UNIVERSIDAD NACIONAL DE COLOMBIA
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Productive development model of the fisheries chain Spanish

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Received: March 10th, 2016. Received in revised form: July 19th, 2017. Accepted: September 30th, 2017

Abstract
This article provides a productive development model, based on an analysis of the productive chain of Spanish fishing sector in general. It is constructed from the behavior diagnostic of each of the chain links and the different organizations of the Science and Technology. The model determines theoretically, optimal quantities, prices and economic benefits, using game theory, the Nash equilibrium and Pareto optimality, following the criteria of the Cournot and Bertrand models for products poorly differentiated and with similar business sizes. The results show that each fishing production unit has to capture, process and sell on average 280 kilograms per day, in order to maximize economic efficiency.

Keywords: Productive development model; Nash equilibrium; Pareto optimality.

Modelo de desarrollo productivo de la cadena pesquera española

Resumen

El artículo, presenta un modelo de desarrollo productivo basado en un análisis de la cadena productiva del sector pesquero español. Está construido gracias a un diagnóstico del comportamiento de cada eslabón de la cadena de diferentes organizaciones de ciencia y tecnología. El modelo determina teóricamente cantidades óptimas, precios y beneficios económicos usando la teoría de juegos, el equilibrio de Nash y el óptimo de Pareto, siguiendo criterios de los modelos de Cournot y Bertrand para productos poco diferenciados y con tamaños de mercado similares. Los resultados obtenidos muestran que cada unidad de producción pesquera tienen que capturar, procesar y vender en promedio 280 kilogramos por día, con el fin de maximizar su eficiencia económica.

Palabras clave: Modelo de desarrollo productivo; equilibrio de Nash; optimización de Pareto.

1. Behavior of the Spanish fishing sector

The demand for fish products and their derivatives in the Spanish market has been favored among other things by concerns about food safety of its society, by the progressive return to work of women, generating higher household incomes, the growing importance of spending on food away from home, as well as its significance of spending on food and beverage purchases.

The Spanish fleet is composed of some 13.000 boats with a capacity of average catch of about 785.000 tons of fish, 470.000 tons of fresh product and frozen averaging 315.000 tons, see Fig. 1. The average price paid per kilogram of product is € 2.2; the price of fresh products is on average 20% higher than frozen.

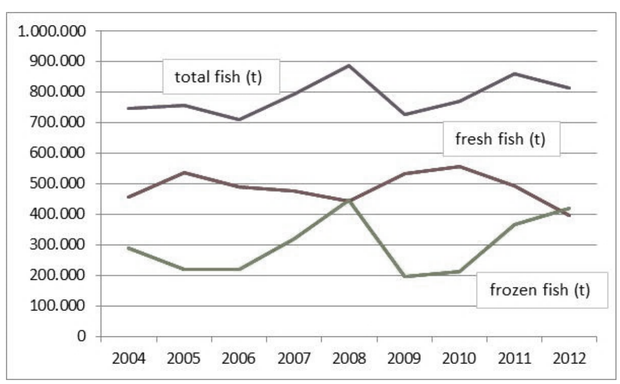

Figure 1. Behavior of fish catching in Spain.
Source: Adapted based presented information on PTEPA [6].

How to cite: Luna, C., Nieto, W., Mercado, H. and Pajares, J., Productive development model of the fisheries chain spanish DYNA, 84(203), pp. 220-225, December, 2017.

DOI: http://dx.doi.org/10.15446/dyna.v84n203.56139

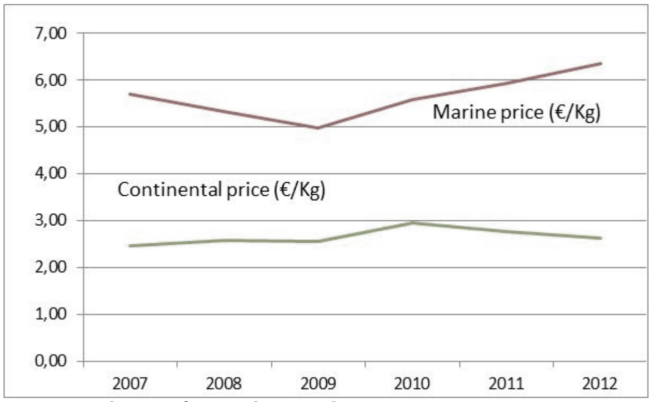

Figure 2. Behavior of aquaculture product prices in Spain.
Source: Data based on PTEPA platform [6].

