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ITALIAN CONSUMPTION OF WILD AND FARMED FISH: DEMAND AND ELASTICITY ESTIMATION

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Abstract

In this paper, we present an analysis of farmed and wild fish in Italy using microdata. Instead of estimating a traditional parametric model such as AIDS, we employ Artificial Neural Networks (ANNs) and evaluate elasticities using a method specific to the non-parametric framework. As input variables, we consider not only the traditional economic factors but also some socio-demographic ones.

Introduction

As in many industrialized countries, fish consumption in Italy has greatly increased in the last few years, both in terms of quantity and household expenditure. This is mainly due to the developments in the food habits in the last decades. In the European Union, average per capita consumption is rather high: around 26.3 kg (equivalent world figure 16 kg). According to Ismea (2005), data for single countries, Portugal exhibits the highest consumption level (over 59 kg), followed by Spain (47.5 kg) and France (31.3 kg). In Italy, average fish consumption has been relatively stable around 22 kg since 1995. After a marked decrease in 2002, domestic fish consumption has increased since 2004. In aggregate, Italian domestic purchase of fish is over 416,000 tonnes, the expenditure is over 3,662 million Euro (Ismea, 2005). The percentage of domestic consumption out of the total is around one third.

Nowadays, aquaculture is one the main sources of fish products. Indeed, catch fishing activity is considered to cause marine biodiversity to change, with losses from both the ecological and economic points of view. In Italy, aquaculture has developed strongly in the last few years. The position of the country is such that all common farming techniques (intensive, extensive, mariculture) can be realized in different environments (fresh and salt water) with over ten species commonly farmed for human food, including freshwater fish (trout, carp, catfish, sturgeon), saltwater fish (bass, mullet, gilthead), and shellfish (mussels,

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clams). As far as these species are concerned, the weight of the farmed product now exceeds that of the wild fished product, which is becoming less relevant in the market.

The aim of this study is to analyse Italian fish consumption, distinguishing between wild and farmed fish, including the above species. This is carried out using the Artificial Neural Network (ANN), in particular to estimate the demand curve and its elasticities. Among the input variables, some socio-demographic factors are included, since it seems that, together with the traditional economic variables (price and income) also some non-economic factors such as the demographic structure, can affect consumers' choices.

Data Description

General Description of the Data

The data set consists of observations of domestic fresh fish consumption for a sample of 6288 households, representative of the entire national population, and coming from the Osservatorio ACNielsen survey of Italian household expenditures in the year 2004. The survey does not consider so-called "away from home expenditure" (hotels, restaurants and coffees). The data set is constructed by monitoring the expenditures realized through the big distribution, cash-and-carry outlets, and traditional commerce. A very useful characteristic of this data set is that it is enriched also by much detail and information about the product.

Data are available in specific data sets for four Italian regions: North-West (Piemonte, Valle d'Aosta, Lombardia and Liguria), North-East (Veneto, Friuli, Trentino ed Emilia), Centre (Toscana, Umbria, Marche, Lazio e Sardegna), South (Abruzzo, Campania, Calabria, Basilicata, Molise, Puglia e Sicilia). Some demographic information is also available, particularly about the reference person of the household, for example his/her education level and social position (employed, unemployed, retired etc.). Some of this demographic information for the sample is shown in Tables 1-3.

Table 1: Gender of the Sample Reference Persons

Gender	Frequency	Percentage
Male	5443	86,6%
Female	845	13,4%

Source: ACNielsen

Table 2: Geographic Breakdown of Sample

Geographic Area	Frequency	Percentage
North-West	1757	27,9%
North-East	1135	18,1%
Centre	1054	16,8%
South	1509	24%
Island	833	13,2%

Source: ACNielsen

Table 3: Household Income Levels per capita

Income per capita per month	Frequency	Percentage
Less than 260 €	546	8,6%
from 260 to 420 €	1364	21,7%
from 420 to 620 €	1786	28,5%
over 620 €	2592	41,2%

