator takes a value lower than 0.05, which is usually considered to be a very small value for a coefficient of variation. Negligible net price variations would suggest that the absolute LOP is verified.

As shown in column 1 of table 8, the values of the indicator obtained from estimates of equation (2) under Assumption A1 when using all transactions (model A) and when using only transactions from all matched buyers (model B) are very close (0.071 and 0.069). Our indicator for monkfish decreases sharply to just 0.027 (model C) when restricting the sample of transactions to those in the main group of well interconnected fish markets.[16] Relaxing Assumption A1 does not change the results by much. When controlling for buyer composition effects, our indicator decreases only very slightly to 0.025 (model D). This suggests that, for monkfish, there is not much sorting of buyers across fish markets. The very small value of our indicator suggests that the absolute LOP is verified when considering the main group of well interconnected fish markets, which includes most of the markets on the Atlantic coast.

[Insert table 8 here]

Next, we repeat the analysis for the other species. Interestingly, table 7 shows that the main group of well interconnected fish markets always comprises only markets located on the Atlantic coast. It does not include any market on the Mediterranean coast. Once again, this pattern supports the idea that the two coasts are not integrated. As shown in table 8, most transactions occur in the main group for every species. The proportion of fish transactions in the main group is 83.3% for sole, 84.2% for langoustine, 78.2% for sea bass, 68.1% for hake, 90.0% for John Dory, and 79.8% for squid. Our dispersion indicator computed under

Assumption A1 decreases when considering the main group for all species. The decrease is by far the largest for hake, from 0.246 to 0.094.

When relaxing Assumption A1, our indicator is quite stable for every species. Again, this suggests that composition effects related to buyer heterogeneity are negligible. Results are in line with LOP for almost all species. Indeed, our indicator is below 0.05 for monkfish, sole, langoustine, sea bass and John Dory. It remains quite small even for squid and hake, as it takes the respective values 0.068 and 0.100. Overall, our results suggest that fish markets are integrated when considering only transactions occurring in the main group of well interconnected fish markets, which are all located on the Atlantic coast.

Conclusion

In this paper, we have investigated spatial price variations for several fish species using a unique exhaustive dataset on fish transactions that occurred in the French fish market in 2007. An original aspect of our work is that we are able to take into account spatial differences in buyers' willingness to pay and in sellers' production costs by modeling the unobserved heterogeneity of agents. We estimate a price equation that includes observable fish characteristics as well as seller, buyer, time and local market fixed effects. Spatial variations in prices net of composition effects are captured by the variations in local market fixed effects.

Our results suggest that the absolute LOP would not hold for most of the selected fish and crustacean species when considering all local fish markets, although one cannot rule out the existence of remaining biases due to unobserved heterogeneity. A key reason is that fish markets in France are located on two separate coasts, the Atlantic and the Mediterranean. Vessels never move from one coast to the other to land fish as moving costs are prohibitive. When considering only transactions completed in local fish markets that are well interconnected by flows of buyers and sellers, net price variations are very small for nearly all species, which is in line with the absolute LOP.

Footnotes

1. Still related to the LOP but not directly related to our paper, some articles have focused on the relationship between the international price dispersions and exchange rates (Isard 1977; Rogoff 1996). It has also been shown that much of the observable price dispersion within Europe could be attributed to how tradable the goods are, and how tradable the inputs required to produce them are (Crucini, Telmer and Zachariadis 2005).

2. This is in contrast with papers comparing the evolution of local prices, in which the "relative" LOP is tested instead. See Broda and Weinstein (2008) for a discussion.

3. For a full description of the electronic auction systems for fish markets in France, see, for instance, Guillotreau and Jiménez-Toribio (2006, 2011).

4. See http://www.criees-france.com/index.php?id_site=1&id_page=47 for further details. The reported value does not include fish directly exported to foreign countries or sold through domestic contracts (which represent more than 20% of sales).

5. This is a nine-figure identifier attributed to each legal unit called the SIREN number. Each buyer is characterized by a unique SIREN number. The aim of the survey by France Agrimer was to match the SIREN numbers with the accounts registered with the fish markets.

6. For the seven selected species, we excluded the transactions with missing information on size, presentation or quality (3,533 observations deleted). We further dropped the 0.1% upper and lower values of the price distribution (2,002 observations deleted). We also excluded, for each species, local fish markets with fewer than 100 transactions in 2007 (696 observations deleted). The number of local fish markets thus varies across species in our empirical analysis.