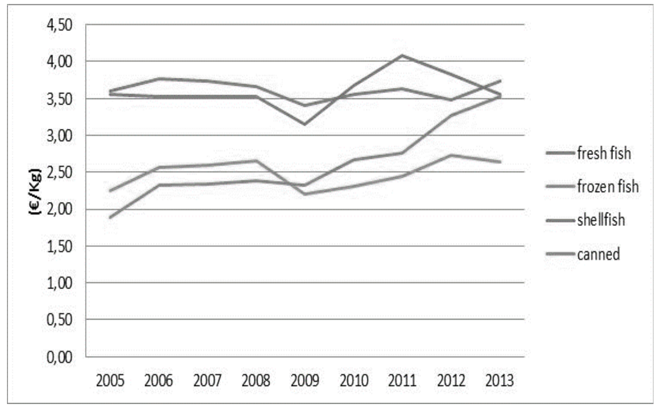

Figure 3. Behavior of imported fish products prices in Spain
Source: Data based on PTEPA platform [6].

Aquaculture has been presenting an important role in the development of the fisheries sector, its contribution of 267.000 tons of fresh product on average in recent years is considered significant, with values between 20% and 30% below capture prices, Fig. 2 shows the behavior. It is an important alternative for those processors, requiring a constant supply of product with low variability in the prices of raw materials.

Spain imports averaged 1’600.000 tons per year, of which 240.000 are of fresh product, 550.000 tons are frozen products, 570.000 tons of shellfish and 240.000 of canned products. On average, the pay is € 3 per kilogram of imported product, but in the case of fresh product, the price is 50% higher than the price of fresh product caught, see Fig. 3. In Total, in the Spanish market enters 2’652.000 tons of product, including fresh, frozen, shellfish and canned product. Of which are exported on average 983.000 tons, 106.000 tons of fresh, 517.000 tons of frozen, 196.000 tons of shellfish and 164.000 tons of canned.

In general the price of exported products is 10% below import prices, marked mainly by the price of frozen products, 30% lower than the imported ones. Not so, with the price of exported Spanish canned product, with a value 35% higher than that paid for imports, see Fig. 4.

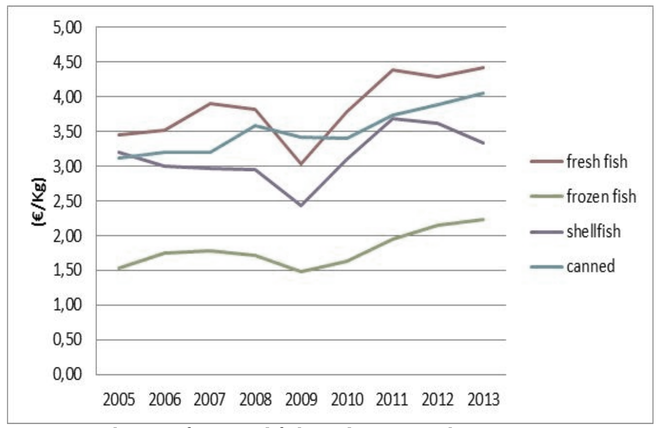

Figure 4. Behavior of exported fish products prices by Spain
Source: Data based on PTEPA platform [6].

If, to the total of fish product entering the Spanish market, we subtract exports, then we have a total of 1’669.000 tons on average to be consumed by Spanish people. But as shown in the consumption records from the Ministry of Agriculture Food and Environment of the Government of Spain, they are consumed on average 1’242.000 tons of fisheries products per year, representing a balance of 427.000 tons found on the shelves in supermarkets, shops, production companies and trading companies as product inventory. Of the 1’242.000 tons of fish products consumed on average per year in Spain, 564.000 tons are fresh products, 141.000 tons of frozen fish products, 357.000 tons of shellfish and 180.000 tons of canned. Table 1 shows the behavior of the fishing chain in Spain.

Table 1.
Behavior of the productive chain of fishing in Spain.

	Quantity T	Price €/Kg
Catch	785 000	2.2
Aquaculture	267 000	1.6
Import	1’600 000	3.0
Total Income	2’652 000	
Export	983 000	2.6
Spanish market	1’669 000	
Annual consumption	1’242 000	7.0
Annual Inventory	427 000	

Source: Data based on PTEPA Platform [6].

