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MARKET COMPETITION BETWEEN FARMED AND WILD FISH: A LITERATURE SURVEY

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MARKET COMPETITION BETWEEN FARMED AND WILD FISH: A LITERATURE SURVEY

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PREPARATION OF THIS DOCUMENT

This publication contributes to FAO's ongoing activities and examines market competition between farmed and wild fish, its consequences and policy implications, in particular for the future development of aquaculture. It was initiated as part of a larger technical study by Trond Bjørndal, Audun Lem and Alena Lappo that analysed future demand and supply of food to 2030 from an economic point of view (Lem, Bjørndal and Lappo, 2014). This report found that, in the future, aquaculture development is likely to drive fish markets. The current study offers further insights in this regard.

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ABSTRACT

A wide range of interactions occurs between wild fisheries and aquaculture. These interactions can be classified as technical, environmental and market (or economic). The objective of this publication is to identify market competition interactions between wild fisheries and aquaculture and to analyse their consequences through a survey of the existing relevant literature. Most studies on competition interactions between aquaculture and wild fish are based on a reduced number of species and markets. Studies have mostly focused on the most-traded species (salmon and trout, shrimp and prawn, catfish and tilapia, and seabass and seabream) and the main consumer markets (United States of America and European Union [Member Organization]). Owing to the low number of studies in the literature and the diversity of results reported, findings can only be generalized with caution.

CONTENTS

ABBREVIATIONS AND ACRONYMS

3SLS	Three-Stage Least Squares procedure
CBA	capture-based aquaculture
CBF	culture-based fisheries
CSIC	Agencia Estatal Consejo Superior de Investigaciones Científicas
DSES model	Dynamic Simultaneous Equations System model
EU	European Union (Member Organization) (in tables)
FAD	fish aggregation device
FAO	Food and Agriculture Organization of the United Nations
IFFO	Marine Ingredients Organisation (formerly International Fishmeal and Fish Oil Organisation)
NAFTA	North American Free Trade Agreement
NHH	Norwegian School of Economics
OECD	Organisation for Economic Co-operation and Development
SNF	Centre for Applied Research (Samfunns-ognæringslivsforskning)
USA	United States of America (in tables)

EXECUTIVE SUMMARY

World capture production has been stagnant for the last two decades, with a large percentage of world fish stocks fully or overexploited, while aquaculture production continues to increase at high rates. This situation in capture fisheries may also limit aquaculture's expansion capacity, owing to limitations in the production of fishery-based feeds and seed supply. On the other hand, it offers aquaculture the possibility to increase its market share and become the main supplier for fishery products.

However, interactions between fisheries and aquaculture are wider and more frequent, owing to the sharing of fish resources, common ecosystems and common markets. Interactions caused by sharing the same resource (fish in its wide sense[1]) can result from biomass transfer from fisheries to aquaculture through fish-based feeds (e.g. fishmeal, fish oil and trash fish), and through the collection of wild seed and broodstock – as well as from aquaculture to fisheries through escapees and restocking. In fact, restocking is increasingly contributing to capture fisheries through the release of juveniles that restore overfished stocks and enhance catch rates in wild fisheries. However, released individuals can have an impact on wild populations, including those of different species.

Negative effects caused by the sharing of common ecosystems include: (i) modification of habitats affecting fisheries' resources and activities (e.g. mangrove clearing for shrimp ponds, seabed disturbances through anchoring of aquaculture cages or pens, damage to seagrasses, alteration to reproductive habitats and biodiversity loss); (ii) eutrophication of water bodies owing to excess nutrient release, leading to anoxia and fish mortality, which also impact negatively on biodiversity and wild fish stocks; (iii) release of diseases and chemicals. Nevertheless, aquaculture can be an alternative source of income for fishers, their families and their communities, providing them with more opportunities and economic development.

