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AN INTERPRETATIVE MODEL OF AQUACULTURE MULTIFUNCTIONALITY: A METHODOLOGICAL FRAMEWORK DEFINITION*

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Abstract

International trade agreements and the new EU CAP targets require the definition ofa new type of subsidy, depending on the non-market functions provided by production activities. The aim of the research project reported in this paper is to find a model to reward multifunctionality of aquaculture, defining all the positive externalities it involves and trying to calculate a monetary value for each of these.

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JEL classificatrion: P28, Q52, Q53, Q57, Q58

Introduction

The recent reform of the Common Agricultural Policy (CAP) has completely changed the way the EU supports farm sector. Most subsidies will be replaced by a new "single farm payment", independent of the volume of production. Farmers are free to produce what the market wants, but are required to keep all farmland in good agricultural and environmental condition ("cross-compliance") and to respect environment, food safety and animal welfare standards.
Moreover, since the 1994 Uruguay Round Agreement on Agriculture liberalized trade in agricultural products, WTO member countries have carried out a substantial progressive reduction in support and protection. Nowadays there is no possibility to continue directly subsidizing market products, and so

* This paper represents a previous attempt to describe a methodological framework for the definition of the interpretative model of aquaculture multifunctionality. The debate within the EAAE Seminar was useful in better defining some variables in the analysis, and for this reason we are grateful to all participants at the Seminar, and in particular to Prof. L. Venzi, G. Antonelli and P. Pulina for their useful advice.

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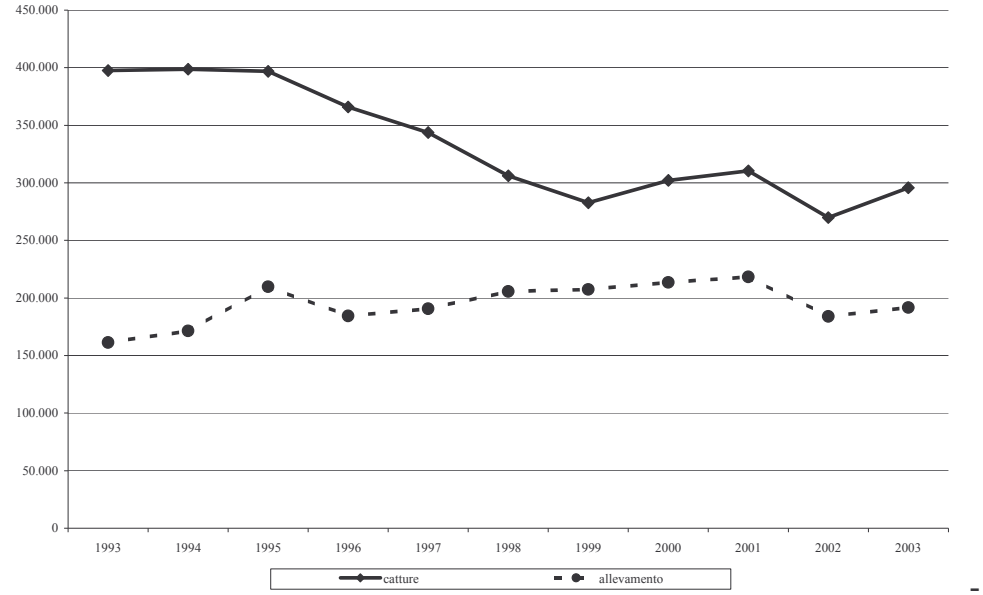
it is necessary to find a new way, not in conflict with international agreement, to supporting farmers financially.
Amongst WTO members, there is a need to give financial aids to fishery sectors, and particularly those that concern land improvement, such as aquaculture. The promotion of sustainable fisheries can achieve both stable, safe and efficient supply of food to people, and a better development of marketing in commercial fisheries.
It is possible to establish a type of subsidy which provides income stability to farmers and avoids the neglect of production, decoupled from the level of production but strictly linked to the farming activities. It is necessary to detect all the non-market goods that production activities involve, and to define the amount that the community will pay for each of them. Many secondary functions which agriculture performs may be referred to the multifunctionality concept because, while producing commodities, it simultaneously produces many by-products provided at different levels, such as welfare-enhancing amenities, that, most often, are considered only in a positive way. Among these, we can mention: maintaining and preserving rural landscapes, biodiversity, wildlife habitats and traditional ways of country life, as well as rural development and new employment opportunities.

