Exploring the Potential Competition in the Salmon Industry: a Scenario Analysis of Genetically Modified Fish Marketing

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1. Introduction

Worldwide fish demand is expected to increase dramatically in the coming years, not only due to population growth but also because of increasing disposable income. Fish farming is becoming increasingly important, especially for high value species, to satisfy the demand, and a rapid increase in aquaculture production has been observed (FAO, 2010). Salmon farming is the fastest growing sector in world aquaculture; aquaculture in turn is the fastest growing food industry in the world (McLeod et al., 2006).

The purpose of this paper is to describe the potential effects of Genetically Modified (GM) salmon introduction and marketing on structure and competition within the salmon industry. This study is part of the EU-funded Project PEGASUS (*Public Perception of Genetically modified Animals – Science, Utility and Society*, 7th FP).

Transgenic fish may offer many economic advantages for aquaculture, like disease resistance and enhanced growth (Beardmore and Porter, 2003; Maclean, 2003). The biotech company Aqua Bounty Technologies, headquartered in Waltham, Massachusetts (US) has produced a transgenic salmon breed known as AquAdvantage®. The GM salmon is modified using a salmon growth hormone (GH) gene. In non-modified salmon growth hormone production is decreased during the cold winter months. Using a promoter from an antifreeze gene, the inserted gene is also expressed in the cold season. The new promoter thus disrupts the salmon's normal growth cycle. As a whole, the modification works by making the salmon growth cycle continuous rather than seasonal, as is the case in unaltered varieties. The result causes the fish to grow to a marketable size within 18 months, instead of 3 years. The process does not actually produce a bigger fish. Moreover, feed conversion is more efficient (Entis, 1998; Clifford, 2009). The GM Salmon could lower the costs of production by reducing the amount of feed and other inputs needed to produce one salmon (Smith et al., 2010).

The Food and Drug Administration (FDA) is now considering whether to approve this product for marketing: according to AquaBounty, FDA has signed off on five of the seven sets of data required to demonstrate that the fish was safe for consumption and for the environment[1]. In particular, to address environmental concerns about the potential risk of escape of transgenic salmon, AquaBounty has incorporated multi-level biological and physical containment measures. The company assures that all AquAdvantage® Salmon will be sterile (triploid) and single sex (female), so that in the event of escape into the environment, they will be unable to reproduce and establish breeding populations, or breed with native fish populations. Moreover, AquaBounty will only sell AquAdvantage® Salmon to growers who raise them in secure confined systems (Clifford, 2009). Thus, if approved, the growth-enhanced GM salmon could be the first genetically engineered food animal approved for human consumption.

We have analyzed the potential effect of GM salmon introduction on salmon industry structure and competition with qualitative scenario analysis. We have consulted 204 experts from 89 companies all over the world to get information on the driving forces leading the future of the salmon industry and the GM salmon introduction. The valid responses (n=14) were used in a cross-impact analysis with the logic-verbal technique, resulting in three scenarios: “GM salmon for dinner”, “GM salmon doesn’t take off” and “GM fish banning”.

[1] Pollack A., *Genetically Altered Salmon Get Closer to the Table*. The New York Times, June 25, 2010.

Next paragraph gives a description of the method we have applied. In paragraph 3 we analyse the salmon industry structure and the driving forces of GM salmon introduction. We report the results of the experts' consultation in paragraph 4; the fifth paragraph provides a narrative description of the three scenarios. Finally, we discuss the results and give some conclusions in paragraph 6.