Source: ACNielsen

In Figure 1, domestic purchases (by volume) of fish are shown for the year 2004. As can be seen, fresh fish is the main component of total consumption.
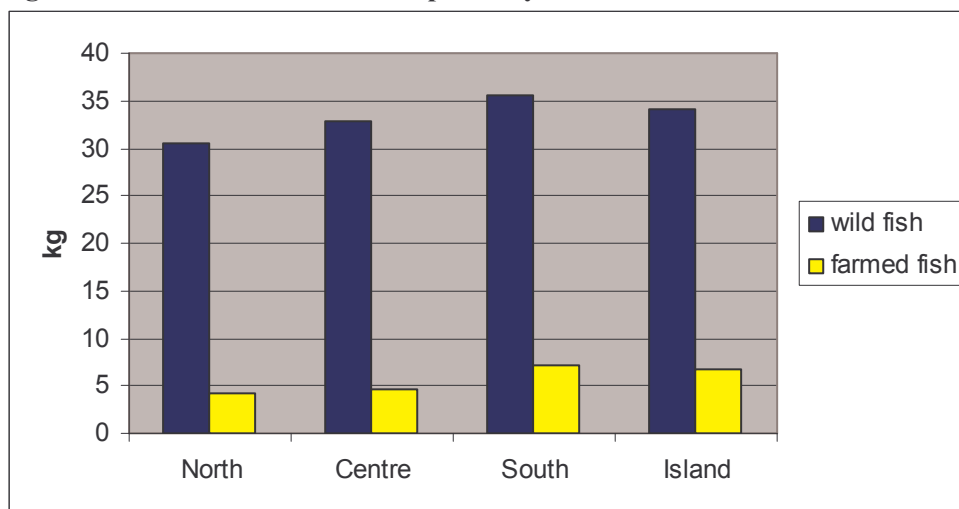
Figure 1: Italian Domestic Fish Purchases (by volume, 2004)

Source: derived by authors from ACNielsen.

Fish Consumption and Demographic Variables

Figure 2 shows that in general the consumption of fish is higher in the South and Islands than in the North. Indeed, the amount of total fish consumed in the South is 39.42 (kg per household), whereas in the North it is 32.51 kg. This is evident both for wild and farmed fish, although for the latter the territorial discrepancy is much higher. The amount of farmed fish consumed in the South is 7.11 kg per household, in the North it is 4.24 kg, in the Islands it is 6.82 kg, and in the Centre it is ?? kg.
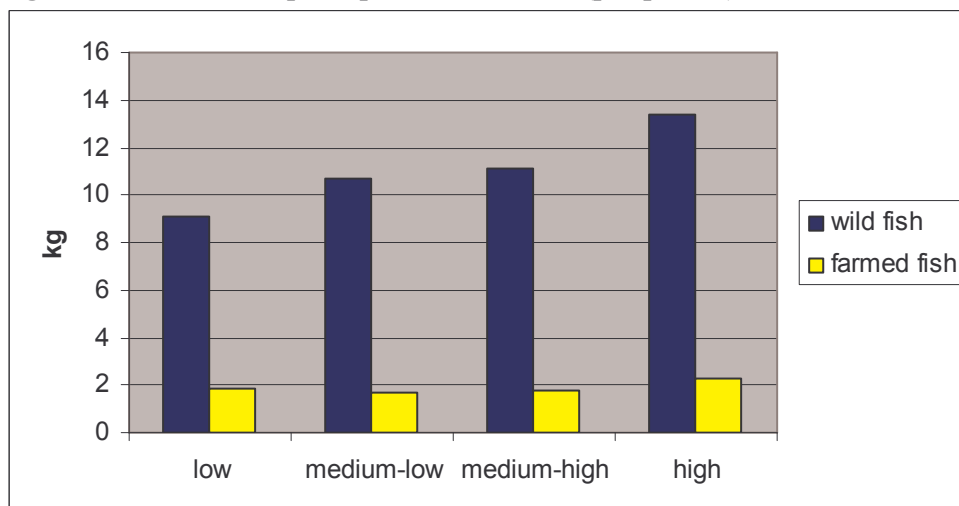
Figure 2: Household Fish Consumption, by Territorial Area

Source: derived by authors from ACNielsen.

Figures 3 to 6 show consumption per person, using an equivalence scale: children under 14 years old are attributed a weight of 0.5[3]. In Figure 3, the consumption of fish is represented per income class, where the classes are identified as follows: income less than 260 €; between 260 and 420 €; between 460 and 620 €; over 620 €. We can see that the average consumption increases with the income level. This is particularly evident for wild fish, where comparing the consumption of the low income class to that of the high income class there is an increases of around 44%, whereas for the farmed fish the analogous increase is around 23%.

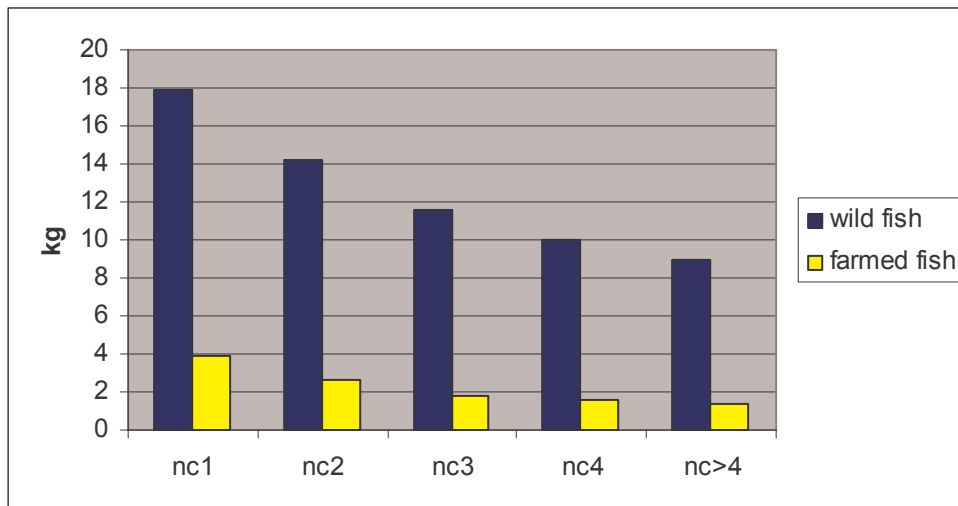**Figure 3: Fish Consumption per Income Class (per person)**