2. Analysis and results of the Spanish fishing sector

The methodology used for the analysis of the Spanish fishing industry is based on executing the following steps: first, the function of demand for fish products in recent years is established in terms of quantity consumed (thousands of tons) and unit prices (€ per kilogram), is considered the behavior of demand as a normal statistical distribution with a mean “μ” and standard deviation “σ”. Second, it is established theoretically, the optimality to produce quantities using game theory and calculating the Nash equilibrium, following the criteria of Cournot and Bertrand models, as well as prices and profits for companies that compete in an oligopolistic market and a poorly differentiated product, with similar sizes. For the calculation of marginal cost, whose indicator value will be lower in the years of this study; the indicator with which you work is the balance point, or minimum production where the company covers its fixed costs

Table 2.
Real demand for fishery products.

Year	Quantity (000 t)	Price (€/Kg)
2004	1.199	6,29
2005	1.219	6,50
2006	1.237	6,92
2007	1.254	7,11
2008	1.250	7,14
2009	1.262	7,43
2010	1.254	6,98
2011	1.230	7,32
2012	1.215	7,29
2013	1.219	7,45

Source: Data based on PTEPA Platform [6].

amount. Third, the production volume and product price is established, taking into account the results obtained in the previous step.

Table 2, presents the actual demand for fish products in Spain, in the last 10 years in terms of volume (thousand tons) and prices (€ per kilogram). It is considered that the behavior of the demand distribution is normal with a mean μ= 1’242.000 tons and σ = 39.000 tons deviation.

If we also consider that product demand is deterministic, that is, that customers know in advance the price of the products, then customers would demand greater amount of product, to the extent that the price is lower. The same way, we can see this situation like an assignment problem and linear programming. The problem of weighted matching in a bipartite graph, otherwise known as the assignment problem, is defined as follows.

An assignment problem consists of:

- A set N of n agents,
- A set X of n objects,
- A set $M \subseteq N \times X$, of possible assignment pairs, and
- A function $v: M \rightarrow R$ giving the value of each assignment pair.

Therefore, an assignment is a set of pair $S \subseteq$ M such that each agent $i \in N$, and each object $j \in X$ is in, at most in one pair in S. A feasible assignment is when all agents are assigned an object and is optimal if it maximizes:

$$\sum_{(i,j)\in S} v(i,j) \qquad (1)$$

Under these conditions, the demand function is represented in Fig. 5.

The regression line representing the demand function D (p) is given by:

$$D(p) = 22{,}952 - 0{,}0128(Q) \qquad (2)$$

The value of a = 22,952 and b = 0,0128

According to the above, the maximum value would demand the Spanish market 1’293.000 tons of fishery products (μ + 3 σ) at a price of € 6,65 per kilogram. By contrast, the minimum value of tons would demand the Spanish market is 1’175.000 tons of fishery products (μ - 3 σ) at a price of 7,58 euros per kilogram.

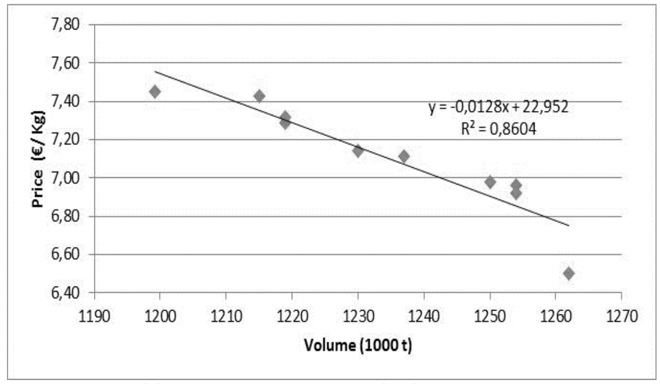

Figure 5. Plot of function adjusted demand for fish products.
Source: The authors.

To work in a practical way, “using” the concept of Nash equilibrium, it is performed a comparative analysis of the results obtained in the game theory, under the criteria of Cournot and Bertrand is performed. It is only considered the theory of non-cooperative, emphasizing payments, information and the simultaneity of the games. It is assumed that there is a rational decision of players, where their decisions maximize expected utility.

Game theory, describes a set of strategic interactions that include restrictions on the actions of the players, who act as companies competing in a market with poorly differentiated products. Each player proposes a solution within a set of solutions that tends to maximize their profits; game theory suggests reasonable solutions for kinds of games and examines their properties.

Game theory defined as a "bag of analytical tools" designed to help understand the phenomena we observe when market decisions interact. The basic assumption is that the theory assumes that market decisions remain well defined objectives; they are rational and take into account the knowledge and expectation of other decisions according to market performance and strategic rationality [2]. The term of rationality defined as the manner in which the player conducts its elections, i.e. chooses and makes decisions based on reason [3].