2. Methodology: Scenario Analysis

Scenarios are internally coherent pictures of possible futures (Mietzner and Reger, 2005). These are based on different assumptions about driving forces[2] and their interaction. Scenario analysis should include both ''pictures'' or description of different futures and plausible pathways to these futures (Meyer, 2007). Many predictions were made with this technique in different fields including food systems (Reilly and Willenbockel, 2010).
Scenario analysis requires an in-depth knowledge of the context analysed and can be useful for both managers, helping them to understand future threats and opportunities and to efficiently manage changes, and public authorities, providing information about plausible future developments and supporting their decision making process.
Many scenario analysis are reported in the literature. The distinction between qualitative and quantitative scenarios is generally accepted. A qualitative or descriptive scenario is used when the time horizon of the analysis is long and few data are available. Usually it is based on a narrative description of the possible future evolution of the context without quantifying outputs, but only describing the factors influencing them (Swart et al., 2004). Quantitative scenarios usually apply a mathematical or statistical model. The use of both approaches, qualitative and quantitative, is sometimes the best solution to provide a complete analysis while benefiting from the advantages of both. In this study we applied both approaches; however, here we present only the results of the qualitative analysis, that was the starting point of the following quantification. Scenarios can also be classified according to their aims among projective, exploratory and normative (Reilly and Willenbockel, 2010). Our analysis is exploratory in nature, because it focuses on drivers of change that are exogenous to the system.
The method we have applied includes different steps (Mietzner and Reger, 2005): the first was to provide a detailed description of the current situation (the baseline scenario) and past and present trends. The information on the production chain and market were collected through the literature review and web search (including official statistics, such as FAOStat), giving a complete picture of the actual situation. Secondly, we have consulted a number of experts to identify the main driving forces of GM salmon introduction. We used web interviews with questionnaire and telephone interviews. Many information were collected in this way, also used for the next quantification phase. Finally, we have identified the links between the driving forces to give a description of the scenarios[3]. We have considered a time horizon of ten years.

[2] Driving forces are key internal forces (such as knowledge and competence of management and workforce) and external forces (such as economy, competitors, technology) that shape the future of an organization. The more are the effects generated by one force in the context considered, the more it will influence other forces and will be considered very important for the specific sector.
[3] We can identify three main methodologies to this aim: intuitive logics, trend impact analysis and cross-impact analysis. In particular, we applied the latter; cross-impact analysis is a formalized method where the researcher has to assess, often with experts' help, the main variables and uncertainties surrounding the

3. The Salmon Industry and the Driving Forces

3.1 The salmon industry and markets

Global supply of salmonids has increased by about 36% since year 2002, from 2.2 million tonnes to approx. 3 million tonnes in 2009. The majority of the increase has come from increased farming of Atlantic and Pink salmon. Global farmed salmon production has exceeded the world's total harvests of wild salmon since 1998. Farmed Atlantic salmon, which has seen a growth in supply every year, constitutes more than 90% of the farmed salmon market, and more than 50% of the total global salmon market (Le Curieux-Belfond et al., 2009). The development of salmon farming depends on many factors like market demand and competition, availability of environmental resources, technical development and transfer, infrastructures, investments, human resources and institutional system (Bostock et al., 2010). The rapid increase of salmon farming was possible thanks to the decline of production costs, mostly because of better food conversion rate (FCR), development of new fish vaccines and new farming techniques. Proponents of salmon aquaculture argue that fish farming is a more reliable and predictable business than wild salmon capture fisheries. As long as large amount of salmon have been farmed, this caused a corresponding drop in the price of even high-value products (McLeod et al., 2006).

The most important salmon producers are Norway (900 thousand tons estimated in 2010), Chile (240), United Kingdom (160) and Canada (140)[4]. These four countries supply more than 90% of world production of farmed salmon, the largest portion of which is Atlantic salmon (1.4 million tons per year).

Recently, Norwegian fresh salmon meet more competition from Chilean frozen salmon in the European market[5]. This together with strong competition between mainly Norwegian and Chilean salmon in the Japanese market, and the increase in export from Scotland and Norway to USA due to reduced supply from Chile shows that the market is becoming more and more globalized (Marine Harvest, 2010). However, the production regions still have 'home markets' since only frozen salmon can be available in large volumes for distant markets (Bostock et al., 2010).

The increase of world salmon aquaculture and the relative decline of wild-caught fish contributed to reduce the seasonality of fish processing and consumption, as well as variability of quality and quantities processed. Technological change in salmon farming, processing and retailing have replaced labour with capital equipment, increasing economies of scale and, in some stages, economies of scope. Retailers, which now sell 60-90% of salmon in many EU countries, have larger requirements in terms of timing, regularity, quantity and quality. Finally, consumers are increasingly demanding fresh fish, but also more varieties and processed products. This has led to concentration in several stages and more vertically integrated chains (Tveterås and Kvaløy, 2004). This concentration process has been more accelerated in North America and in the UK, while

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sector. Their coherent crossing, without using any statistic model, leads to the scenarios definition. This approach is also called "logic-verbal technique" (Mietzner and Reger, 2005).