7. Market values are, in decreasing order: 69.1 million euros (M€) for monkfish (144,436 transactions), 68.6 M€ for sole (245,987 transactions), 46.4 M€ for sea bass (182,885 transactions), 44.8 M€ for langoustine (91,888 transactions), 29.2 M€ for squid (93,529

transactions), 20.4 M€ for hake (196,950 transactions), and 14.1 M€ for John Dory (54,113 transactions).

8. Previous studies considering price variations as the dependent variable include Engel and Rogers (1996), Crucini, Telmer and Zachariadis (2005), Broda and Weinstein (2008) and Imbs et al. (2010).

9. Note that our specification is symmetric in c and c', which means that the difference between c' and c is redundant with the difference between c and c'. As a consequence, we only consider differences for pairs (c, c'), such that $c < c'$. Also, we do not include additive local market fixed effects in specification (4) as Imbs et al. (2010). First, it is not consistent with a specification of price differences. Second, our goal is to evaluate differences across local markets and not to control for them on the right-hand side of (4).

10. Note that our weighting scheme is not optimal, and one may want to implement feasible general least squares (FGLS). However, its implementation is not straightforward, because differences in estimated market fixed effects are squared. Moreover, FGLS can perform badly at a finite distance. Therefore, we did not investigate in that direction.

11. We ran an alternative specification that included fish quantity as a regressor. This additional covariate does not affect our previous results and does not improve the fit of the model. For this reason, as well as for the potential endogeneity of quantity due to a missing variable problem (since fish availability can influence both its price and the size of fish lots), we choose to exclude quantity from our other specifications. The estimated parameter of quantity has the expected negative sign: larger quantities are, on average, sold at a cheaper price per kilo.

12. Hake can be targeted by vessels that are as different as trawlers, gillnetters and hand-liners; or they can be harvested as bycatch by vessels bottom trawling langoustine. Fish quality varies according to the type of fishing gear. Price variations of hake may thus be

explained by seller fixed effects as they capture unobserved heterogeneity in fish quality. Results for pooled species are available in table A4.

13. One may think that an alternative explanation could be the existence of spatial disparities in vessel costs that involve local fuel costs and deductions by local fish markets for landing fish. However, spatial variations of these costs are very small in France. Moreover, it is unlikely that prices reflect these costs, since prices are fixed at auctions and cannot be influenced by fishermen.

14. Descriptive statistics on the average and standard deviation of distances are given in table A5 in the supplementary appendix online. The percentage reported in the text is given by

$100 * \left[\exp\left(\sqrt{0.037\log(386.5+260.1)} - \sqrt{0.037\log(386.5)}\right) - 1\right]$.

15. Regressions by species show that the positive effects of both the scarcity index and its interaction with the coast dummy are entirely driven by hake, whereas counterintuitive negative effects are obtained most often for other species. This casts doubt on the relevance of the scarcity index.

16. The sample restricted to the largest group comprises 110,642 transactions representing 88.2% of transactions from matched buyers.

References

Abowd, J., F. Kramarz and D. Margolis. 1999. "High wage workers and high wage firms." *Econometrica* 67(2):251-233.

Abowd, J., F. Creecy and F. Kramarz F. 2002. "Computing person and firm effects using linked longitudinal employer-employee data." Cornell University Working Paper.

Abowd, J., F. Kramarz and S. Woodcock. 2008. "Econometric analyses of linked employer-employee data." In L. Matyas and P. Sevestre P., eds. *The Econometrics of Panel Data*. Kluwer Academic Publishers, pp. 727-760.

Andrews, M., T. Schank and R. Upward. 2006. "Practical fixed-effects estimation methods for the three-way error-components model." *Stata Journal* 6(4):461-481.

Asche, F., D. Gordon and R. Hannesson. 1996. "Tests for market integration and the Law of One Price: the market for whitefish in France." *Marine Resource Economics* 19(2):195-210.

Broda, C., and D. Weinstein. 2008. "Understanding international price differences using barcode data." NBER Working Paper 14017.

Chiang, F.S., L. Jonq-Ying and M. Brown. 2001. "The impact of inventory on tuna prices: An application of scaling in the Rotterdam inverse demand system." *Journal of Agricultural and Applied Economics* 33(3):403-411.

Combes, P.P., G. Duranton and L. Gobillon. 2008. "Spatial wage disparities: Sorting matters!" *Journal of Urban Economics* 63(2):723-742.

Crucini, M., C. Telmer and M. Zachariadis. 2005. "Understanding European Real Exchange Rates." *American Economic Review* 95(3):724-738.

Engel, C., and J. Rogers. 1996. "How wide is the border?" *American Economic Review* 86(5): 1112-1125.

Fan, C., and X. Wei. 2006. “The Law of One Price: Evidence from the transitional economy of China.” *Review of Economics and Statistics* 88(4):682-697.