Marketing interactions considered from an economic point of view show that aquaculture has lowered seafood prices, mainly because of increased supply (i.e. increased competition). If the two products (farmed and wild fish) are close substitutes, farmed fish will win market share from wild fish. If demand is not perfectly elastic, the price will decline, as will the incomes of producers of wild fish (fishers). However, if the two products are not substitutes, there are no market effects, and the increase in supply of farmed fish will only lead to a price decrease for those fish. Moreover, increased production from aquaculture, jointly with increased marketing, can also enhance and indirectly improve processing and market access to similar wild-caught products.

Market integration between farmed and wild species implies that farmed and wild fish prices follow the same long-run pattern. Current knowledge of competition interactions between aquaculture and wild fish is based on a reduced number of species and markets. Studies have mostly focused on salmon, shrimp, tilapia, seabass and seabream in United States and European Union markets, these being the most-traded species and the main consumer markets.

Market integration (i.e. price decreases in capture species owing to a growing aquaculture supply) has been proven for different species and markets, but has been rejected in other cases. This suggests that some species and markets are more likely to be affected than others, but no general trends have been detected. Owing to the diversity of the results reported and the low number of studies in the literature, these findings can only be generalized with caution.

Results are also sensitive to the period investigated. Fish markets are dynamic and are changing continuously. Competition (market integration) between species may take some time to develop once a farmed species reaches the market (e.g. the quality or reputation of farmed production may improve with time). Moreover, consumer preferences change over time, in part because of marketing

[1] Includes all aquatic organisms considered in capture fisheries and aquaculture (e.g. fish, crustaceans, molluscs, etc.).

campaigns and external factors (e.g. the economic crisis). For example, frozen and fresh tilapia prices did not follow a similar trend in the United States of America, but the economic and financial crisis of 2008 has made consumers more price-sensitive, substituting fresh tilapia from South America with frozen tilapia from Asia, which has a lower price. Thus the economic downturn may have produced changes in demand, strengthening price linkages between some products.

We expect that competition interactions between farmed and wild fish may increase in the future, as a larger part of fish supply will come from aquaculture, and that sales of semi-processed products (e.g. fish fillets) in supermarkets and large retailers will increase their market share. A recent study analysing development of fish markets up to 2030 shows that, in the future, prices of both captured and farmed fish will be largely driven by developments in aquaculture production. At the same time, per capita fish consumption is likely to be maintained if not increased in most scenarios, although important differences among regions of the world will remain. In fact, in the future, it could be that some aquaculture species would be integrated (directly compete) with meat products such as chicken.

On the other hand, there is growing interest among certain consumers in buying local food – and wild-caught seafood in particular. Thus it is possible that certain local, wild-caught varieties (e.g. large-sized products) could successfully create or maintain their market segment (i.e. niche), and not enter the market integration that most wild-caught varieties will enter with imported production.

1. INTRODUCTION

Production from world capture fisheries has been fluctuating at about 90 million tonnes per year over the last two decades, with 93.9 million tonnes recorded in 2013 (82.2 million tonnes from marine fisheries and 11.7 million from inland fisheries) (FAO, 2015a).[2] On the other hand, aquaculture production shows an increasing trend that resulted in total production of 97.2 million tonnes in 2013 (ibid.).[3] Aquaculture, probably the fastest growing food-producing sector in the world, now accounts for 50 percent of the world's fish supply for human consumption (FAO, 2015b). This is because some 21.7 million tonnes of capture fisheries production were not destined for human consumption in 2012 (FAO, 2014).

A wide range of interactions may occur between wild fisheries and aquaculture. Thus the evolution of aquaculture has been and still is closely related to capture (wild) fisheries. Competition and interactions between capture fisheries and aquaculture can be classified in three main groups: technical, environmental and market or economic. These interactions may result in both beneficial and harmful consequences for both sectors.

