Potential benefits of biotechnology in aquaculture : the case of growth hormones in French trout farming

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POTENTIAL BENEFITS OF BIOTECHNOLOGY IN AQUACULTURE :

The case of growth hormones in French trout farming

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SUMMARY

The development of aquaculture is of special interest in order to meet the demands for fish. The recent developments in animal biotechnologies are revealing interesting perspectives on productivity. At the farm level for trout aquaculture a significant positive effect can be demonstrated when growth recombinant hormone (rtGH) is used. An hormonal chronic treatment will lead to a substantial decrease in production costs.

The social benefits of the diffusion of rtGH are examined in an ex ante consumer-producer framework. Several scenarios based on credible hypotheses concerning supply and demand shifts are considered. Basic scenarios in which the adoption is adopted gradually must be considered socially advantageous. But this result is very sensitive to consumer reactions, and the social advantage largely decreases if there is a drop in demand. The most socially successful scenarios assume that the diffusion of the rtGH leads to a production diversification towards more highly processed products. Moreover the short term impacts of a consumer's boycott of rtGH are also considered. It will lead to a severe drop in total sales. So we may think that the adaption of rtGH would result in social benefits in the long term but the transient phase will be difficult.

The emergence of biotechnology in agriculture is taking place in an economic and political climate that is difficult to gauge. In Europe, there is great concern over the use of genetically engineered growth hormones in stock farming. The effects and risks are seen as regards to natural animal husbandry, preservation of traditional environmentally related farming, increases in output surpluses and consumer protection. The most controversial issue deals with the administration of bovine somatotropin to dairy cows. Fears have been expressed as to the risks these hormones may create for people, animals and the environment. But the debate has focused mainly on the social and economic impacts. Milk surpluses are largely due to intensification of milk production. Therefore small farms are not likely to benefit from the use of bovine somatotropin. This hormone is likely to accelerate the trend towards a higher concentration of the milk industry. As new biotechnology products are perfected, each process has to be considered on a case-by-case basis. In contrast to conventional stock farming, the farming of fish poses specific problems because the majority of total output comes from harvesting, not from breeding.

The first part of this paper is devoted to the economic and technical background of fish farming. There is a discussion of biotechnology and trout farming in France is used as an example. The second part examines the potential benefits of growth hormones. It provides an ex ante assessment of the gains in producer and consumer surplus made from the adoption of this biotechnological process. Several shifts in demand and supply are considered and benefits are derived in each case.

1. BACKGROUND

11. Economic aspects

As indicated in figure 1 during the fifties and sixties the ocean fishing industry grew rapidly with a threefold increase. This growth was due to a greater commercial exploitation of conventional species with more efficient fishing gears. The building of large fishing fleets capable of operating in distant waters allowed for considerable catches of unexploited resources. In the seventies, there was the depletion of the Peruvian anchovy stocks and total landings reached a plateau. The 3.8 % annual rate of the eighties indicates slight growth of the industry during this period.

Figure 1.

Today the ease of harvesting is tending to decline and total catches in marine fishing areas are unable to attain a level of much more than a level of 85 million metric tons. It is clear that, in the long term, worldwide catches are limited while, at the same time, an upward trend in demand exists, even in developed countries. In these countries food is now bearing the weight of demands for better nutrition and increased pleasure. This involves specific demands for "natural" foods. The recognition of the nutritional and medical advantages of a fish diet explains the increasing demand for fish. Taking this into consideration aquaculture is the only way to increase the production of fish protein..

In 1984, total output of aquaculture, which includes fish, mollusks, crustaceans and aquatic plants, was about 4.1 million tons and reached 6.6 million metric tons in 1988 [8]. In Western Europe, the aquaculture of salmonids (trout and salmon) is the main breeding process used whereas Central Europe produces more lake fish. Trout farming is predominant in the inland waters of EEC countries with a total of 144 000 metric tons of trout produced in 1989 [9]. This figure must be compared to the 40 000 metric tons of trout produced in the USA and the 36 000 metric tons produced in France, the leading European producer.