[4] FAO – Globefish, 2010, available at: http://www.globefish.org.

[5] However, the reduction in Chilean production in 2009, as a result of disease outbreaks (ISA - infectious salmon anemia), have reduced total global supply and therefore pushed prices higher. Norway, the largest producer and exporter of salmon, has been the main benefiter of Chile's production problems, although many Norwegian producers operating in Chile have also been hurt by the same problems.

in Norway and Chile there are several more companies with a significant production volume (Marine Harvest, 2010).

World salmon consumption can be divided among five major markets: the European Union fresh and frozen market, the Japanese fresh and frozen market, the U.S. fresh and frozen market, canned salmon markets and other markets. There are significant differences between these markets in their sources of supply, species and products consumed and short-run market conditions (Knapp et al., 2007).

The Japanese fresh and frozen salmon market was the world's largest market. However, the rapidly growing European Union now consumes a slightly larger volume. In 2004, U.S. fresh and frozen salmon consumption was only about half that of Japan or the European Union. The European market is dominated by Norwegian and UK industries. Norway has accounted for about half of total European consumption, while the United Kingdom has accounted for about one-quarter. American wild salmon accounts for only about 4 percent of total EU consumption. All five markets are important for North American wild salmon. Canned salmon markets account for the largest share of North American salmon production. The Japanese market, which formerly accounted for the largest share, has declined in relative importance due to declining North American production and exports of frozen sockeye salmon. Consumption of farmed salmon grew dramatically between 1989 and 2004 in all markets except for canned salmon. In both relative and absolute terms, consumption grew more in the European fresh and frozen market. The EU accounted for about 50 percent of the increase in world farmed salmon consumption during this period, the U.S. for 20 percent and Japan for 11 percent.

In the EU in 2009 over half of the Atlantic salmon was marketed by retailers, especially large scale retailers, while 45% by Ho.Re.Ca. (hotels, restaurants and catering). Almost two third of whole salmon and fillets were sold fresh and about one third frozen. In the EU salmon fillets and smoked salmon have an equal market share of 32% each, while whole fish has about 19% (Marine Harvest, 2010). The European market for smoked salmon was 125,000 tonnes in 2009, whereof France and Germany were the major and growing markets with a total market size of approximately 45,000 tonnes.

3.2 The Driving Forces of GM Salmon Introduction

From the literature, we can indicate four major categories of driving forces able to affect transgenic growth-enhanced GH salmon introduction: production, market, public acceptance and consumption, and regulatory framework.

The category "*Production*" includes four other forces:

a) *Productivity:* GM salmon is expected to grow faster than the non GM one; it reaches the marketable size in an half of the time and it shows an increase, from 10% to 25%, of the feed conversion rate too (Entis, 1998; Aerni, 2004). These technical features can have both positive and negative effects on other factors (positive: reduction of production costs, increase salmon production and consumption; negative: potential environmental and animal welfare problems).

b) *Production cost:* GM salmon introduction may reduce production costs like feed, medic, labour, while increasing other cost components connected to confined systems and new regulations (e.g. traceability and labelling).

c) *Profit:* profits depend on production costs, market price and property right legislation.

d) *Producer's acceptance:* potential profits may influence producers' acceptance.

Into the category "*Market*", we have identified four other forces:

a) *Global supply:* this aspect is influenced by productivity, producers' acceptance and market price.
b) *Market structure:* the marketing of GM salmon will likely cause the exit of small producers and the increase of market concentration and integration (Le Curieux-Belfond, 2009), as well as a higher dependence of producers from input suppliers (Beardmore and Porter, 2003). Market price and production costs can modify market structure, which can influence the profit distribution along the production chain.
c) *Market price:* the main factors that affect market price are production costs, supply level, market structure and chain integration; prices, in turn, can influence the acceptance of producers and consumers.