The purpose of this paper is to identify these interactions and to analyse their consequences. The main focus will be on market competition and economic integration. In particular, a survey of the relevant literature is provided. Most studies of competition interactions between aquaculture and wild fish are based on a reduced number of species and markets. They have focused on the most-traded species (salmon and trout, shrimp and prawn, catfish and tilapia, and seabass and seabream) and the main consumer markets (United States of America and European Union [Member Organization]).

This report is organized as follows: Section one provides a classification of interactions between aquaculture and capture fisheries and analyses their consequences. Section two presents a review of the literature on market competition interactions. The final section gives some concluding observations.

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[2] Landings from marine fisheries correspond mainly to 67.8 million tonnes of fish, 6.6 million tonnes of molluscs, 6.0 million tonnes of crustaceans and 1.3 million tonnes of aquatic plants, while landings from inland fisheries correspond mainly to 10.8 million tonnes of fish, and 0.5 and 0.4 million tonnes of crustaceans and molluscs respectively (FAO, 2015a).

[3] Of this production, 47.1 million tonnes correspond to fish, 27.0.
million tonnes to aquatic plants, 15.5 million tonnes to molluscs and 6.7 million tonnes to crustaceans (FAO, 2015a).

2. CLASSIFICATION OF INTERACTIONS

Based on Soto *et al.* (2012) and Knapp (2015), the following classification of the existing interactions between wild fisheries and aquaculture is suggested:

- Joint production interactions
    - Capture-based aquaculture: harvest of wild individuals for aquaculture grow-out
    - Culture-based fisheries: production of farmed juveniles for wild fisheries
- Feed interaction: wild-caught fish as feed for aquaculture
- Environmental/ecosystem interactions
    - Genetic mixing
        - Ranched fish
        - Escaped fish
    - Diseases and pollution
    - Use of wild fish habitat for farmed sites
- Regulatory interactions
    - Conflict or cooperation
- Shared infrastructure interactions
    - Processing, transportation, retailing
- Market interactions
    - Competition
    - Market development
- Innovating interactions

In the following, we will define and explain these interactions.

2.1. Joint production interactions

Capture-based aquaculture or the harvest of wild individuals for aquaculture grow-out. Many aquaculture activities rely on wild individuals (eggs, post-larvae, juveniles, small adults or even broodstock to produce eggs) to obtain their livestock. This often happens when it is not possible to replicate the full biological cycle of a species, or when it is cheaper to use wild juveniles than farmed ones. Lovatelli and Holthus (2008) estimate that capture-based aquaculture (CBA) represents some 20 percent of total world aquaculture production.

Bluefin tuna (*Thunnus thynnus*) may be the most emblematic species in those aquaculture activities using wild specimens to be grown in captivity (tuna ranching) – even if captured specimens are normally at an adult stage and are just being fattened until the best moment for sale. Conversely, there are more than 70 species involved in CBA: eels, mussels, oysters, lobsters, mullets, etc. (ibid.).

Culture-based fisheries or the production of farmed juveniles for wild fisheries. This is the process of releasing hatchery raised (farmed) juveniles into the wild with the aim of recapturing them once they mature and achieve market size. Culture-based fisheries (CBF) are increasingly involved in restoring overfished wild populations (i.e. restocking), thus improving catch rates in wild fisheries (Lorenzen *et al.*, 2000; Lovatelli and Holthus, 2008). In this way, CBF may contribute to sustaining and even increasing the revenues of fishing fleets, as well as to the recovery of endangered species. This is a common practice for certain species in given areas, for example salmon in Alaska and Japan, flounder in Japan, carp, tilapia and catfish in Cuba, Mexico and several Asian countries (Soto *et al.*, 2012).

The potential of CBF as a cost-effective means of increasing fish supplies is widely recognized (Quiros, 1998; De Silva, 2003). However, released individuals can have an impact on wild populations and this can include those from other species. In this sense, tilapia introductions can have significant negative effects on local biodiversity (Canonico *et al.*, 2005). However, knowledge of the long-term impacts of CBF on the biodiversity, structure and function of ecosystems is still limited (Soto *et al.*, 2012).