French consumption of fishery products is over twice that of fishery products harvested in France. The French harvesting figures is close to 0.9 million metric tons. Moreover, there is a growing trend in French consumption. During the eighties consumption per capita increased by 30 %. So the development of aquaculture is of a special interest in France in order to meet the demands for fish. The recent developments

in animal biotechnologies are revealing interesting perspectives on productivity since these techniques are capable of resulting in large improvements.

12. Fish and biotechnology.

Beyond the fact that fish aquaculture leads to greater exploitation of water resources, production of fish provides several benefits compared to other conventional livestock production : fish produce a large amount of gamets and, in salmonids, fertilization occursed outside of the body cavity thus leading to the possibility of technological manipulation of eggs. Moreover, as heterotherm vertebrate, fish do not need high energy expenditure for maintaining body temperature and thus have a better food conversion efficiency compared to other animals.

In France, development of fish aquaculture, mainly concerning rainbow trout (Oncorhynchus mykiss) imported from North America, appears well adapted for intensive farming. As indicated by figure 2, development of trout production in France was very rapid. Several successive improvements of technology explain this change. In the 1960s, use of dry pellets permitted artificial feeding; more recently, development of prophyllaxis and water oxygenation technology maintained a constantly increasing production. However, recent constraints associated with the use of water and impact of fish farming on water quality, led to a plateau in the French production of rainbow trout.

Figure 2.

Parallel to the development of fish production, special attention was paid to research with particular emphasis on projects dealing with nutrition, physiology of reproduction and genetics This research led to the development of new techniques such as controlling the spawning season by photoperiod manipulation, hormonal synchronization of spawning, production of steril triploid fish and obtention of monosex fish population. Thus, trout production is now shifting from a small family structure to industrial structure using high technology.

Several of the above techniques belong to biotechnology, defined as genetic engineering applied either to farm animal or to microorganisms producing recombinant peptides. This last technique, which can produce a large amount of proteins at a lower cost compared to chemical synthesis,has been used successfully to produce recombinant

Growth Hormone (GH) by several private companies. Use of this recombinant peptide in fish farming has benefited from much research devoted to endocrine control of growth in fish: these studies have emphasized the potential interest of fish GH, i.e. an hormonal factor which has very significant biological effects and a product with flexible uses.

13. Zootechnical effects.

The main biological effect of GH in fish is a stimulation of growth. However, recent studies in salmonids indicated that GH is also able to stimulate ability to adapt to seawater. This paper only concentrates on the growth effects of GH technology. Alternative positive effects of GH supplementation involve (i) a higher efficiency of food conversion thus leading to sparing of dietary protein (ii) reduction of pollution by decreasing nitrogen wastes and (iii) reduction of fat deposition in the flesh. Negative effects at the liver physiology level have also been reported. Analysis of the litterature on the growth response to GH treatment in rainbow trout and in coho salmon indicates that it is more efficient when applied to slow growing strains or when rearing conditions are unfavorable (low environmental temperature, for example). Moreover, use of fish recombinant hormone compared to other vertebrate GH leads the use of lower doses of hormones. Although these studies have been made using implants or repeated injections, the development of such technology in fish farming will require suitable methods for GH application, i.e. oral administration by diet. Digestive tracts in fish have been proven able to absorb macromolecules, thus oral administration of GH stimulates growth in rainbow trout. This method must now be improved by the use of additives which will protect the hormone from the digestive action of the stomach and stimulate intestinal absorption.

The impact of chronic rtGH supplementation taken from the study of a 1g trout until 1 month before sale in 6 different French conditions is representative of the European situation in different technical level situations. In general, it appears that the use of rtGH has negative or no effects on pan-size trout production when applied to farms having an elementary diagram of production. However, a significant positive effect can be demonstrated when rtGH is used in combination with other technologies (for example, oxygenation, controlled phoperiod). In the case of filet production, positive effects of rtGH can be observed in both elementary or high technical situations. Effects of rtGH are still positive although less important for production of large trout. Overall, it seems reasonable to consider the use of rtGH only when trout production is limited by the water

resources of the farm. Under such circumstances, hormonal chronic treatment associated with other technologies leads to a substantial increase in trout production in any given situation. This would necessitate important restructuration of the farm and significantly increase the risk associated with a permanent functioning of the farm at full capacity . Consequently, only farmers having a high technical ability will obtain benefits from the use of such hormonal supplementation.