With certainty, we have a set of actions

$$A=\{a_1, a_2, a_3, \ldots a_k\} \text{ (3),}$$

a set of results produced by action

$$X=\{x_1, x_2, x_3, \ldots x_k\} \text{ (4)}$$

and a function x: $A \rightarrow X$ which states that every action has a single result. An optimal response is defined as a strategy that provides better results than all other possible strategies against a given opponent's strategy:

$$U_{j1(Si,sj)} \geq U_{j1(S,sj)} \text{ .(5)}$$

Nash equilibrium is defined as a combination of strategies in which each strategy is optimal for another answer. Since the players have no reason to change strategy, this combination of strategies are said to be in balance:

$$U_{j1(Si,sj)\geq}U_{j1(S,sj)} \quad (6)$$

And

$$U_{j2(Si,sj)\geq}U_{j2(Si,S)} \quad (7).$$

Assuming that game theory offers a unique solution to a problem, this, a solution of Nash equilibrium if each player is willing to choose this prediction, which must be the best answer for each player of the alternatives of other players [4]. To set how close the entrepreneurs are from the Spanish fishing sector to Nash equilibrium, we calculate using the Cournot and Bertrand models´ criteria.

2.1. Cournot model for the Spanish fisheries sector

In the Cournot model, the strategies available to each company are the different amounts that they can produce [5]. If a number of companies competing in the market for a homogeneous product, they decide simultaneously the amount of production to bring to market, and the price is the same for all, with equal marginal costs for all "c", regardless of costs fixed, the quantity total produced in Nash equilibrium is given by the equation:

$$Q*(i) = n\left(\frac{(a-c)}{(n+1)b}\right) \quad (8)$$

For the calculation of the total quantity to produce in the optimal Nash equilibrium, the production chain is taken as an integrated business unit, consisting of n = 13.000 units, or companies engaged in fishery, with values a = 22,952 and b = 0,0128, given in the demand function.

The only value that is required to be determined is the marginal cost or "c", which corresponds to the marginal cost of the year which point of balance is the smallest of all the years studied in the capture process, see Table 3.

So, for 2004, where the balance point below was obtained in all the years of this study, the value of the marginal cost is c = 2,377 €/kg.

Table 4, shows that the Cournot model proposes capturing 1’608.000 t of fish, corresponding to the Nash equilibrium value for the 13.000 business units or ships. The selling price “P” is 2, 38 €/kg for a total profit “U” of three million euros.

Table 3.
Balance point in the process of fish capture.

Year	Quantity “Q” (t)	Cost “c” (€/Kg)
2004*	693.552	2,377
2005	1’004.671	2,084
2006	723.969	2,195
2007	958.668	2,060
2008	913.745	2,107
2009	842.683	2,560
2010	718.253	2,371
2011	834.126	2,284
2012	720.400	2,195

Source: Data Based on PTEPA Platform [6].

Table 4.
The Cournot Model of fish capture.

Parameter	Value	Units
n	13.000	
a	22,952	
b	0,0128	
c	2,377	€/Kg
Q*	1’608.000	t
P*	2,38	€/Kg
Income	3.813 mill	€
Expenses	3.810 mill	€
U	3’000.000	€

Source: The authors.

Table 5.
The Bertrand Model for fish capture.

Parameter	Value	Units
n	13.000	
a	22,952	
b	0,0128	
c	2,377	€/Kg
Q*	1’608.000	t
P*	2,377	€/Kg
Income	3.811 mill	€
Expenses	3.811 mill	€
U	0	€

Source: The authors.

2.2. Bertrand model for the Spanish fisheries sector

Firms compete in prices, manufacturing and selling all the quantities that consumers demand at that price. Similarly to the Cournot oligopoly model, the Bertrand equilibrium is the Nash equilibrium of the game defined by Bertrand model. In the Bertrand oligopoly, the market is shared by "n" companies that want to maximize their profits “U”; U1, U2…Un, in that manufacture a homogeneous product and they compete on price. The demand function is given by q (p) for duopoly and is represented as follows:

$$\mathrm{q(pi\,,pj)} = \left\{\begin{matrix} 0 \text{ si pi} > \text{pj} \\ \text{q(pi) si pi} < \text{pj} \\ \frac{\text{q(pi)}}{2}\text{si pi} = \text{pj} \end{matrix}\right\} \quad (9)$$

The function determines the sale by the company whose price is lower, so is the same case to oligopoly, where cohabit "n" companies in a competitive market. Selling is done by companies whose prices are lower than the others to cover the demand.