2.2. Feed interaction: wild-caught fish as feed for aquaculture

In developed countries, aquaculture has focused mainly on the culture of high-trophic-level carnivorous species with high economic value, which require significant amounts of fishmeal and fish oil in their diets (Deutsch *et al.*, 2007; Hasan and Halwart, 2009; Naylor *et al.*, 2009; Tacon *et al.*, 2012). Although many species are used in the production of fishmeal and fish oil, oily fish such as small pelagics are the main ones. Thus small pelagic forage fish species (e.g. anchovies, herring, mackerel and sardines) serve mainly as farm feed inputs (Tacon and Metian, 2009).

FAO (2014) estimated that 21.7 million tonnes of global production were destined for non-food purposes in 2012. Of this, 16.3 million (75 percent) were reduced to fishmeal and fish oil. The residual 5.4 million tonnes were largely used as fish for culture (fingerlings, fry, etc.); ornamental purposes; bait; pharmaceutical uses; and as raw material for direct feeding in aquaculture (e.g. trash fish), for livestock and for fur animals. About 35 percent of world fishmeal production was obtained from fish by-products (residues) in 2012. The use of by-products instead of whole fish can affect the composition and quality of fishmeal and consequently may affect its share in feeds used in aquaculture and livestock farming (ibid.).

Wijkström (2009) divides ‘whole’ fish used for fishmeal and fish oil into three group:

- **Industrial-grade forage fish**. This fish has no market as food for human consumption. Total fisheries production is converted into fishmeal and fish oil – without which fisheries would have to cease production. The main species are gulf menhaden, sandeel, Atlantic menhaden and Norway pout, with a total annual production of 1.2 million tonnes.
- **Food-grade forage fish**. This fish has a limited market for human consumption and is commonly used for reduction. Fishmeal plants process what the food-fish markets do not consume. The main species include Peruvian (*anchoveta*), Japanese, European and other anchovies, capelin, blue whiting and European sprat.
- **Prime food fish**. This refers to fish that has a regular market for human consumption, but mainly owing to large landing fluctuations and its perishability, some is also destined for fishmeal production. The main species in this category are Chilean jack mackerel, chub mackerel, and other species of sardine, mackerel and herring.

In summary, Wijkström (ibid.) concludes that there is a net addition of 7–8 million tonnes of fish supplied for human consumption from aquaculture that, as forage fish, would not have been used. However, it should be noted that herring and mackerel in the North Atlantic are examples of prime food fish that have shown a great change in usage: while most of the harvest was used for fishmeal production in the past, virtually all harvest is today used for direct human consumption.

The Marine Ingredients Organisation (IFFO) estimates that, worldwide, 16.5 million tonnes of whole fish and 5.5 million tonnes of by□products (fish parts) were converted into 5.0 million tonnes of fishmeal and 1.0 million tonnes of fish oil in 2008 (Chamberlain, 2011). Indeed, IFFO estimates that 4.8 million tonnes of fishmeal were produced globally in 2009. Sixty-three percent of this was used in aquaculture, mainly to feed salmon and trout, crustaceans, and other marine fish (each of them used about 27 percent of the total fishmeal destined to aquaculture). Fishmeal was also used to feed pigs (25 percent) and poultry (8 percent). The main producers of fishmeal are Chile and Peru (ibid.).

IFFO also estimates that 1.0 million tonnes of fish oil were produced in 2009. Eighty-one percent of all fish oil produced was destined to aquaculture, where it was mainly used in the salmon and trout segment (68 percent). Direct human consumption accounted for 13 percent. The main producers of fish oil are Chile, Peru, the Scandinavian countries and the United States of America (Chamberlain, op cit.).