2. ESTIMATING OF SOCIAL BENEFITS

Since the mid-1950s, numerous studies have examined the contribution of agricultural research to agricultural productivity. Most studies have been ex post, ie they have evaluated completed projects [13). The current study examines the potential benefits of rtGH in an ex ante framework and follows previous works [14] or [1]. Its results are conditioned by ex ante hypotheses concerning supply and demand shifts over time. So the results are credible as long as the hypotheses are credible from the start. This paragraph presents the following model, briefly describes parameters and data, and summarizes the empirical findings.

21. The model

To estimate the social benefits of rtGH diffusion, the Marshallian concepts of consumer and producer surpluses have been used. The basic analytical procedure used in the analyses is illustrated in figure 3 for the case where there is a shift only in the supply curve.

Figure 3.

The original supply curve using the traditional technology is denoted by S_0 and the demand curve by D in figure 3. The original price is P_0 and the quantity supplied and demanded is Q_0. The supply curve shifts to S_1 following adoption and diffusion of the rtGH, resulting in a new price and quantity of P_1 and Q_1.

Let us consider price elasticity of supply, denoted by E_S and price elasticity of demand, denoted by E_D. The supply shift dS is measured horizontally in the same manner as a production increases therefore dS equals A_0C.

As we are close to the initial state A_0 we can write :

$$E_D = \left(\frac{dQ}{dP}\right)_D \frac{P_0}{Q_0} < 0$$

$$E_S = \left(\frac{dQ}{dP}\right)_S \frac{P_0}{Q_0} > 0$$

$$\text{but } \left(\frac{dQ}{dP}\right)_d = -\frac{A_1B}{A_0B}\left(\frac{dP}{dQ}\right) = \frac{A_1B}{BC} \quad \text{and } A_0B+BC=DS$$

then

$$E_S - E_D = \frac{A_0B + BC}{A_1B}\frac{P_0}{Q_0} = \frac{dS}{P_1 - P_0}\frac{P_0}{Q_0}$$

Let us denote $P_1-P_0 = dP$

then

$$\frac{dP}{P} = -\frac{1}{E_S - E_D}\frac{dS}{Q} < 0$$

To estimate the relative change in quantity we move from A_0 to A_1 along curve D. It may be expressed as

$$\frac{dQ}{Q} = E_D \frac{dP}{P} > 0$$

Consequently, the supply shift with an unchanged demand implies a drop in price whereas the quantities increase. This means a higher consumer welfare expressed in figure 3 by the area $A_0P_0P_1A_1$. Concerning the producer surplus, the welfare change resulting from an increase in quantities of goods and a decrease of the price obtained by the producers, is equal to the difference between the triangles $A_1P_1M_1$ and $A_0P_0M_0$. This difference is not necessarily positive, but the social welfare, as indicated by the shaded area, is positive.

Several formulas have been developed to measure the areas in figure 3. Differences are caused by alternative specifications for the supply and demand curves (eg linear versus constant elasticity) the nature of the supply and demand shifts (eg privotal versus parallel). The various scenarios which are considered below are based on linear specifications and parallel shifts.

It is quite easy to consider simultaneously a shift in the supply curve and in the demand curve [12]. Then :

$$\frac{dP}{p} = -\frac{1}{E_S - E_D}\frac{dS - dD}{Q}$$

$$\frac{dQ}{Q} = \frac{dD}{Q} + E_D\frac{dP}{P}$$

A negative shift in the demand curve combined with a positive shift in the supply curve will induce a decrease in price. But the change of quantity can be positive or negative since the relative change of quantity is the addition of two terms with opposite signs. It is simple to geometrically show changes in producer and consumer surpluses. But in this general case where there is a shift in both demand and supply, there is no general result which permits identification of potential gainers and potential losers.

22. Parameters and data

The empirical estimation of the social benefits from rtGH diffusion requires the specification of the price elasticity of trout demand and supply E_D and E_S, the shift in the trout demand and supply curves dD and dS, and the value of trout price and output, P_O and Q_O.