Four driving forces are related to "*Public Acceptance and Consumption"*:

a) *Public acceptance*: it depends on food safety, environmental and animal welfare aspects. It affects the GM salmon consumption.
b) *Consumers' preferences:* several studies have already analysed consumer's perception and acceptance of GM salmon (e.g. see Chern and Rickertsen 2004). Consumers' perception depends on public acceptance, while influences global consumption.
c) *Global consumption:* global consumption of GM salmon is affected by public acceptance, consumers' preferences and market price.
d) *Human health:* health benefits from an improved nutrition (higher n-3 fatty acid intake) may result from a higher consumption of fish thanks to lower market prices (Smith et al., 2010).

The "*Regulatory framework"* includes four driving forces:

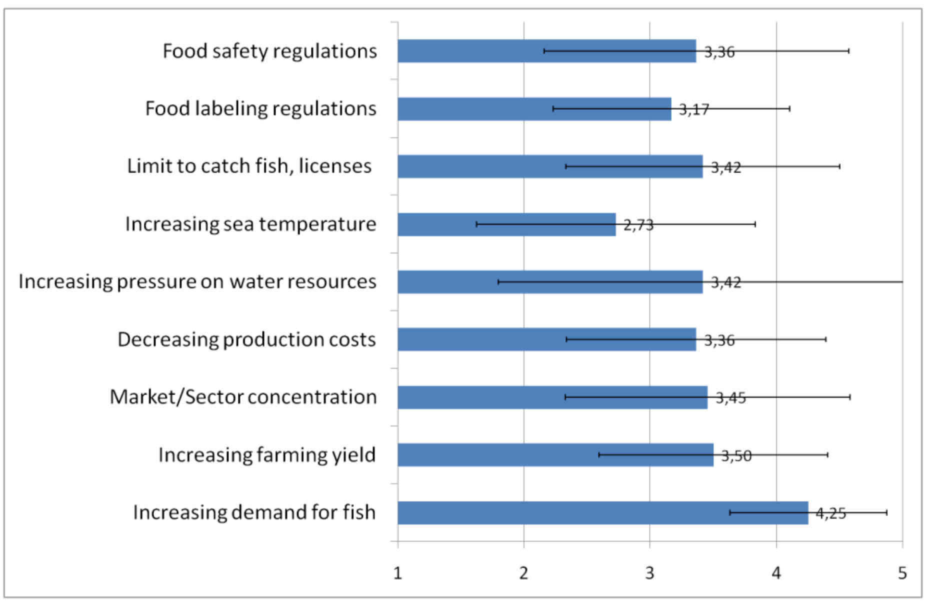
a) *Labelling and traceability:* should GM Salmon have a specific labelling? Although the EU have already specific rules for GMOs, the US salmon industry requires the FDA to stick to current rules that prevent specific labelling for GM food. The introduction of labelling and traceability schemes means higher production costs while, at the same time, improvement of public acceptance.
b) *Intellectual property rights:* this includes legislation aspects like licenses, trademarks and copyrights, which affect production costs.
c) *Environmental impact and policy*: the effects of GM salmon escapes on wild stocks have dominated the debate on environmental risk so far. This risk can be prevented by physical and biological containment (Le Curieux-Belfond, 2009). As noted by Smith et al. (2010), if each GM salmon substitutes for just one non-GM farmed salmon, then waste effluent and pressure on wild sources of fish meal and oil would decline because the GM salmon require less feed to grow. But if GM salmon introduction will expand the overall market enough to offset the input reduction, then environmental pressure will increase.
d) *Animal welfare:* some studies report an increase in disease resistance of GM salmon to bacteria pathogens (Maclean, 2003); negative health effects, like cardiovascular problems, have also been reported, but they need to be evaluated more in details.