Thus aquaculture and other food production activities require the use of fishmeal and fish oil. Whether the increase in demand has raised their prices very much depends on whether fishmeal is a separate market or part of the larger market for meals, of which soy is by far the largest component (Asche and Bjørndal, 2011). Fishmeal and fish oil play a key role in the feeding, and consequently in the costs, of a large number of aquaculture segments. These price increases have caused a structural change in the fishing sector, further developing low-value fisheries, while creating an incentive, for aquaculture, for research and innovation to minimize fishmeal and fish-oil consumption (Kristofersson and Anderson, 2006). In fact, the ratio of wild fish input from industrial feeds to total farmed fish output has decreased from 1.04 in 1995 to 0.63 in 2007 (Naylor *et al.*, 2009). This decrease is owed, in great part, to the increase in omnivorous farmed fish production, as well as to improved efficiency, for example in salmon farming (Asche and Bjørndal, 2011).

Whether demand for fishmeal and fish oil has increased pressure on pelagic stocks depends on the management systems in place (ibid.). In an open access situation, a price increase is likely to lead to further stock depletion. However, in an optimally managed fishery, increased demand for fishmeal will have little or no impact on fish quotas. Nevertheless, considering that most forage fisheries currently are fully exploited or overexploited, this means there are limited opportunities for increasing fishmeal and fish-oil supply from forage fish stocks (Grainger and Garcia, 1996; Alder *et al.*, 2008).

2.3. Environmental/ecosystem interactions

Genetic mixing (ranched fish and escaped fish), diseases and pollution, and the use of wild fish habitat for farmed sites. There are interactions resulting from the common use of resources such as water and land. There can be direct spatial interactions where aquaculture and capture fisheries compete for an area of water (e.g. farms could be placed in an area that fishers are using directly for fishing or as passage) or for port access (Hoagland, Jin and Kite-Powell, 2003).

Aquaculture can also affect fisheries through the modification and disruption of natural habitats and sensitive ecosystems brought about by the construction of aquaculture farms – affecting fisheries' resources and activities. For example, clearance of mangrove areas for building shrimp ponds may reduce settlement habitat for local fisheries, or cause: seabed disturbances through anchoring of aquaculture cages or pens, damage to seagrass, alteration to reproductive habitats and biodiversity loss (Soto *et al.*, 2012). On the other hand, some aquaculture structures could work as fish aggregation devices (FADs) (Dempster *et al.*, 2004).

Excessive nutrient discharges from farms can cause eutrophication of the water, leading to anoxia and fish mortality, which has a negative impact on biodiversity and wild fish stocks (Gowen, 1994).

Confining large numbers of animals in a small area can lead to water pollution, because a substantial fraction of nutrients in animal feed ends up in animal wastes, not all of which can be assimilated by the ecosystem (Mallin and Cahoon, 2003). The use of antibiotics, chemicals and fertilizers can also negatively affect fisheries (Soto *et al.*, 2008).

One of the major environmental challenges with marine aquaculture is the escape of fish from farms, and their subsequent ecological (Jonsson and Jonsson 2006; Thorstad *et al.*, 2008; Johansen *et al.*, 2012; Arechavala-Lopez *et al.*, 2013) and genetic (Skaala, Wennevik and Glover, 2006; Thorstad *et al.*, 2008; Besnier, Glover and Skaala, 2011) interactions with wild conspecifics. As a result of domestication, farmed fish (e.g. Atlantic salmon) display increasingly clear genetic differences from wild conspecifics. Examples are very large, genetically based differences in growth rates under hatchery conditions (Glover *et al.*, 2009; Solberg *et al.*, 2013a,b), gene regulation (Roberge *et al.*, 2006) and reduced survival in the natural environment (McGinnity *et al.*, 1997; Fleming *et al.*, 2000; Skaala *et al.*, 2012). For example, in Norway, which is the world´s largest producer of farmed Atlantic salmon, genetic changes have arisen in local wild populations because of domesticated salmon interbreeding. Interbreeding between farmed escapees and wild conspecifics has resulted in erosion of the population's genetic structure over a period of several decades (Skaala, Wennevik and Glover, 2006; Glover *et al.*, 2012, 2013), and farmed salmon introgression levels approaching 50 percent have been reported in some wild Norwegian populations (Glover *et al.*, 2013). Thus farmed escapees represent a significant threat to the genetic integrity and long-term evolutionary capacity of recipient wild populations (Hindar, Ryman and Utter, 1991; Naylor, Hindar and Fleming, 2005).