Gallegati, M., G. Giulioni, A. Kirman and A. Palestrini. 2011. “What’s that got to do with the price of fish ? Buyers behavior on the Ancona fish market.” *Journal of Economic Behavior and Organization* 80(1):20-33.

Goldberg, P., and F. Verboven. 2005. “Market integration and convergence to the Law of One Price: evidence from the European car market.” *Journal of International Economics* 65(1):49-73.

Graddy, K. 1995. “Testing for imperfect competition at the Fulton fish market.” *Rand Journal of Economics* 26(1):75-92.

Guillotreau, P., and R. Jiménez-Toribio. 2006. “The impact of electronic clock auction systems on shellfish prices: Econometric evidence from a structural change model.” *Journal of Agricultural Economics* 57(3):523-546.

Guillotreau, P., and R. Jiménez-Toribio. 2011. “The price effect of expanding fish markets.” *Journal of Economic Behavior and Organization* 79(3):211-225.

Handbury, J., and D. Weinstein. Forthcoming. “Goods prices and availability in cities”, *Review of Economic Studies*, in press.

Härdle, W., and A. Kirman. 1995. “Nonclassical demand: A model-free examination of price quantity relations in the Marseille fish market.” *Journal of Econometrics* 67(1):527-557.

Imbs, J., H. Mumtaz, M. Ravn and H. Rey. 2010. “One TV, one price?” *Scandinavian Journal of Economics* 112(4):753-781.

Isard, P. 1977. “How far can we push the Law of One Price?” *American Economic Review*, 67(5):942-48.

Kirman, A. 2001. “Market organization and individual behavior: Evidence from fish markets.” In J. Rauch and A. Casella, ed. *Networks and Markets*. London, Russell Sage Foundation, pp. 155-195.

Miljkovic, D. 1999. “The law of one price in international trade: A critical review.” *Review of Agricultural Economics* 21(1):126-139.

Parsley, D., and S. Wei. 1996. “Convergence of the Law of One Price without trade barriers or currency fluctuations.” *Quarterly Journal of Economics* 111(4):1211-1236.

Rogoff, K. 1996. “The Purchasing Power Parity puzzle.” *Journal of Economic Literature* 34(2): 647-668.

Vignes, A., and J.M. Etienne. 2011. “Price formation on the Marseille fish market: evidence from a network analysis.” *Journal of Economic Behaviour and Organization* 80(1):50-67.