For this model, the Nash equilibrium is a price (pi *, pj *... pn *) that maximizes the value of the other n-1 companies, therefore, the only Nash equilibrium is one in which all companies have decided to establish a price equal to its marginal cost, see Table 5.

Therefore, Bertrand model proposes that all companies would be Nash equilibrium when their selling prices are equal to marginal costs, this means that the perceived revenues are equal to expenditures and that none of the 13.000 business units earn a profit.

3. Pareto optimality for the Spanish fishing sector

If game companies are:

$$G = \{s_1, s_2, \ldots s_{13.000}\ ;\ u_1, u_2, \ldots u_{13.000},\} \quad (10),$$

where the profile of the companies is

$$S = \{s_1, s_2, \ldots s_{13.000}\} \quad (11),$$

is dominated from Pareto in the profile:

$$S' = \{s'_1, s'_2, \ldots s'_{13.000}\} \quad (12)$$

long as they present the following inequality:

$$Ui(s'_1, s'_2, \ldots s'_{13.000}) \geq Ui(s_1, s_2, \ldots s_{13.000}) \quad (13)$$

for each one business Ei.
It is then said that the strategy profile:

$$S = \{s_1, s_2, \ldots s_{13.000}\} \quad (14)$$

Pareto is optimal if and only if it is not dominated in Pareto by any other profile. We say then that is inefficient in the Pareto if someone else dominates. That is, if a profile is efficient, strategies cannot switch to any other profile, so no company will lose out, neither any company that comes out winning. The concept of domination refers to composite profiles that include the entire group of companies, while the concept of strategy dominated refers to each individual company. While the concept of Pareto efficiency refers to the social or group of companies, the dominant strategy is a concept of individual efficiency of each company.

In the case of companies engaged in the capture of fishery products, if there is a common knowledge through institutions such as the Spanish Technology Platform of Fisheries and Aquaculture PTEPA[6], the Statistical Services of Fisheries, Ministry of Agriculture, Food and Environment MAGRAMA[7], as well as technology centers and Ainia [8], Anfaco- Cecopesca[9], among others; then companies without setting agreements can design an efficient strategy profile that favors them, so that no company will lose out, or that a company does come out ahead, or (achieve) Pareto optimal.

If we want people in our organizations to share what they have learned, we would do well to create the conditions in which the exchange of results gives way to personal benefit. If I share my knowledge, that is, give it to someone else, then we'll both have a common knowledge that is known throughout the organization. Common knowledge, defined as the significant links that people make in their minds between information and its application to action in a specific environment. Linking knowledge to action is a useful way to differentiate information. [10]

4. Conclusions

The first conclusion is that for a great group of enterprises (n= 13.000) who compete in a sector like fisheries, with little differentiation of their products, the results of Cournot and Bertrand models are similar. This means that there are few possibilities to obtain financial gain.

Table 6.
The Pareto optimal for the Spanish fishing sector.

Quantity "Q" (1000 t)	Utility "U" (mill €/Kg)	Probability Normal	Utility Expected "UE" (mill €/Kg)
1.175	7,92	0,00135	9
1.234	7,16	0,50184	3.070
1.274	6,64	0,97892	5.543
1.275	6,63	0,98136	5.545
1.276*	6,62	0,98355	5.546*
1.277	6,61	0,98552	5.545
1.278	6,59	0,98728	5.544
1.293	6,65	0,99865	5.745

Source: The authors.

Given that in Spain 13.000 business organizations are engaged in capture fishery products, if they drive a common understanding of reliable market information, demand for which has a normal and without establishing agreements statistical behavior, they will capture a total of 1'276.000 tons for year to get the maximum benefit, estimated at 5.546 million euros.

According to results obtained by game theory, with Cournot and Bertrand models, and adopting the Pareto optimal solution, the Spanish fleet to catch fish products, each boat should take a daily average installed capacity of 273 kilograms, for maximum economic yield 426.627 euros per year, see Table 6. Enough to provide the average annual demand of product, without having to import products from abroad and with the possibility of exporting the difference to markets with higher profit margin capacity.

In this case, we studied only the catch link of the fished chain, because it is the weakest one, and therefore represents the capacity of the whole chain. The above analysis can be performed for each of the links in the chain of fisheries; the same methodology followed to determine the optimum amount of fish farming products, canning and companies engaged in marketing as well as prices and number of companies to ensure maximum economic efficiency.

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