The importance of aquaculture

In recent years, demand for seafood has grown, because of changes in consumer preferences, improvement of product quality, better distribution, and increased acknowledgement of health benefits associated with fish consumption. Figure 1 shows trend over the last decade in fish production in Italy, divided into captured and reared fishes.

Figure 1: Trend in fish production in Italy (MT)



Source: Ismea

Until 1999, the two types of productions had different trends; capture decreased by about 30%, whilst rearing increased by the same amount. In recent years, we can observe production that in 2003 reached 295 and 192 thousand tonnes respectively.

The European Commission recently published its proposal for a new European Fund for Fishery (EFF) that will substitute the current Financial Instrument for Fishery Guidance (FIFG) covering the period 2000-2006. The new fund will provide aid to the European fishery industry for the period 2007-2013, with the aim of encouraging the sustainable management and protection of natural resources. In brief, the most important targets will be:

- reducing fishing effort and promoting the adoption of environmentally respectful techniques; ending aids for the renewal of the fleet and encouraging fleet adjustment by aids for the permanent removal of vessels and socio-economic compensation (including professional training for new work, early retirement)
- promoting aquaculture; investment for organic aquaculture and for the development and the application of rearing methods able to reduce the negative impacts of aquaculture on environment and to improve product quality and animal welfare.
- promoting the sustainable development, both in economic aspects (income stability) and in social ones (female work opportunities), of coastal zones characterized by less alternative job opportunities and more damaged by stock depletion.

Aquaculture externalities

Even if it is clear that aquaculture fish rearing activity should be promoted, in order to emphasize its positive effects mentioned above, it may sometimes also have some negative effects on environment. For example: air pollution due to energy consumption; loss of biodiversity caused by the accidental release of non-native species; development of antibiotic-resistant bacteria because of residuals of chemicals used to control fish disease; increase of predators and scavenging birds; water pollution due to uneaten feed and residuals of fish catabolism. In addition, the food supplies for other aquatic organisms can be depleted through the capture of schooling fishes used to produce fishmeal for aquaculture.
We can try to catalogue all possible externalities according to the categories of impact:

- environment: greenhouse effect, air pollution and eutrophication
- natural stock depletion
- alternative/new work opportunities
- human health.

For each of these, it is necessary to evaluate a subsidy that society should pay to aquaculture farmers or, on the contrary, which farmers must refund to the community.
The aim of this analysis is to calculate these payments, in order to answer the question: "how much collectively should be paid for the "other" functions which aquaculture farmers carry on, that's to say, for aquaculture multifunctionality?". The multifunctional subsidy (Sm) may be considered as:

$$\mathbf{Sm = \mu ea + \mu gea + \mu apa + \mu nsda + \mu woa + \mu hha}$$

where each μ will be a payment for different externalities :

- μea = eutrophication
- μgea = greenhouse effect
- μapa = air pollution
- μnsda = natural stock depletion
- μwoa = working opportunities
- μhha = human health

Below are some attempts at evaluating each monetary value.