No commodity model concerning the French trout industry has been estimated. In fact, such a model would be very difficult to estimate because of the poor quality of available data. Nevertheless, the lack of specific parameters can be mitigated since the question regarding the responsiveness of producers has been researched and is well documented in the literature making it possible to choose ad hoc parameters. This procedure is a reasonable one since the welfare measure is not too influenced by the magnitude of price elasticity. So errors of measurement on this parameter have weak

consequences on welfare change measures as we shall see. Using French data concerning substituable commodities like and chicken turkey and data gathered by Askari and Cummings [2], we assumed that short term price elasticity of trout supply is equal to 1.1. and that long term elasticity is 2.5.

In competitive equilibrium the supply function is equal to the marginal cost function. So the annual shift in the aggregate trout supply depends on the rate of adoption of the rtGH and on the reduction in costs that can be achieved at the farm level. A survey of French trout farmers has shown that only a minority have information on biotechnology in aquaculture. This point has been confirmed by interviews given in Germany, Scotland and Norway. So in the short run it is expected that the diffusion would be limited, but on the other hand it would concern only the largest farms. The general attitude in face of the rtGH is consistent with attitudes of French farmers about the use of bovine somatotropin [4]. Questioned on their options, a high proportion of a sample gives of farmers no verdict. But among the dairy farmers, over 60 % have a very negative opinion (only 8 % thought it was a desirable innovation). However, if bovine somatotropin is authorized, the percentage of livestock farmers envisaging using it is as large as the percentage of those refusing it. Moreover, the rate of adoption of bovine somatotropin is increasing with herd size as it is seen in California, [16] or in Canada, [15].

In order to estimate the reduction in costs at the farm level, a linear programming model has been used. Three activities were considered (filet, portion and large trout) and many simulations were run [3]. The utilization of the rtGH would increase the profitability of all farm types through a reduction in production cost and an increase in total sales. Moreover,farmers could maintain total profits with a significant decline in price. Finally, rtGH would achieve high relative benefits for cold water fish farms but other farms would maintain their absolute advantage in terms of average costs.

Combining all the above sources, it was possible to set up various assumptions concerning the vertical shift of the aggregate supply. Then, taking into account price elasticity, the horizontal shift can be derived. So a range from 10 % in the short run up to 50 % in the long run can be expected.

Using a time-series based on national accounts during the period 1949-1988 Combris [6] has estimated demand elasticities for 56 types of commodities. Trout is included in a group composed of meat, poultry and fish with a short-run elasticity ranging from - 0.60 to - 0.90 according to the functional form used. For oysters, which is a close

commodity Dumont [7] found an elasticity equal to - 1.0. For a luxury item such as the Atlantic salmon, the values are - 1.97 and - 1.83 for the United States and Europe, respectively [10].

For trout, we have considered two values - 0.80 and - 1.20 representing a minimum and maximum for the short term. For the long term elasticity we have taken - 1.80. Such a value is meaningful only in case of change in consummer's preference with a shift in favor of more sophisticated products (processed filet trout)..

The demand shift depends on consummer attitudes vis-à-vis trout containing rtGH and more generally towards biotech products. Except the bovine somatotropin issue there has been little work on public acceptance of agrobiotechnology. A consumer survey carried out in Germany, France, Italy and the United Kingdom shows that the consumers' reaction to milk and milk products from biotechnological process would imply a reduction in all four countries. The percentage of consumers saying they would boycott milk ranged between 17 % in Italy to 8 % in France [5]. A similar survey made in New York State indicated that milk consumption could decrease by 5.5 % to 15.6 % if bovine somatotropin was approved [11].

It is clear that food safety questions create a major blockage in the use of growth hormones in livestock production. More particularly, the French example of veal treated with anabolic agents is significant. Campaigns carried out by consumer associations in September 1980 against this fraudulent pratice sharply reduced veal consumption. The drop in consumption in the following weeks reached 40 %. However this drop occurred in the context of a downward trend due to the development of industrial veal farming in 1967 and due to the development of turkey consumption. To sum up, we have considered three basic cases (i) a small decrease in trout demand with an horizontal shift ranging from -5 % to - 10 % (ii) a dramatic drop in trout demand with a shift from -40 % to -80 % (iii) a small increase with a shift from 5 % to 10 %.