Source: derived by authors from ACNielsen.

In Figure 4, where *nc* indicates the number of components in the household, we can see how the consumption per person decreases with the increased household size both for farmed

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[3] The weight 0.5 for children has been chosen following an approach proposed by Carbonaro (1985).

and wild fish. The consumption in case of nc1 (only one person in the household) is around 18 (kg per person) whereas in case of nc>4 (more than 4 people in the household) it is around 9 (kg per person).
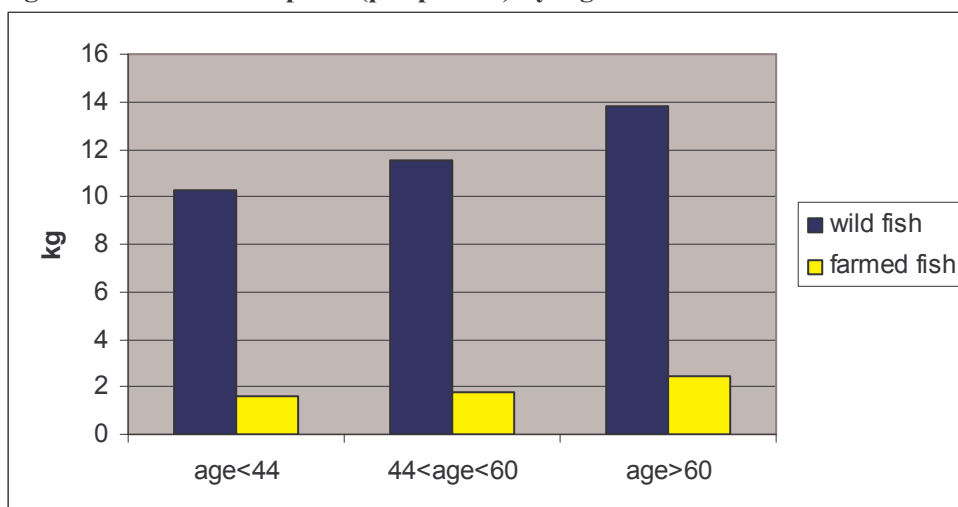
Figure 4: Fish Consumption (per person) by Household Size
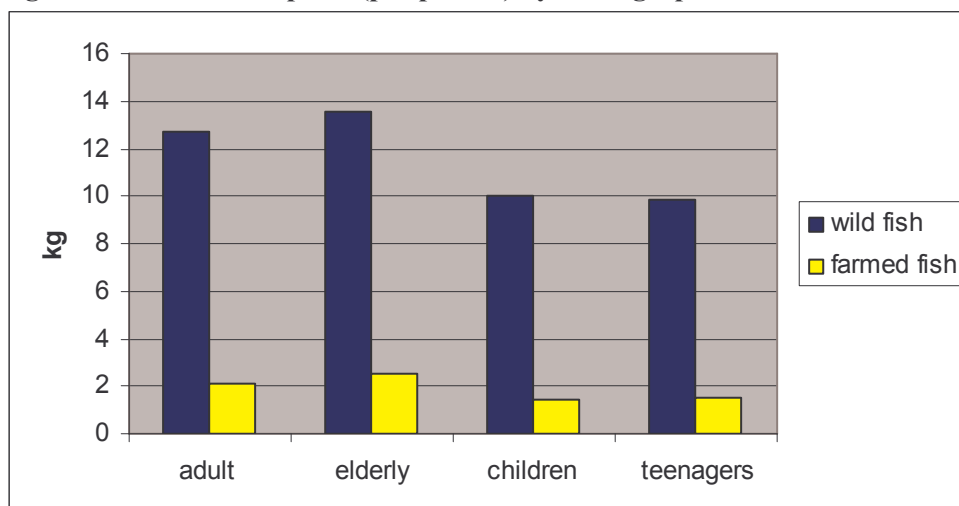

Source: derived by authors from ACNielsen.

In Figure 5, fish consumption per age class of the household head is presented. In figure 6 fish consumption according to different demographic profiles has been analysed. In particular, we consider four demographic profiles: families with adults only (*adult*), with at least one old person (*elderly*), with at least one child, i.e. less than 14 years old (*children*) and with at least one teenager, i.e. up to 20 years old (*teenager*). From Figures 5 and 6, we can observe how the consumption of fish tends to increase with the age of the household head and also we note that in those families with at least one old person the amount of fish consumed is more than in those where there are children or teenagers.