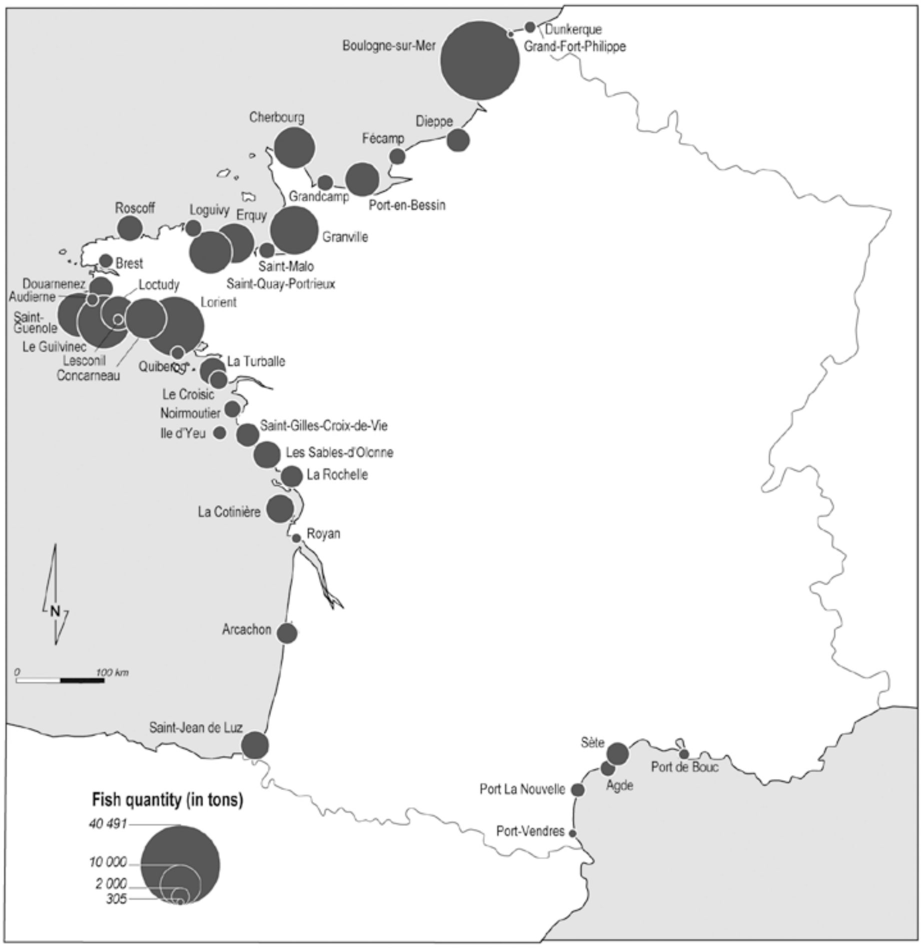

Figure 1. Quantity of fish landed in fish markets in France in 2007

Source: *Association des Directeurs et Responsables des Halles à Marée de France*, 2007.

Note: map constructed by Jérémie Turpin and Christine Lamberts (CNRS-LETG-Nantes-UMR 6554). Data are available on-line at the address: http://www.criees-france.com/index.php?id_site=1&id_page=49.

Table 1. Prices per Kilo in Local Fish Markets

Fish species	Transactions			Fish markets			
	N	$\bar{P}$	$\sigma(P)$	n	$\sigma(\bar{P}_c)$	$\max(\bar{P}_c)$	$\min(\bar{P}_c)$
Monkfish	144,436	6.248	2.485	33	2.559	13.390	4.337
Sole	245,987	14.079	4.956	37	1.971	19.642	10.801
Langoustine	91,888	11.852	5.015	17	3.486	21.126	7.477
Sea bass	182,885	12.172	5.306	37	2.266	19.439	8.461
Hake	196,950	5.002	2.563	31	.754	7.377	3.787
John Dory	54,113	10.484	3.621	32	1.819	14.034	5.382
Squid	93,529	8.251	4.193	35	2.363	14.156	5.121

Source: RIC 2007, authors' calculations.

Note: for a given fish species, N is the total number of transactions, $\bar{P}$ is the mean price of all transactions and $\sigma(P)$ the standard deviation, n is the number of fish markets where transactions occur, $\bar{P}_c$ is the mean price of all transactions in fish market c, $\sigma(\bar{P}_c)$ is the standard deviation of mean prices per fish market, and $\max(\bar{P}_c)$ and $\min(\bar{P}_c)$ are, respectively, the maximum and minimum mean price per fish market. For each fish species, fish markets with less than 100 transactions are dropped from the sample.

Table 2. Descriptive Statistics of the Sample, by Fish Species

Variables	Monkfish	Sole	Langoustine	Sea bass	Hake	John Dory	Squid
Description of the transaction							
Price per kilo (ln)	1.770	2.572	2.385	2.405	1.476	2.279	2.011
Quantity in kilos (ln)	7.980	6.716	7.793	6.841	7.038	6.849	7.303
Size: 1 (large)	0.143	0.191	0.083	0.248	0.079	0.120	0.162
2	0.175	0.180	0.346	0.331	0.192	0.274	0.212
3	0.294	0.179	0.063	0.420	0.187	0.342	0.258
4	0.224	0.183	0.508	0.000	0.250	0.264	0.221
5 (small)	0.164	0.267	0.000	0.000	0.293	0.000	0.148
Presentation: Whole	0.025	0.461	0.140	0.778	0.316	0.242	1.000
Gutted	0.891	0.539	0.000	0.000	0.684	0.758	0.000
Pieces	0.084	0.000	0.030	0.000	0.000	0.000	0.000
Alive	0.000	0.000	0.830	0.222	0.000	0.000	0.000
Quality: Extra (top)	0.398	0.636	0.851	0.673	0.593	0.348	0.503
B	0.574	0.337	0.135	0.300	0.382	0.642	0.496
C (low)	0.028	0.027	0.015	0.027	0.025	0.010	0.001
Description of the market							
Number of fish markets	33	37	17	37	31	32	35
Number of transactions per fish market	4376.8	6648.3	5405.2	4942.8	6353.2	1691.0	2672.3
Number of vessels	1306	2076	372	2449	1361	1185	1323
Number of transactions per vessel	110.6	118.5	247.0	74.7	144.7	45.7	70.7