4. Results: the Experts' Interviews

The driving forces were used to define a questionnaire sent to production chain players; their answers were used to define the future trends of the salmon market and the possible

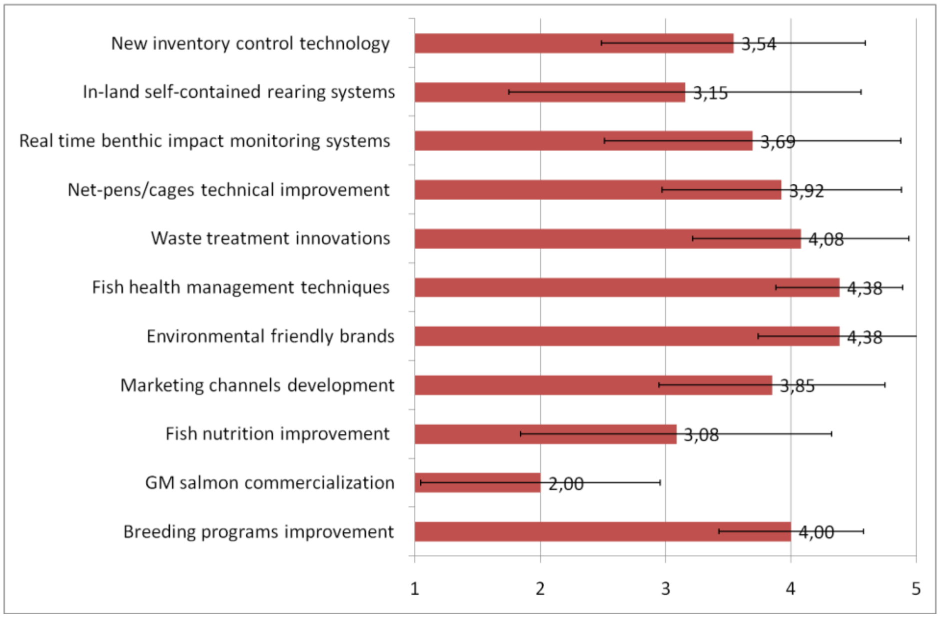
effects of GM salmon introduction. The experts' consultation was necessary to obtain relevant and more detailed information to develop the scenarios.
The expert's list included large and small scale salmon farmers, both integrated and not integrated, food and other input supplier (e.g. technical equipments), processors (e.g. smoked and fillet salmon), traders (including exporters), consultant and research institutes involved in the salmon market. A total number of 204 experts were contacted from 89 companies all over the world. The focus was heterogeneity rather than homogeneity. These experts were contacted by email in July 2010 and received a copy of the questionnaire and a letter providing explanation of the survey's aim. We have received fourteen answers from producers, both integrated (3) and not integrated (1), input suppliers (3), researchers (2), consultants (2), processors (2) and traders (1); their answers were used to define the scenarios.
We asked the most important factors affecting farmed salmon industry in next ten years. Respondents had to assess the importance of these items on a Likert scale from 1 to 5 (1 is "*not important at all*" and 5 is "*very important*"). The items were the increase of demand of fish, market concentration, decrease of production costs, introduction of new regulations about market (licenses), labelling and food safety (Fig. 1). The answers were quite homogeneous except for the most important factor, i.e. the increasing demand for fish; the only aspect considered not important is the increasing sea temperature.

Fig. 1: Factors affecting farmed salmon industry (mean and standard deviation).



Then, we asked for the importance of the introduction of some technical innovations, including genetic modification. Very interestingly, GM salmon introduction seems to be the least important from the expert replies (Fig. 2). Fish health management techniques (e.g. vaccines), branding of environmental friendly salmon farming, and waste capture, removal and treatment innovations (e.g. ozone treatment) and breeding programs improvement are the most important innovations according to the experts. Then each technical variable has been crossed with all the forces identified at the beginning of our analysis. This process helps to understand how every single technical innovation influences a specific driving force of the sector. The experts, for example, believe that the introduction of GM salmon in the market will have effects on yields and production costs. The other forces won't be affected by this application.

Fig. 2: Research and development in aquaculture (mean and standard deviation).