Figure 5: Fish Consumption (per person) by Age Class of Household Head

Source: derived by authors from ACNielsen.

Figure 6: Fish Consumption (per person) by Demographic Profile of the Household
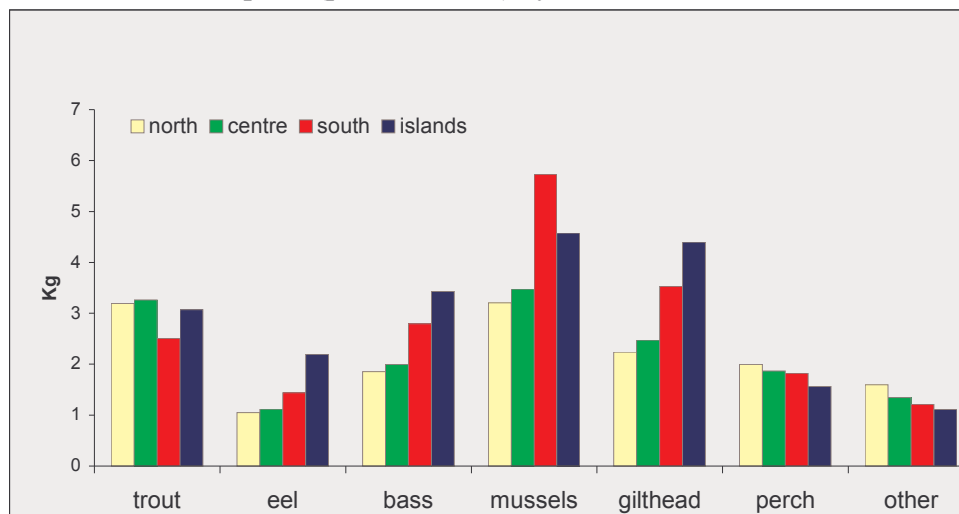

Source: derived by authors from ACNielsen.

Figures 2-6 all show that the difference between the consumption of farmed and wild fish is still very marked. Italian people seem to exhibit strong preference towards wild fish rather than farmed fish. However, this result must be interpreted very carefully since not all the wild fish types are also available from aquaculture. This means that sometimes the consumer who is interested in a particular variety of fish has no other option but the wild fish sector. Therefore the result that appear in these graphs are not always due to a real preference, but often to a lack of alternative. Moreover, it has to be observed that in the farmed fish category we included only those types of fish that are mainly farmed.

In Figures 7-10, the average fish consumption inside the aggregate farmed fish is analyzed according to different demographic variables. To build these graphs, a subsample of 3201 families was considered, i.e. only those that have a non-zero consumption of farmed fish. Figure 7 presents the average farmed fish consumption per territorial repartition. Mussels seem to be the most consumed, though with different proportions depending on the geographic area, followed by gilthead and trout. The trout, in particular, is more consumed in the North probably because it is in general more easily available (there are more aquaculture structures for trout) and also for cultural reasons.
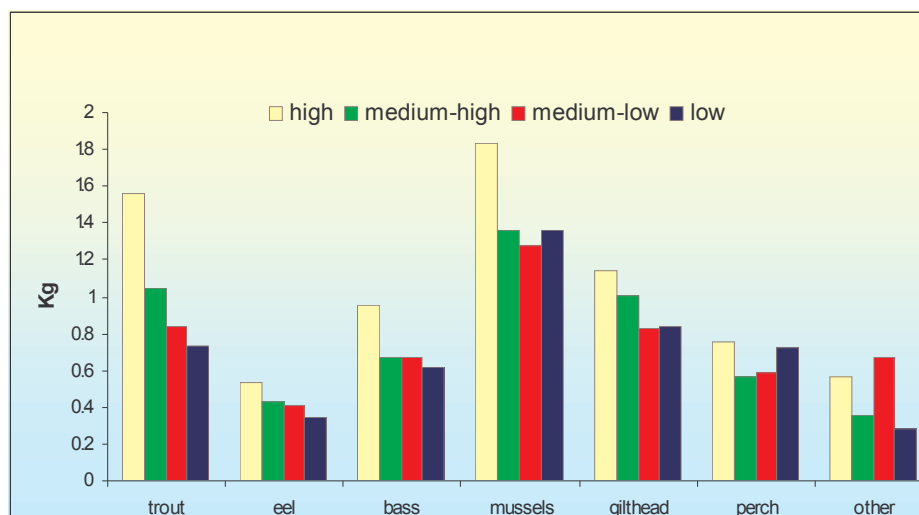
Figure 7: Farmed Fish Consumption (per household) by Territorial Area

Source: derived by authors from ACNielsen.