Number of accounts	1644	1909	912	1897	1686	1366	1678
Number of transactions per account	87.9	128.9	100.8	96.4	116.8	39.6	55.7
Number of matched buyers	903	1021	540	1011	925	772	948
Number of transactions per matched buyer	139.3	194.5	162.6	148.7	193.4	57.0	80.7
Mobility							
% of vessels mobile among fish markets	0.165	0.151	0.234	0.130	0.189	0.138	0.135
% of accounts among fish markets	0.000	0.000	0.000	0.000	0.000	0.000	0.000
% of matched buyers mobile among fish markets	0.233	0.235	0.213	0.233	0.253	0.215	0.204
% of vessels mobile among accounts	0.887	0.943	0.960	0.940	0.935	0.871	0.901
Number of vessels per account	18.2	26.2	17.8	25.1	24.0	12.9	14.1
% of vessels mobile among matched buyers	0.896	0.936	0.961	0.935	0.939	0.873	0.895
Number of vessels per matched buyer	27.1	38.6	26.9	37.2	37.2	18.7	19.6
Total number of transactions	144,436	245,987	91,888	182,885	196,950	54,113	93,529

Source: RIC 2007, authors' calculations.

Note: reported figures for Size, Presentation and Quality are shares.

Table 3. Estimates of the Log Price of Monkfish

Variables		(1)	(2)	(3)	(4)
Size:	2			0.037***	0.032***
(ref: 1 Large)				(0.013)	(0.004)
	3			-0.088***	-0.090***
				(0.022)	(0.008)
	4			-0.122***	-0.130***
				(0.025)	(0.009)
	5 (Small)			-0.240***	-0.258***
				(0.027)	(0.011)
Presentation:	Gutted			-0.143**	-0.192***
(ref: Whole)				(0.068)	(0.031)
	Pieces			0.590***	0.460***
				(0.099)	(0.037)
Quality:	B			-0.044***	-0.017
(ref: Extra)				(0.013)	(0.011)
	C (Low)			-0.550***	-0.511***
				(0.064)	(0.028)
Month fixed effects		NO	YES	YES	YES
Seller fixed effects		NO	NO	NO	YES
Account fixed effects		NO	NO	NO	YES
Fish market fixed effects		YES	YES	YES	YES
Variance of fish market fixed effects		0.053	0.054	0.015	0.016
Number of observations		144,436	144,436	144,436	144,436
R^2		0.458	0.520	0.743	0.796

Source: RIC 2007, authors' calculations.

Note: (1), (2) and (3) are estimates from OLS models, (4) are estimates from fixed effect models. Standard errors clustered by fish market and month are in parentheses, significance levels being, respectively: 1% (***), 5% (**) and 10% (*). The variance of fish market fixed effects is computed using the number of transactions as weight.

Table 4. Variance Decomposition of the Log Fish Price at the Transaction Level for the Seller and Account Fixed Effect Model, by Fish Species

Decomposition	Monkfish		Sole		Langoustine		Sea bass		Hake		John Dory		Squid	
Var(size + presentation + quality)	0.0476	41.5%	0.0591	36.2%	0.0830	45.1%	0.0530	27.0%	0.1270	45.2%	0.0540	32.4%	0.0079	4.3%
Var(month FE)	0.0074	6.4%	0.0066	4.0%	0.0316	17.2%	0.0287	14.7%	0.0083	2.9%	0.0109	6.6%	0.0468	25.4%
Var(seller FE)	0.0065	5.7%	0.0105	6.4%	0.0114	6.2%	0.0134	6.8%	0.0397	14.1%	0.0129	7.8%	0.0104	5.7%
Var(account FE)	0.0040	3.5%	0.0160	9.8%	0.0045	2.5%	0.0158	8.0%	0.0280	10.0%	0.0190	11.4%	0.0148	8.0%
Var(fish market FE)	0.0159	13.8%	0.0097	5.9%	0.0304	16.5%	0.0149	7.6%	0.1151	41.0%	0.0134	8.0%	0.0506	27.5%
2*Cov(size + presentation + quality ; month FE)	-0.0013	-1.1%	-0.0014	-0.9%	-0.0001	-0.1%	0.0050	2.6%	0.0028	1.0%	-0.0015	-0.9%	-0.0040	-2.2%
2*Cov(size + presentation + quality ; seller FE)	0.0201	17.5%	0.0013	0.8%	0.0058	3.1%	0.0132	6.7%	0.0195	6.9%	0.0037	2.2%	0.0022	1.2%
2*Cov(size + presentation + quality ; account FE)	-0.0004	-0.4%	0.0066	4.0%	0.0039	2.1%	0.0066	3.4%	0.0140	5.0%	0.0058	3.5%	0.0014	0.8%
2*Cov(size + presentation + quality ; fish market FE)	-0.0048	-4.2%	-0.0038	-2.3%	-0.0089	-4.8%	-0.0033	-1.7%	-0.0999	-35.6%	-0.0013	-0.8%	0.0129	7.0%
2*Cov(month FE ; seller FE)	-0.0006	-0.5%	0.0001	0.1%	-0.0020	-1.1%	0.0042	2.2%	0.0005	0.2%	-0.0003	-0.2%	-0.0016	-0.8%
2*Cov(month FE ; account FE)	0.0003	0.3%	0.0006	0.4%	0.0016	0.9%	0.0020	1.0%	0.0009	0.3%	0.0005	0.3%	0.0048	2.6%
2*Cov(month FE ; fish market FE)	-0.0002	-0.1%	-0.0002	-0.1%	0.0023	1.2%	-0.0031	-1.6%	0.0016	0.6%	-0.0002	-0.1%	-0.0101	-5.5%
2*Cov(seller FE ; account FE)	0.0005	0.4%	0.0012	0.8%	0.0004	0.2%	0.0022	1.1%	0.0062	2.2%	0.0026	1.6%	0.0017	0.9%
2*Cov(seller FE ; fish market FE)	-0.0036	-3.2%	-0.0046	-2.8%	-0.0247	-13.4%	-0.0066	-3.4%	-0.0776	-27.6%	-0.0096	-5.8%	-0.0073	-4.0%
2*Cov(account FE ; fish market FE)	0.0000	0.0%	0.0000	0.0%	0.0000	0.0%	0.0000	0.0%	0.0000	0.0%	0.0000	0.0%	0.0000	0.0%
Var(residual)	0.0235	20.4%	0.0616	37.7%	0.0447	24.3%	0.0499	25.5%	0.0951	33.8%	0.0566	34.0%	0.0536	29.1%
Var(gross price)	0.1148		0.1634		0.1839		0.1961		0.2810		0.1665		0.1842	