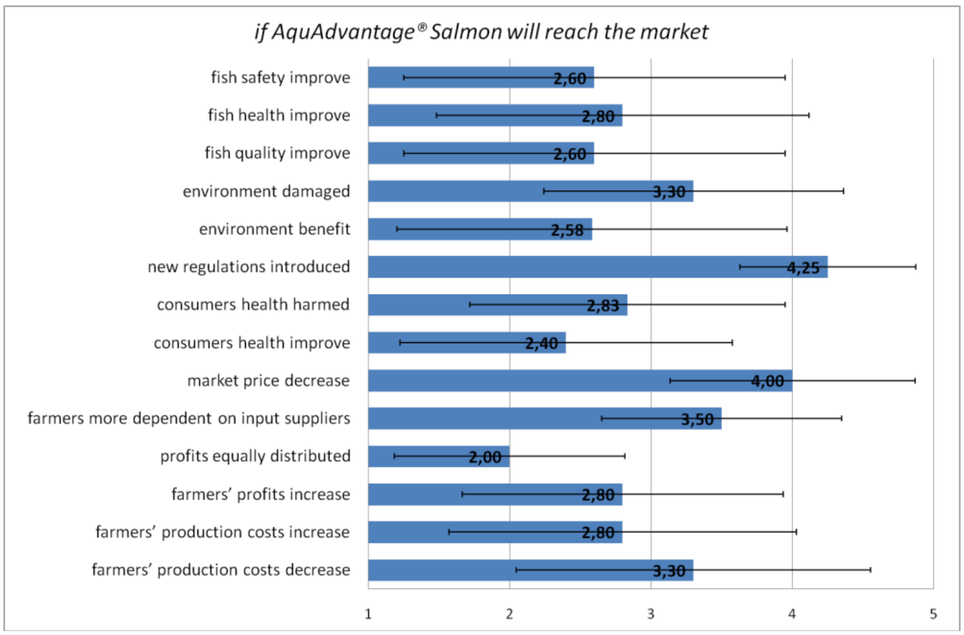
In the last part of the questionnaire, the experts expressed their opinions on specific questions about GM salmon. In this way, it was possible to highlight all the possible effects caused by GM salmon. In general, the experts believe that GM salmon is still far from the market (Tab. 1) although, at the beginning of this section, the experts were provided with information about the recent advancements of AquAdvantage® Salmon application at the FDA. Moreover, the experts are doubtful on the acceptance by consumers, producers and retailers, especially in some countries. Consumers' and producers' acceptance is likely to be higher in emerging and developing economies (such as Chile and Eastern Asia), in Oceania and in the US.

Tab. 1.: Agreement on the introduction and public acceptance of GM salmon.

Item	**Mean**	**Std dev.**
GM salmon will reach the market within 5-10 years	1,92	1,12
GM salmon will reach the market later than 10 years	2,31	1,18
GM salmon will never reach the market	3,00	1,28
Consumers will accept worldwide	2,31	1,03
Consumers will accept in some countries	3,00	1,15
Producers will accept worldwide	2,31	1,11
Producers will accept in some countries	3,15	0,99
Retailers will accept worldwide	2,31	1,03
Retailers will accept in some countries	3,38	0,87

Finally, we asked, if AquAdvantage® Salmon would reach the market, what would be the possible effects (Fig. 3). GM salmon introduction provides contradictory answers from the experts; these uncertain variables were used for the scenarios definition. The experts generally agree that GM salmon introduction will cause new regulations to be introduced (e.g. labelling, traceability, etc.), will reduce market price because of farmers costs decrease, will make farmers more dependent from input suppliers and will pose some risks to the environment. Moreover, they believe that profits will not be equally distributed across the supply chain. Also consumer's health, according to the experts, is more likely to be harmed than improved by GM salmon introduction.

Fig. 3: Possible effects of GM salmon introduction (mean and standard deviation).



5. Future scenarios for GM salmon

According to the answers provided by expert consultation, it was possible to develop three different scenarios. In general, different scenarios have to be realistic, internally consistent and defined in such a way to cover the widest possible range of uncertainty (Lindgren and Bandhold, 2009).

The three scenarios were named as "GM salmon for dinner", "GM salmon doesn't take off" and "GM fish banning". The following narrative description provides a general overview of each.