Among the environmental impacts, aquaculture has had an influence on catches of species used as inputs for the aquaculture industry. In certain parts of the world, this has affected and displaced wild populations in areas where intensive farming has been implemented, causing environmental degradation (Gillett, 2008). These kinds of negative interactions are often less problematic in developed countries, owing to more-restrictive regulations and effective controls.

Asche and Bjørndal (2011) distinguish between global or national and local environmental impacts of aquaculture. While the issue of the ‘fishmeal trap’ – relating to the issue of potential scarcity of fishmeal – obviously is a global concern, matters such as organic waste, antibiotics and chemicals, escapees and sea lice are clearly local concerns.

Conflicts regarding the use of water resources and common space are frequent between the fisheries and aquaculture sectors, but fisheries are not the only competing sector. Aquaculture expansion is often hampered by the development of other economic sectors, mainly tourism, energy production, recreational navigation and sports.

2.4. Regulatory interactions

Regulations can lead to situations of conflict and cooperation between the aquaculture and wild fisheries sectors. Many issues dealing with aquaculture inputs, resource use and outputs have common governance issues with fisheries (Soto *et al.*, 2012). A clear example is conflicts between small-scale fishers and fish farmers in coastal areas.

2.5. Shared infrastructure interactions

Post-harvest activities such as processing, transportation and retailing can benefit from farmed production when wild production is not sufficient to ensure full capacity. This can happen because of seasonality and variability of wild catches, or just a low level of wild production (e.g. due to overfishing). One example is the proposed development of industrial parks for aquaculture in Galicia, Spain, where processing facilities would be shared with fishers (Bjørndal and Øiestad, 2011).

2.6. Innovating interactions

Innovations taking place in aquaculture may benefit wild fisheries, or, vice versa, **i**nnovations taking place in wild fisheries may benefit aquaculture. For example, diverse product presentations (e.g. boneless and skinless fillets) developed for aquaculture products have been used later for wild products (e.g. cod). Logistics and transportation represent another example. Large-scale airfreight of fish was initially developed for farmed salmon, a technology now used for many other species, wild and farmed.

2.7. Market interactions: competition and market development

From an economic point of view, aquaculture has affected (decreased) seafood prices, mainly owing to increased supply (Anderson, 1985). Competition (substitutability) between wild and farmed species would lead to a decrease, or at least limit any increase, in wild fish prices (Anderson, 1985). Anderson (ibid.) shows that, in a situation of open access in capture fisheries with low production and thus high prices, the presence of aquaculture increases fish supply, which reduces consumer price. Consequently, fewer fishers exploit the resource, leading to increases in the natural fish stock as well as fishery production (owing to a backward supply curve in fisheries [Copes, 1970]). Thus the introduction of aquaculture leads to a higher total fish supply.

While Hannesson (2003) found that the overfishing problem in wild fisheries (of all species) was not significantly reduced by the development of aquaculture, other authors have shown that aquaculture products may contribute to a decrease in wild catch product prices (see, for instance, Béné, Cadren and Lantz, 2000; Asche *et al.*, 2005; Norman-López and Bjørndal, 2009). Lem, Bjørndal and Lappo (2014) analyse the development in fish prices up to 2030. They assume that the production of capture fish remains more or less stagnant, while various scenarios are considered for the future expansion of aquaculture. A main conclusion of their analysis is that it is the future development of aquaculture that will determine the prices of both capture and farmed fish. Moreover, if the future growth rate for aquaculture is not much less than that observed in the past two decades, fish prices in general will not increase much in the coming two decades.