In Figure 8, the consumption of farmed fish according to the income level is presented. Mussels, gilthead and trout are the most consumed. It is possible to recognize, in general, a common pattern over all kinds of fish. Indeed, for most fish typologies the consumption tends to increase with the increase of the income class. Perch is an exception, probably because of its affordable price.

Figure 8: Farmed Fish Consumption (per person) by Income Level

Source: derived by authors from ACNielsen.

In Figure 9, we can see how the consumption tends to decrease with the household size. From Figure 10, similarly to what was shown in Figures 5 and 6, it is clear that families with mainly adults and old people tend to have a higher consumption per person than families with children. In Figures 9and 10, it is also confirmed once more that mussels, gilthead and trout are the most consumed typologies of fish.
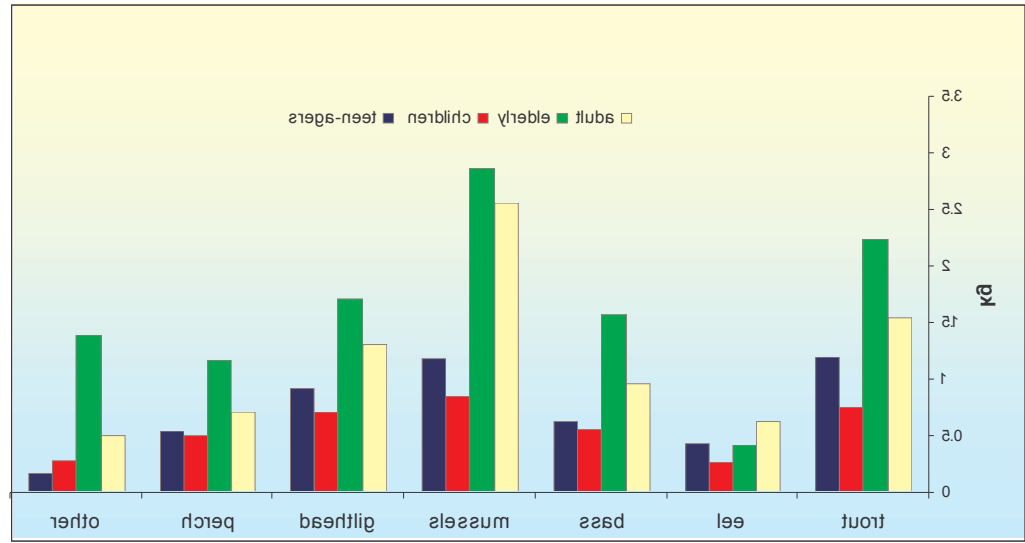
Figure 9: Farmed Fish Consumption (per person) by Household Size

Source: derived by authors from ACNielsen.

Figure 10: Farmed Fish Consumption (per person) by Household Type

Source: derived by authors from ACNielsen.

Methods

A very simple neural network (Azoff, 1994, Giordano and La Rocca, 2002) consists of four elements: a set of inputs (independent variables), a weight vector, a processing element/step and an output (dependent variable). The processing element (referred to in the neural network literature as a "node") generate the output by weighting, summing and transforming the input variables. If a linear transformation function is used, this simple neural network model is identical to the familiar regression model. Usually, a tractable transformation function with the proper shape and bounds, as well as desirable analytical properties is the logistic function.

The major limitation of this simple network configuration is that the number of different input/output patterns that can be accurately modeled is severely limited. Moreover, the relationships between the inputs and the outputs is limited to smooth monotonic functions. To accommodate more complex relationships between inputs and outputs a more sophisticated network is needed.

By adding an intermediate layer of processing elements to the simple input-output model above, a 3-layer (input, intermediate or hidden, output) structure can model a large number of complicated input-output patterns. Usually, the input variable and intermediate nodes are fully connected, that is every input variable is weighted and combined (summed and transformed) by every output node. While clearly violating the modeling principal of parsimony in model building, neural networks trade off elegance for the ability to model complex phenomena. The weight vectors can be estimated in a variety of ways. The most common method to estimate these weights, is a learning algorithm called "back-propagation", which is, essentially a two-phase, gradient, descent optimization algorithm and the goal is to minimize the sum of squared errors:

$$E = \sum_{k} (\mathbf{Q}_k - \hat{\mathbf{Q}}_k)^2 \qquad (1)$$

where $\mathbf{Q}_k$ is the actual output and $\hat{\mathbf{Q}}_k$ is the estimated by the network. The objective of the estimation process is to iteratively adjust the weight vectors in order to minimize E. And if the
training is successful, one finds that E, given in (1), reduces.