Source: RIC 2007, authors' calculations.

Note: the variance decomposition is based on estimates for the various species reported in table A4 in the supplementary appendix online. FE stands for fixed effects.

Table 5. Estimates of the Squared Price Difference $(\Delta\psi_{cc',s})^2$ between Fish Markets

Variables		(1)	(2)	(3)	(4)	(5)
Constant		0.047***	-0.152***	-0.025***	-0.034**	-0.025***
		(0.003)	(0.014)	(0.009)	(0.010)	(0.009)
Fish species:	Sole	-0.023***	-0.034***	-0.028***	-0.023***	-0.023***
(ref: Monkfish)		(0.005)	(0.005)	(0.005)	(0.006)	(0.006)
	Langoustine	0.042*	0.079***	0.075***	0.065***	0.078***
		(0.022)	(0.023)	(0.023)	(0.024)	(0.024)
	Sea bass	-0.013***	-0.022***	-0.017***	-0.011*	-0.011*
		(0.005)	(0.005)	(0.005)	(0.006)	(0.006)
	Hake	0.131***	0.123**	0.118**	0.122**	0.120**
		(0.049)	(0.048)	(0.048)	(0.050)	(0.049)
	John Dory	-0.007	-0.008	-0.006	-0.005	-0.005
		(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
	Squid	0.069***	0.056***	0.061***	0.065***	0.066***
		(0.006)	(0.006)	(0.006)	(0.007)	(0.007)
Distance in kilometers (log)			0.037***	0.008***	0.009***	0.008***
			(0.003)	(0.002)	(0.002)	(0.002)
Coast effect				0.102***	0.102***	0.089***
				(0.012)	(0.012)	(0.008)
Normalized squared difference in local share					0.010*	-0.001
					(0.006)	(0.002)
Normalized squared difference in local share						0.069***
x Coast effect						(0.025)
Number of observations		3,552	3,552	3,552	3,552	3,552
R^2		0.139	0.198	0.254	0.256	0.271

Source: RIC 2007, authors' calculations.

Note: Specifications are estimated by weighted least squares. The weight for an observation involving fish markets c and c' is given by $\min(N_c, N_{c'})$, where N_c and $N_{c'}$ are the numbers of transactions occurring in fish markets c and c', respectively. Standard errors are computed by bootstrap using 100 replications and are reported in parentheses, significance levels being, respectively: 1% (***), 5% (**) and 10% (*). The fish market fixed effects are based on estimates reported in table A3 in the supplementary appendix online.