Aquaculture also has a positive influence through development of new markets and the promotion of seafood consumption in general (Valderrama and Anderson, 2008). By its contribution to decreased seafood prices, aquaculture has accelerated the globalization of trade and increased the concentration and integration of the seafood industry worldwide. Quality improvements and new product developments have been encouraged, changing the way of doing business, with stronger market orientation and risk reduction owing to decreased price volatility.

Price interactions operate at a global level and can have serious consequences for producers in developed countries when the imported species come from countries with significantly lower production costs. Less-efficient wild fisheries and aquaculture firms may experience decreases in profits, compromising their futures. However, certain fisheries, especially those well managed, could benefit from a fishing-effort reduction. This could lead to increases in the catches and profitability per boat, while achieving significant improvements in quality (Knapp, 2007), without reducing the short-term total quantity of seafood available to consumers.

3. LITERATURE REVIEW ON COMPETITION AND MARKET INTERACTIONS BETWEEN FARMED AND WILD FISH

The development of prices over time provides important information on the relationship between products, as has been widely recognized by economists such as Cournot (1838), Marshall (1947) and Stigler (1969). Market integration analysis using time series data for prices has been applied to a number of seafood products. It is particularly useful in analysing a large number of products, as demand analysis in such cases is not feasible (Asche, Gordon and Hannesson, 2004). Relationships between variables have typically been studied with ordinary regression analysis. This analysis can be used when variables (i.e. prices) are stationary (Squires, Herrick Jr. and Hastie, 1989; Asche, Gordon and Hannesson, 2004). However, many economic variables show trends and thus, by definition, are non-stationary. When non-stationary time series are used in a regression model, relationships that appear to be significant may emerge from unrelated variables (spurious regression). Thus the use of cointegration methodology is required to find real long-run relationships between non-stationary variables. As most seafood prices have been found to be non-stationary, cointegration is the most commonly used empirical tool to test for market integration.[4]

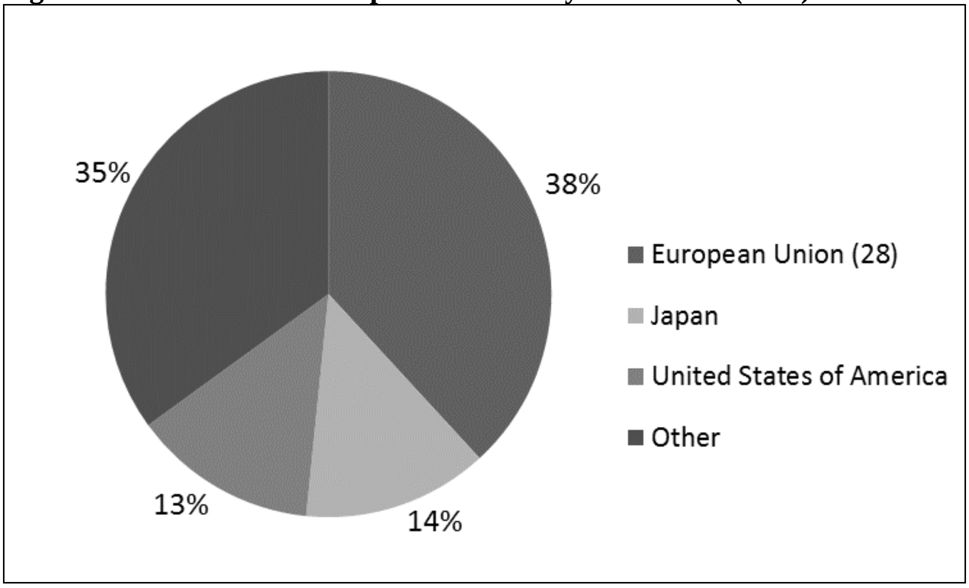
Considering the stagnation in world wild capture fisheries and the fast growth of the aquaculture sector, it is reasonable to expect that productivity improvements in aquaculture will lead to a reduction in the cost of production. If the two products (farmed and wild fish) are close substitutes, farmed fish will win market share from wild fish. If demand is not perfectly elastic, the price will decline, as will the incomes of fishers. However, if the two goods are not substitutes, there are no market effects, and the increase in the supply of farmed fish will only lead to a price decrease for farmed fish (Asche and Bjørndal, 2011).