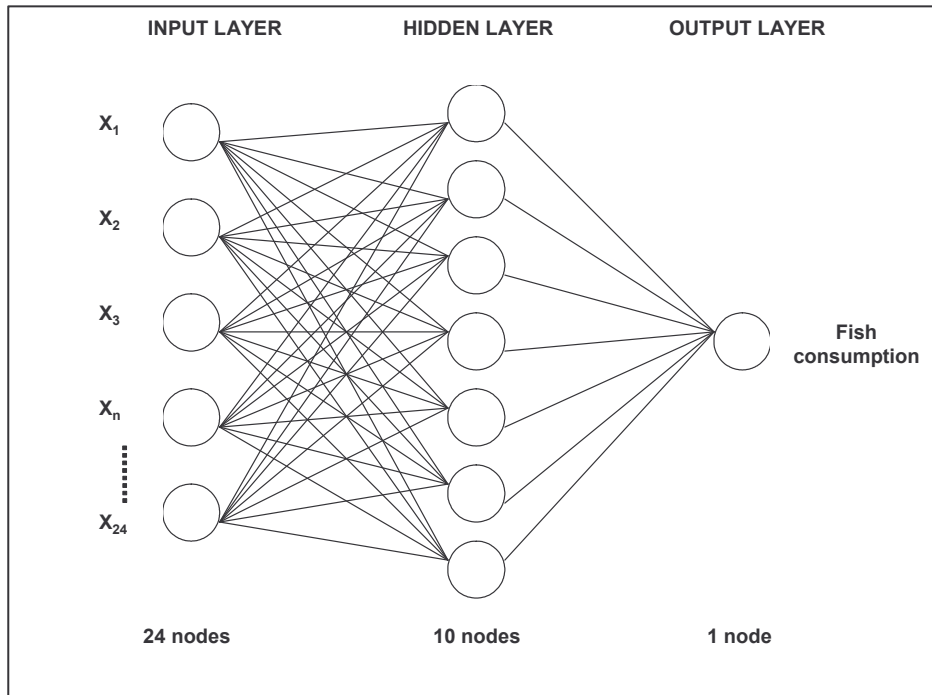**Figure 11: Architecture of Artificial Neural Network (ANN)**

Table 4: Input variables

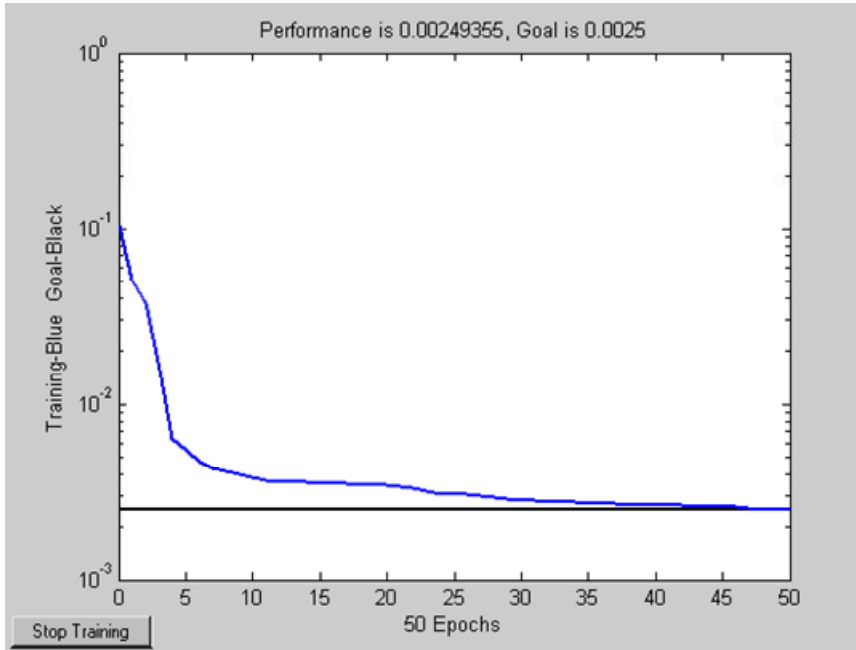| Name of the input variable	Description
Gender	Female and Male
Household Age	Up to 44 years old; from 45 to 60 years old; over 60 years old.
Education level	High (graduation); medium (high school diploma); low (elementary school diploma, no diploma)
Geographic area	North West; North East; Centre; South; Islands
Social position	employed; unemployed; other
Economic status	Income less than 260 €; between 260 and 420 €; between 460 and 620 €; over 620 €
Prices	Price of fish
Income	Total fish expenditure

In the training stage, only a part of the data set is presented to the network and the holdback sample (that is the part that has not been used for training) is afterwards to check the performance of the neural network in reproducing the output. This validation part is necessary to be able to use the neural network model with any degree of confidence.

In this work we employed a feed-forward ANN. The information only goes from the input to the output and there is no connection between the layers. The architecture of our ANN, which consists of 24 input layers, 10 hidden layers and 1 output layer is represented in Figure 11.

In the following table, the input variables of our ANN are reported. As we can see, together with the traditional economic variables (price and income) we have also some demographic variables.