23. Social benefits according to various scenarios

Combining the different values of the parameters we have defined credible scenarios. They can be classified according to four categories.

(i) Basic scenarios in which the innovation is adopted gradually so the relative horizontal shift of trout supply equals 10 % in the short term and then 50 % in the long term. Short term price elasticity of trout supply is 1.1. and long term price elasticity is 2.5. On the demand side there is no shift and price elasticity varies between -0.8 and -1.2.

(ii) The most credible scenarios are variants of basic scenarios in which reductions in trout demand are taken into account. Two cases are considered. The first one assumes that there is a slight horizontal shift of trout demand equal to -5 % and nothing in the long term. The second one combines a short term decrease of -10 % and a long term decrease of -5 %. So the short term drop is followed by a gradual relative increase. However this increase is not large enought to offset the initial drop.

(iii) This category corresponds to the most optimistic expectations. The diffusion of the rtGH is very successful since it is accompanied by diversification towards filet trout and large trout which are more profitable. There is an increase in demand, the relative horizontal shift is 5 % in the short term and 10 % in the long term. Moreover trout demand becomes more elastic. In this case price elasticity is supposed to reach -1.8 which is the value observed for salmon demand.

(iv) These scenario rely on pessimistic assumptions. There is a more or less widespread rejection of rtGH by consumers corresponding to the situation observerd after the campagns against veal treated with anabolic agents. Here the relative horizontal shift of demand ranges from -40 % to -80 %. These are short term scenarios.

Each scenario thus involves specific price and quantity variations. remaining within the framework of a static equilibrium approach, changes in producers and consumers surplus were derived for each individual scenario.

Before summarizing the results, we should mention the danger of any mechanistic vision which would lead to erroneous conclusions. This can be understood by considering two extreme cases for the distribution of rtGH and consumer reactions. On the individual farm, the use of rtGH can increase production considerably, which implies a potential growth in the national production which could be in the order of 50% if the innovation becomes very widespread, all other factors being equal. But the "all other factors being equal" qualification is not satisfied due to the interaction between supply and demand. Quantities actually produced will be much lower and in the end, the production increase

will be less than 20%. Similarly, a collapse in the demand would be partly resisted by lower prices.

24. Social benefits for selected scenarios

Table 1 gives the parameters which define four selected scenarios. Each one illustrates one of the basic categories which have been defined.

Table 1.

The current market equilibrium is used as a reference point for the calculations. It is :

Q_0 = 36 000 metric tons, P_0 = 2017 Ecus/kilogram

Changes in price and output are reported in table 1 and producer' and consumer' surplus variation are displayed in the diagram.

Basic scenarios are illustrated with scenario 1. For constant demand, gradual rtGH distribution scenarios create a significant price drop in the short term (4-5%), followed by a larger drop in the long term (14-15%), almost compensated by increased production (4-5% in the short term, 12-16% in the long term) which results in stable or slightly reduced revenue in the long term. However the saving in production costs allow producers to improve their situation with an increased surplus. Consumers will profit from this innovation therefore it must be considered socially advantageous.

The above results are sensitive to consumer reactions (scenario 2). A slight drop in demand limited to the short term does not affect the social advantage of rtGH. However it does lead to a larger price drop and a more limited increase in quantities. Surplus variation remains positive but much lower. If the diffusion of rtGH is accompanied by a significant and long term reduction in demand its social advantage largely decreases. Moreover there are credible scenario for which social surplus is decreasing so we cannot consider that rtGH is socially advantageous.

Scenario 3, that we qualified as optimistic, is based on production diversification towards more highly processed products together with an improved brand image and a long term increase in the demand. It would create a small increase in prices (2%), in

quantities produced (2 then 6%), and in revenue. This would then significantly improve producer and consumer situations. However diversification would lead to a relative increase in production cost, which would partially compensate for the benefits due to rtGH. The result is a fairly limited increase in the producers and consumers surplus.