Eutrophication

Aquaculture activities have a significant effect on the quality of ambient waters. The most important contaminants in waste water, from both on-shore and off-shore farms, are phosphorus and nitrogen originating from uneaten feeds and from fish excretions. Significant dangerous effects linked to eutrophication are: noxious algae blooms, excessive aquatic plant growth, and water oxygen depletion. A proxy for monetary value of damage caused by this

kind of pollution is assumed to be the purification cost paid by water consumers in the region; for example in Apulia region this is about 0.32€/mc.
Thus it is possible to define the monetary value for eutrophication starting from the farm's water consumption for each production cycle and using:

$$\mu ea = WV * Pc$$

where

- WV=Water volume utilized (mc)
- Pc= purification cost (€/mc)

Greenhouse effect

Energy needs in aquaculture activity are strictly linked to rearing methods: on-shore farms need a substantial amount of energy to pump water in fish ponds and to condition the environment, and generally this kind of intensive farms utilize electricity. In extensive farms, the management of off-shore cages takes up less energy, depending on boats utilized, but, above all, because they use diesel fuel. In each case, aquaculture activities give rise to gas emissions, primarily CO_2, but also nitrogen dioxide NO_x and CH_4, that increase the greenhouse effects whose damages, as is well known, are associated with changes in climate conditions.
To evaluate the external cost of the greenhouse effect due to energy use in aquaculture rearing methods it is necessary:

- to calculate the power consumption of aquaculture farms
- to calculate the amount of CO_2 arising from 1 kWh
- to assess a monetary value for the damage caused .

Thus, the "greenhouse effect" externality damage may be calculated as:

$$\mu Age = Ea * F * MVge$$

where

- μAge = aquaculture "greenhouse effect" externality damage (€/qCO_2)
- Ea = aquaculture energetic consumption (kWh)
- F = factor to calculate emission of CO_2 due to energy source (g/kWh)
- MVge = unit monetary value for damages linked to greenhouse effect (€/tmCO_2)

Energetic consumption levels in aquaculture are easy to be find because they are linked to the equipment used, but there are some problems with their relative emissions. As said before, CO_2 production depends on the two kinds of power sources used in aquaculture, i.e. electricity and oil. In particular, we referred:

- for electricity, to what the Italian electricity company (ENEL) calculates as the amount of CO_2 produced by 1 kwh: about 489g CO_2;
- for oil, to what ExternE (EU project 1997) estimated to be the emissions for one kWh, that is about 800g CO_2.

In the EU project ExternE, there was also an appraisal of which impact categories were involved in CO_2 emission: human health, agriculture, increased sea levels, water availability, biodiversity, and meteorological events, and an unit monetary cost for harm of 73.43€/mt of CO_2 produced was proposed.

Air pollution

As we said above, CO_2 is only one of the gases emitting during power consumption. Thus we have to consider other contaminants, amongst which the main ones are: sulphur dioxide SO_2, responsible fpracid rain and acidification of waters, deriving from the roasting of sulphur-containing mineral ores or from other industrial processes; nitrogen oxides NO_X; carbon monoxide CO; hydrocarbons COV from vehicle exhausts; and microscopic particles (PM 10) formed from most reactions involving combustion.
Starting from the energy consumptions of farms, we need to evaluate:

- the amount of emissions for each contaminant
- the monetary value of damage linked to each contaminant.

For this determination we also referred to two EU Commission projects:

1. CORINE - Air – Coordination of Information on Environment
2. ExternE – Extenalities of Energy

The CORINE - AIR project calculated the emissions of most important air contaminants from different energy sources, so it is possible to evaluate the amounts of contaminants starting from energy consumption. The monetary values adopted are calculated in the ExternE project and are related to the established link between air pollution, morbidity and death rates.
In the following table are the amounts of emissions for the two kinds of source power and the related monetary damage values.

	f :air contaminant emissions (g/kWh)		**mv**: damage values
	Electricity	Diesel	(€/mt)
SO2	2,002	42,00	10.765
NOx	0,714	105,00	9.769
PM 10	0,079	4,20	10.754
CO	0,068	25,20	3
COV	0,014	16,80	1.039