A main characteristic of an ANN is that it is trained to produce the output. In the training phase a part of the sample is presented to the network. In our case the network receives 5200 pairs of input and output as examples, without being explained how the output is obtained from the input. The holdback sample (in our case 1000 examples) is then used to check the performance of the ANN in the validation phase. In the following graphs, the performance of our ANN is represented. As we can see in Figure 12, after 50 iterations (epochs) the error in formula (1) has been minimized.

Figure 12: Artificial Neural Network Performance

The usual summary measure of the effects of price and income (input) changes on quantity (output) is some form of elasticity. There are two forms of price elasticity to consider. The first is the self-elasticity which measures the effects of a variation of the price of the good i on the quantity of the same good. The second is the cross-elasticity which measures the effects of a variation of the price of the good i on the quantity of the good j.

The traditional methods for determining income and price elasticity involve estimating econometric models. The relationship between prices (income) and quantity is characterized by interactions, non linearity and asymmetric cross-effects, so it has been developed i) models which have very desirable properties to model also those characteristics as the Rotterdam, LES and AIDS models (Deaton and Muellbauer, 1980a, parametric approach) and ii) alternative techniques as ANN which are well suited to modelling complex relationships such as those found in wine market data.

As mentioned in the introduction, in this work we followed the ANN non-parametric approach, and decided to compute the elasticity with a method based on observing the change in the individual choice probability for a change in the relevant system variable (Subba Rao et al., 1998). The following steps were carried out:

1. run the calibrated neural network for the training sample by increasing the price (income) by different percentages;
2. consider the normalized output w_{ij} as equivalent to choice probability;
3. let w_{ij}^{*} be the output normalized for price j after P% change in the price of the good j;
4. use the following formula to compute a series of individual choice elasticity by increasing the price between 1% to 100%:

$$I\varepsilon_{i,j,k} = \frac{w_{ijk} - w_{ijk}^{*}}{w_{ijk}} \bigg/ \frac{P}{100} \qquad (2)$$

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where j is the input generic variable, i is the generic hidden layer and k is the output;

5. calculate the probability-weighted average of these individual elasticity and obtain the aggregate demand elasticity.

This method is very powerful. Firstly, it allows the construction of the reaction of the consumers to different price variations for every household in the sample by computing the individual elasticity. Secondly, it makes possible to obtain the sample average demand curve by computing the weighted average of the individual elasticity for every increase of the price.
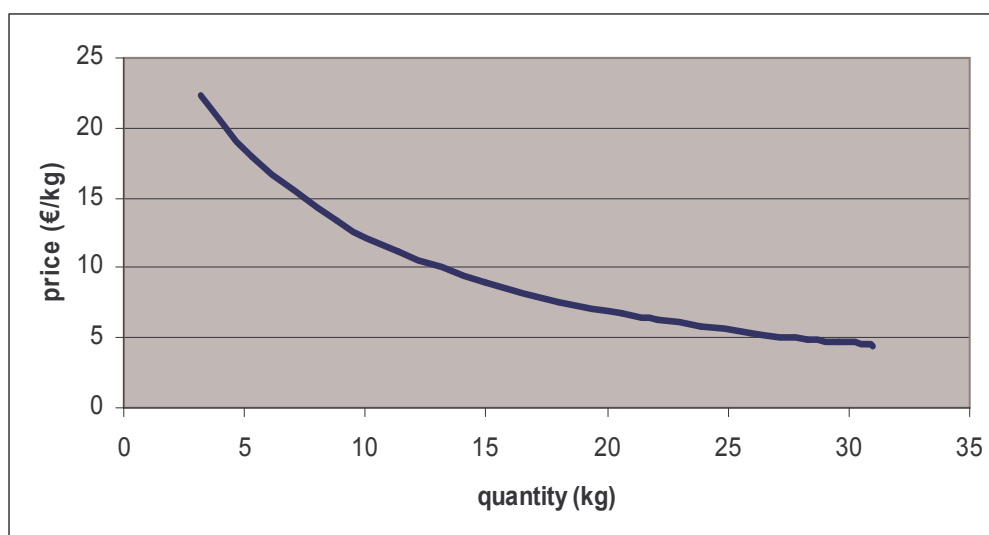
Results