Table 6. Estimates of the Squared Price Difference $(\Delta\psi_{cc',s})^2$ between Fish Markets, by Fish Species

Variables	Monkfish	Sole	Langous-tine	Sea bass	Hake	John Dory	Squid
Constant	-0.011	-0.003	-0.092***	-0.009	0.109***	-0.013	-0.012
	(0.010)	(0.013)	(0.022)	(0.012)	(0.035)	(0.025)	(0.011)
Distance in kilometers (log)	0.004*	0.004	0.039***	0.005*	-0.008*	0.009	0.012**
	(0.002)	(0.003)	(0.008)	(0.003)	(0.005)	(0.006)	(0.002)
Coast effect	0.128***	0.004	0.501***	0.053***	0.306***	0.020	0.178***
	(0.007)	(0.005)	(0.035)	(0.007)	(0.012)	(0.014)	(0.013)
Number of observations	528	666	136	666	465	496	595
R^2	0.450	0.035	0.467	0.223	0.233	0.061	0.341

Source: RIC 2007, authors' calculations.

Note: Specifications are estimated by weighted least squares. The weight for an observation involving fish markets c and c' is given by $\min(N_c, N_{c'})$, where N_c and $N_{c'}$ are the numbers of transactions occurring in fish markets c and c', respectively. Standard errors are computed by bootstrap using 100 replications and are reported in parentheses, significance levels being, respectively: 1% (***), 5% (**) and 10% (*). The fish market fixed effects are based on estimates reported in table A3 in the supplementary appendix online.

Table 7. Composition of Well-Interconnected Groups of Fish Markets, by Species

Group (by decreasing size)		Monkfish	Sole	Langoustine	Sea bass	Hake	John Dory	Squid
Group 1:	Nb of fish markets	21	25	10	25	20	20	22
	List of fish markets	AC - AD - CC - CH - CR - EQ - GL - GR - GV - IO - LC - LN - LO - LS - NO - RO - SG - SJ - SQ - TB - YE	AC - AD - BL - CC - CH - CR - DP - EQ - FP - GL - GR - GV - IO - LC - LN - LO - LS - NO - RO - RY - SG - SJ - SQ - TB - YE	CC - CR - EQ - GV - LC - LN - LO - LS - SG - TB	AC - AD - BL - CC - CH - CR - DP - EQ - FP - GL - GR - GV - IO - LC - LN - LO - LS - NO - RO - RY - SG - SJ - SQ - TB - YE	AC - CC - CH - CR - EQ - GL - GV - IO - LC - LN - LO - LS - NO - RO - RY - SG - SJ - SQ - TB - YE	AC - AD - BL - CC - CH - CR - EQ - GR - GV - IO - LC - LN - LO - LS - RO - SG - SJ - SQ - TB - YE	AC - BL - CC - CH - CR - DP - EQ - GL - GR - GV - IO - LC - LN - LO - LS - NO - RO - RY - SG - SJ - SQ - TB
Group 2:	Nb of fish markets	2	4	1	5	6	3	3
	List of fish markets	AG* - ST*	AG* - PN* - PB* - ST*	IO	AG* - PN* - PB* - PV* - ST*	34* - AG* - PN* - PB* - PV* - ST*	AG* - PN* - PB*	AG* - PN* - PB*
Group 3:	Nb of fish markets	2	1	1	1	1	1	1
	List of fish markets	PN* - PB*	PV*	RY	GO*	GO*	GO*	GO*
Group 4:	Nb of fish markets	1	1	1		1	1	1
	List of fish markets	GO*	GO*	AG*		AD	PV*	ST*
Group 5:	Nb of fish markets	1		1			1	1
	List of fish markets	PV*		ST*			ST*	PV*
Group 6:	Nb of fish markets	1		1			1	1
	List of fish markets	RY		SJ			DP	FP

Group 7: Nb of fish markets	1						
List of fish markets	DP						
Number of fish markets	29	31	15	31	28	27	29
Number of groups	7	4	6	3	4	6	6

Source: RIC 2007, authors' calculations.

Note: List of fish markets, by location. * indicates locations on the Mediterranean coast.

Atlantic. AC : Arcachon - AD : Audierne - BL : Boulogne - CC: Concarneau - CH: Cherbourg - CR : Le Croisic - DP : Dieppe - EQ : Erquy - FP : Fécamp - GL : Saint-Gilles Croix-de-Vie - GR: Granville - GV : Le Guilvinec - IO : Oléron - LC : Loctudy - LN : Lesconil - LO : Lorient - LS : Les Sables d'Olonne - NO : Noirmoutier - RO : Roscoff - RY : Royan - SG : Saint Guénolé - SJ : Saint-Jean de Luz - SQ : Saint Quay Portrieux - TB : La Turballe - YE : Ile d'Yeu.

Mediterranean. 34 : Copemart - AG : Agde - GO : Le Grau du Roi - PB : Port de Bouc - PN : Port La Nouvelle - PV : Port Vendres - ST : Sète.