The μ for air pollution will be:

$$\mu_{ap} = Ea(fSO_2 * mvSO_2 + fNO_x * mvNO_x + fPM_{10} * mv\ PM_{10} + fCO * mv\ CO + fCOV * mv\ COV)$$

New/alternative job opportunities

Crop production systems are characterized by an erratic labour requirement rate, due to the concentration of cultural operations, i.e. the harvesting or plantation; moreover, in our regions we promote a specialization of crop production that emphasizes this concentration of demand for workers, creating in some periods a big worker supply, with consequently social problems, although a government benefit is provided for unemployed time. Aquaculture may represent a possibility for taking up labour coming from the primary sector, because it does not need specialized workers, and, extensive farms especially have an homogeneous need for workers throughout the year. Thus will be created job opportunities for workers and monetary savings for society. Payment to aquaculture farmers for this positive externality may be calculated as:

$$\mu woa = (Pt - Bu) * hs$$

where:

- Pt = standard pay for a temporary employee
- Bu = standard unemployment benefit
- hs = temporary employee hours

Human health

It is well known that one of the most important positive effects of fish consumption on human health is related to the content of omega-3 fatty acids. Dietary fish intake has been associated with a reduced risk of fatal cardiac arrests, and in general to benefits on cardiovascular health; people who regularly eat fish have a significantly lower risk of heart disease and sudden cardiac death. The content of omega-3 is different according to fish species: higher in fatty fishes, lower in shellfish.
Many trials have shown a beneficial effect of fish intake corresponding to a daily consumption of 1g of omega-3 (on average, 2 fish meals in a week). In fact, men who were instructed to eat fish had a 29% decline in all-causes mortality linked to cardiovascular diseases, as compared with those in the placebo group. We can assess the benefit on human health as a monetary value making reference to the frequency of cardiovascular diseases in Italy (1.200.000 admissions to hospital) and to the corresponding public expenditure for treatments (855 million €). The monetary value for the positive effects on human health should be calculated as

$$\mu hh = Ap * C\Omega 3 * Pes$$

where
Ap= aquaculture production (Kg)
CΩ3=Ω3 contents of fish species (g/kg) (only edible part)
Pes= public expenditure saving €

Natural stock depletion

Although reared product does not have the organoleptic characteristics of wild fish, nutritional aspects make it a good substitute for the sea product. On the other hand, consumers often are not able to distinguish a sea product from a reared one. As just seen, the general increase in fishery product consumptions is related to a substantial rise in aquaculture production with respect to capture; so it seems that reared fish may represent a good alternative to the much more expensive sea products.
In this case, it should be possible to consider compensation as a monetary value because the reared product supply avoids part of the environmental impact of captures. In this case, the negative externalities of captures refer to: natural stock depletion, incidental taking of non-commercial species in drift nets, death of large marine animals linked to trawling operations, capture of juvenile fish who never have a chance to reproduce because of small net holes, destruction of natural habitat by bottom trawling or illegal destructive techniques (dynamite and cyanide fishing), and rock hammering.
The payment for fish farmer should be calculated as

$$\mu nsda = (Pccf - Pcrf) * Qrf * s$$

where:

- Pccf = production cost of captured fish (€)
- Pcrf = production cost of reared fish (€)
- Qrf = production of reared fish (kg)
- s = factor depending on species, risk, seasonality

Conclusions

To increase its spread, aquaculture activity needs a sturdy prop that is strongly related to all externalities it carries out. This subsidy would be linked to the economic values of these externalities, which are very difficult to quantify especially considering the different territories in which aquaculture is practised. This aspect is particularly interesting because it is in line with new CAP reform stances, in which the system of financial aids has a deeply regional approach. Thus it is necessary to apply the proposed method in different areas in which aquaculture may represent an opportunity (rural systems with lagging development; protection of decayed and undertreated natural systems) or a strengthening of its competitiveness with other sectors, in particular with capture fisheries. The next step of the research plan will be to test the proposed model in several different areas of Apulia Region characterized by these features.

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