Estimating the Demand Curve

The demand curve is obtained by augmenting the price of increasing percentages and estimating correspondingly the output (keeping constant the other input variables). So the individual demand curve of the families is obtained. The demand curves in Figures 13 and 14 are obtained by averaging the individual demand curves.
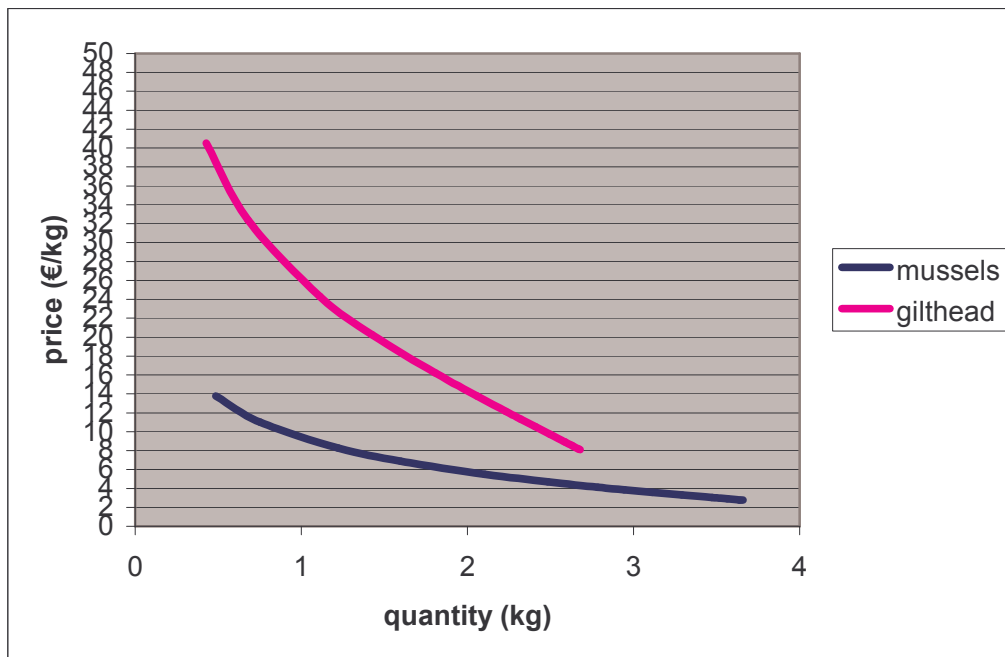
In general, the demand curve gives information about how the consumer reacts to price variations. Following this approach, the demand curve can determined for families with a specific demographic profile. Therefore it is possible to study the reactions of the consumer focusing on specific demographic groups, what can be called a sort of demographic group-oriented demand curve analysis.

Figure 13: Estimated Demand Curve for Wild Fish

In Figure 14, it is interesting that gilthead appears to have a much more rigid demand curve than mussels, which means that the consumers are less sensitive to variations in the price of gilthead than of mussels.

Figure 14: Estimated Demand Curve for Farmed Fish (Mussel And Gilthead)

The elasticity is then computed using the Subba-Rao approach. For every household, the output is estimated by increasing the price with different percentages and then the individual elasticity is determined using formula (2). The elasticity is finally calculated as average (weighted or not) of the individual elasticities.

Table 5: Income Elasticity Estimates

	Non-weighted Elasticity	Weighted Elasticity
Wild Fish	1.098	0.6417
Farmed Fish: Gilthead	0.381944	0.3681
Farmed Fish: Mussels	0.672222	0.35

Table 6: Price Elasticity Estimates

	Non weighted self-elasticity	Weighted own elasticity	Non-weighted cross-elasticity	Weighted cross elasticity
Wild Fish	-1.05	-0.96	0.003	-0.005
Farmed Fish: Gilthead	-0.55	-0.33	0.021	-0.027
Farmed Fish: Mussels	-1.05	-0.51	0.08	0.049

As a preliminary comment, we observe that a numerical difference between weighted and non-weighted elasticity is expected, since to our knowledge there is no way to compute the confidence intervals for these estimates. Wild fish exhibits an elasticity close to one, and therefore it is almost a luxury product with a very elastic demand curve. Gilthead and mussels have a smaller elasticity, especially gilthead. As far as the price elasticity are

concerned, again wild fish has higher elasticity. The consumer reacts to price variations of wild fish much more than in case of price variations of farmed fish. Cross-elasticities are very close to zero; this is difficult to interpret. In fact, the category wild fish (so heterogeneous compared to the other two categories) might not be the right substitute product.

Conclusions and Future Developments

In this paper, we have analysed the Italian demand for fresh fish with a particular interest in a comparison between farmed and wild fish. We estimated the demand curve and its elasticities using the Artificial Neural Network, that is a non-parametric, approach. As input variables we considered not only the traditional economic factors but also some socio-demographic ones.

The main result is that the consumption of farmed fish is definitely lower than that of wild fish. Many reasons can explain this phenomenon. Firstly, wild fish is generally perceived by the consumer as tasting better and being also more nutritious and healthier. Then, most fish varieties in Italy cannot be farmed, and therefore very often the farmed fish category does not encounter all the consumer preferences as the wild fish does. We also show that there are differences in the consumption due to some socio-demographic variables, mainly territorial area and income class, but also the demographic profile of the household. Among our future research lines there is the study of demand for specific demographic groups since we have seen that by using the ANN approach this is definitely possible.

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