Table 8. Variance of Local Market Fixed Effects, by Species and Specification

Specification	Monkfish	Sole	Langoustine	Sea bass	Hake	John Dory	Squid
Model A. All transactions - specification: mobility of sellers only							
Control variables: fish characteristics + month FE + seller FE (with mobility of sellers) + account FE + local market FE							
Number of transactions	144,436	245,987	91,888	182,885	196,950	54,113	93,529
Variance of local market FE	0.0159	0.0097	0.0304	0.0149	0.1151	0.0131	0.0506
% in total variance	13.8%	5.9%	16.5%	7.6%	41.0%	8.0%	26.9%
$\sigma(P)/\mathrm{m}(P)$	0.1915	0.1571	0.1798	0.1841	0.3592	0.1791	0.2155
$\sigma(\text{Local market FE})/\mathrm{m}(P)$	0.0712	0.0383	0.0731	0.0508	0.2298	0.0508	0.1118
Number of local markets	33	37	17	37	31	32	35
Standard deviation of bilateral price differences	0.2888	0.1555	0.4818	0.2168	0.3672	0.2486	0.3461
Model B. Transactions from all matched buyers - specification: mobility of sellers only							
Control variables: fish characteristics + month FE + seller FE (with mobility of sellers) + account FE + local market FE							
Number of transactions	125,831	198,564	87,819	150,356	178,938	44,019	76,470
Variance of local market FE	0.0150	0.0082	0.0143	0.0157	0.1325	0.0121	0.0522
% in total variance	13.8%	5.2%	7.8%	7.8%	47.0%	7.8%	27.1%
$\sigma(P)/\mathrm{m}(P)$	0.1871	0.1537	0.1802	0.1865	0.3586	0.1719	0.2173
$\sigma(\text{Local market FE})/\mathrm{m}(P)$	0.0694	0.0351	0.0503	0.0521	0.2457	0.0479	0.1131
Number of local markets	29	31	15	31	28	27	29
Number of groups of well-interconnected local markets	7	4	6	3	4	6	6
Standard deviation of bilateral price differences	0.2085	0.1459	0.4548	0.2099	0.4121	0.2492	0.3427

Model C. Transactions from matched buyer, restriction to the most important group of local markets - specification: mobility of sellers only							
Control variables: fish characteristics + month FE + seller FE (with mobility of sellers) + account FE + local market FE							
Number of transactions	110,642	165,340	73,922	117,614	121,809	39,631	60,999
Variance of local market FE	0.0021	0.0080	0.0083	0.0064	0.0176	0.0104	0.0149
% in total variance	2.1%	6.2%	4.7%	3.6%	5.0%	7.4%	11.1%
$\sigma(P)/\mathrm{m}(P)$	0.1843	0.1408	0.1747	0.1789	0.4206	0.1638	0.1910
$\sigma(\text{Local market FE})/\mathrm{m}(P)$	0.0266	0.0350	0.0380	0.0339	0.0944	0.0446	0.0637
Number of local markets	21	25	10	25	20	20	22
Number of groups of well-interconnected local markets	1	1	1	1	1	1	1
Standard deviation of bilateral price differences	0.0857	0.1439	0.3029	0.1192	0.2521	0.2719	0.1859
Model D. Transactions from matched buyers, restriction to the most important group of local markets - specification: mobility of buyers and sellers							
Control variables: fish characteristics + month FE + seller FE (with mobility of sellers) + buyer FE (with mobility of buyers) + local market FE							
Number of transactions	110,642	165,340	73,922	117,614	121,809	39,631	60,999
Variance of local market FE	0.0019	0.0109	0.0078	0.0044	0.0197	0.0127	0.0167
% in total variance	1.9%	8.5%	4.5%	2.4%	5.6%	9.1%	12.5%
$\sigma(P)/\mathrm{m}(P)$	0.1843	0.1408	0.1747	0.1789	0.4206	0.1638	0.1910
$\sigma(\text{Local market FE})/\mathrm{m}(P)$	0.0252	0.0409	0.0370	0.0279	0.0996	0.0494	0.0676
Number of local markets	21	25	10	25	20	20	22
Number of groups of well-interconnected local markets	1	1	1	1	1	1	1
Standard deviation of bilateral price differences	0.0780	0.1779	0.3228	0.1054	0.2415	0.2935	0.2135

Source: RIC 2007, authors' calculations.

Note: P is the logarithm of transaction unit price, $m(P)$ is its average and $\sigma(P)$ is its standard error. FE stands for fixed effect. $\sigma(\text{Local market FE})$ is the standard error of local market fixed effects weighting fish markets by the number of transactions. The variance of local market FE is computed using the number of transactions as weight.