Scenarios 4 describes a short term situation. It is based on the assumption that rtGH will be rejected by consumers. In this case the reduced demand is cancelled out and overcomes the positive effects of the innovation on the production cost. Price drops of 26 % and a quantity reduction 19 % are then possible. This is the scenario experienced after the consumers' boycott of veal. It leads to a severe drop in total sales and therefore in producers surplus and consumers well-being.

Although we may think that the adoption of rtGH would result in social benefits in the long term, shared by producers and consumers, the transient phase is difficult. The difference between success and rejection is very small. Rejection would completely restructure the industry. The strategy for success would appear to involve diversification and improvements to the brand image. Even so, some effects on the structure of the industry should be expected, and some producers will benefit from the surplus more than others.

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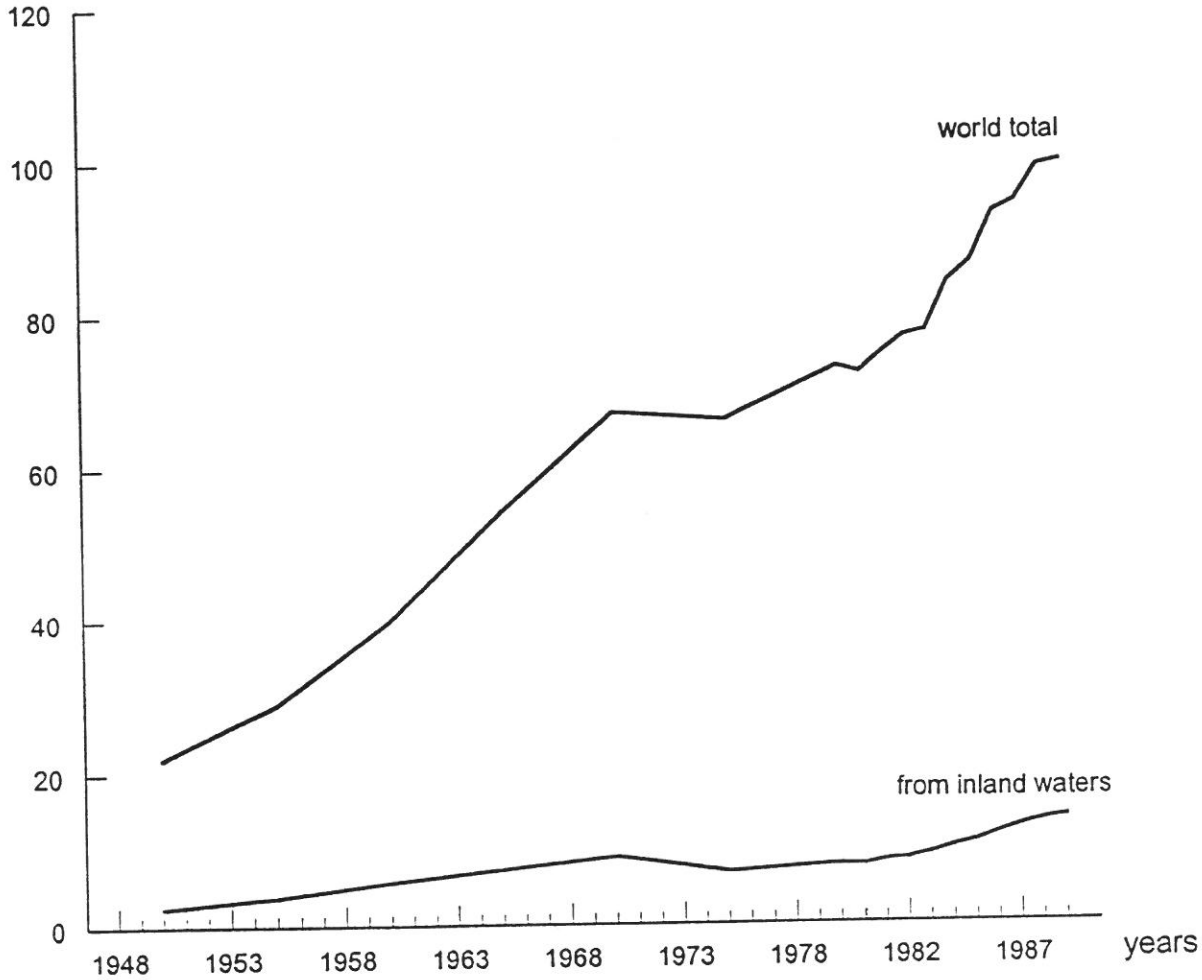
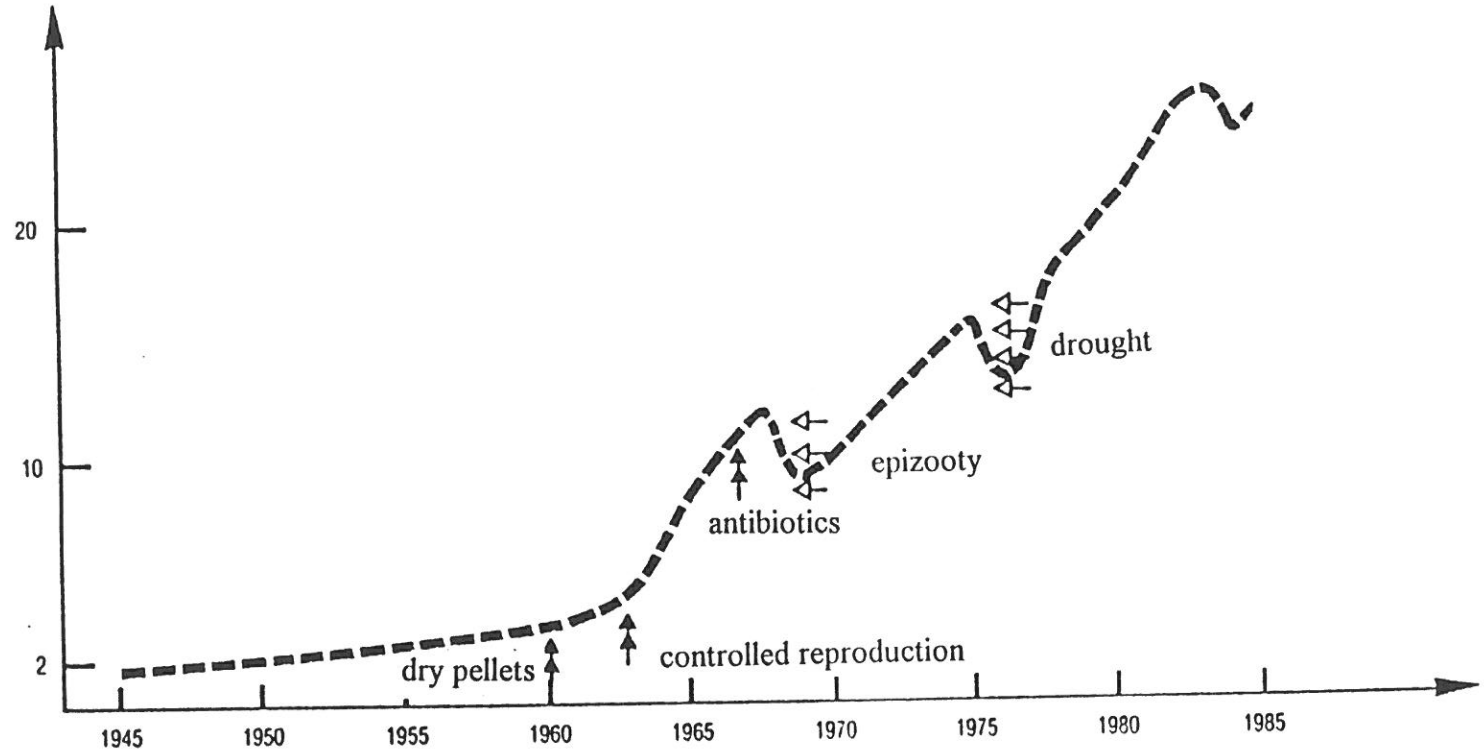
Figure 1. Fishery commodities : Total World catch in million metric tons (aquaculture, mammal and aquatic plants excluded)



Sources : FAO, 1991 Fisheries Circular 710
FAO Yearbook Fishery Statistics vol 69,1989