In the first scenario ("*GM salmon for dinner*") the GM salmon will be introduced in the market, and will be produced, accepted and consumed especially in some countries (Chilean and Canadian production for US and Asian market, Australia production for Eastern Asian market) and by some type of consumers. This will lead to a sort of market segmentation both at international level, between countries, and within the same country between different type of consumers. For instance, Bennet et al. (2005) found that in the United States older, higher income, non African American males are the most likely to consume GM fish and seafood. Market price will decrease because of the higher

production and cost reduction (better feed conversion rate); at the same time profits will not equally be distributed across the supply chain. Large scale farmers will more likely introduce this technique and market will become more concentrated. There will be great attention on regulatory framework and the introduction of new regulations like traceability and labelling of GM salmon, as well as physical and biological containment of GM fish that will prevent, but not totally exclude, GM salmon escapes.
In the second scenario, GH transgenic salmon will be commercialized especially in some countries (Chilean production for US market, Australia production for Asian market), but it will encounter the strong resistance of consumers and consequently of most producers; at the same time retailers will rather accept GM salmon on their shelves ("*GM salmon doesn't take off*"). Other innovations will be introduced by the salmon industry like improved breeding programs, net-pens/cages technical improvement, waste treatment etc. These innovation will lead to an increase in salmon farmers yields and to a reduction of production costs, causing a consequent market price decline. There will be also great attention on regulatory framework (e.g. traceability, labelling) as well as physical and biological containment of GM fish, especially in some countries (e.g. Australia). This unequal application will cause the concentration of GM salmon production in those countries where regulations are loosely applied (e.g. Chile).
Transgenic salmon will not be commercialized because of the high environmental risks posed by its production and because of the strong parallel resistance of consumers, retailers and producers ("*GM fish banning*"). For this reason, companies will focus their research project in other areas (fish health management techniques, reduction environmental impact, breeding programs, etc.), leading to higher production efficiency and lower costs. Large scale and highly integrated producers will reduce market prices accelerating market concentration. In the marketplace there will be a development of marketing programs to brand environmental friendly farming techniques and other specific salmon quality attributes; this will leave some market niches to small scale farmers.

6. Discussion and conclusions

Increasing demand of fish is considered by the experts as the most important factor driving salmon farming industry in the future. In fact, demand of fish has grown fast in the past and is also expected to keep on growing because of increasing population and changes in consumption patterns in developing countries (Bostock et al., 2010). Many have argued that GM salmon may become important given the present and projected increasing demands for fish (Entis, 1998; Maclean, 2003), although different opinions still exist (McLeod et al., 2006).
The experts consulted don't believe that GM salmon introduction is an important technical innovation in the next future. This result may confirm the reluctance of producers to accept this innovation, unless wholesalers (e.g., salmon trading companies), retailers and consumers signal their willingness to buy such fish (Aerni, 2004). Other researchers have considered that once commercially available, GM salmon could drive down the price of farmed salmon. This could cause economic losses to some farmers, accelerating the concentration process of the sector, and forcing many to accept the new technology (Le Curieux-Belfond, 2009). Interestingly, according to the experts, producers' dependence on input (eggs/smolts) suppliers will likely increase (as also

argued by Beardmore and Porter, 2003) and profits will be hardly distributed equally along the supply chain. This pessimistic "future" picture may be a possible explanation of their actual reluctance.

The experts also think that consumers will hardly accept this product worldwide, whereas consumers' willingness to purchase may be higher in some countries (i.e. US, Eastern Asia). This is consistent with some studies having shown a higher price discount required for GM salmon by European compared to US consumers (Chern and Rickertsen 2004).

Some other interesting features emerged from the analysis. For instance, we noted that projected increasing sea temperature is not important for the experts; this contradicts some studies that found, for instance, that the expected change in temperature in the Northeast Atlantic may have potential economic consequences on the salmon farming industry in Norway (Torbjørn, 2008).

Finally, according to the first scenario ("*GM salmon for dinner*") the GM salmon will soon reach the market, being produced in some specific regions for some specific markets. In all scenarios the resistance of European consumers to GM food, especially if animal food, will prevent the marketing in the EU and the production development in Norway and UK, at least within the time horizon analysed (ten years). In the two other scenarios, "*GM fish banning*" and "*GM salmon doesn't take off*", its introduction will be more complicated because of consumers' and producers' reluctance to buy and produce this fish. Instead, new innovations will be introduced to increase productivity, while improving the environmental sustainability of salmon farming.

With this scenario analysis, we have provided a consistent and global picture of the likely effects of GM salmon introduction in the future development and competitive arena of salmon industry. Next step will be the quantification of the qualitative results presented in this study.

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