Figure 2. Changes in trout farming output in France in million metric tons



Source : French fish farming

IMPACT OF rtGH ADMINISTRATION
Social, producers and consumers benefit

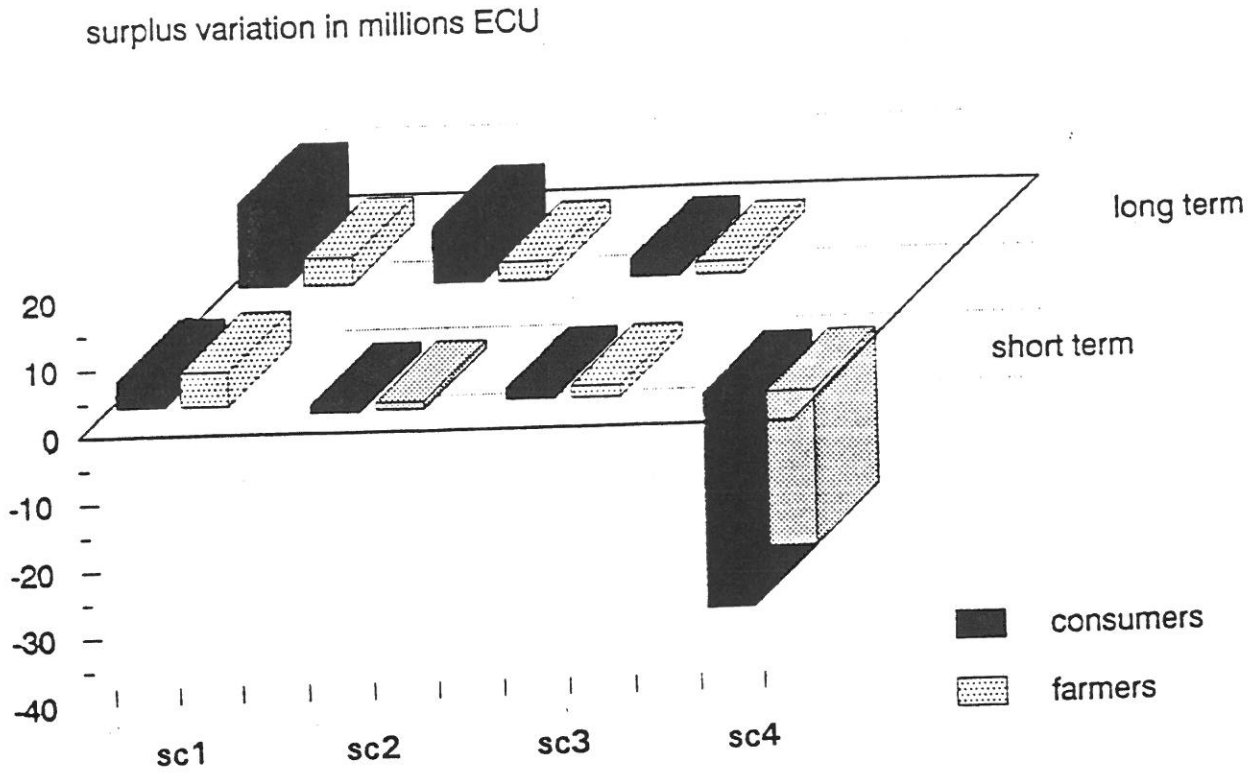


Table 1. Parameters and outcome of selected scenarios

Scenario	Own-price elasticity				Horizontal shift				Change in price		Change in output	
	Short term		Long term		Short term		Long term					
	Supply	Demand	Supply	Demand	Supply	Demand	Supply	Demand	Short term	Long term	Short term	Long term
1	1.1	- 0.8	2.5	-0,8	0.10	0.	0.50	0.	- 0.05	- 0.15	0.04	0.12
2	1.1	- 0.8	2.5	- 0.8	0.10	- 0.10	0.50	- 0.05	- 0.11	- 0.17	- 0.02	0.08
3	1.1	- 1.2	2.5	- 1.8	0.	0.05	0.	0.10	0.02	0.02	0.02	0.06
4	1.1	- 0.8			0.10	- 0.40			-0.26		- 0.19	