Current knowledge of competition interactions between aquaculture and wild fish is based on a limited number of species and markets. Studies have mostly focused on salmon and trout, shrimp and prawn, catfish and tilapia, and seabass and seabream in European Union, Japanese and United States markets, which are the most-commonly traded species and the main consumer markets.

European Union (Member Organization) (28), Japan and the United States of America received 65 percent of all seafood imports in value in 2011. In fact, in that year, Japan and the United States of America were the individual countries receiving most imports, with almost US$18 billion each, followed by China (US$7.8 billion) and several European Union countries. The only other non-European Union country in the top ten is the Republic of Korea, which occupies ninth position with US$3.2 billion (FAO, 2015a).

[4] See for example, Asche, Bremnes and Wessells, 1999; Asche, 2001; Jaffry *et al.*, 2000; Quagrainie and Engle, 2002; Nielsen *et al.*, 2007; Norman-López and Asche, 2008; Nielsen, Smit and Guillen, 2009.

Figure 1. Share of seafood imports in value by destination (2011)

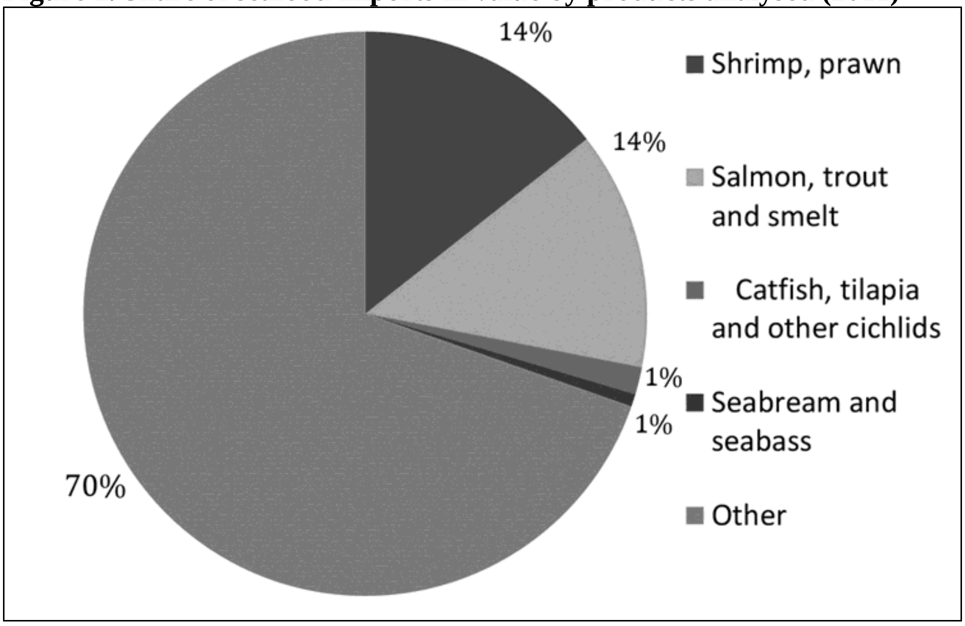


Source: FAO (2015a).

Shrimp and prawn, and salmon, trout and smelt are the two main species groups traded internationally, reaching US$19 and US$18 billion, respectively, in 2011. They are followed by tuna, bonito and billfish with almost US$14 billion; cod, hake and haddock with US$12.4 billion; squid, cuttlefish and octopus with US$6.5 billion; and herring, sardine and anchovy with US$4.7 billion (FAO, 2015a). However, only for the first two groups does a significant part of the production come from aquaculture.

There are also a relevant number of studies on catfish and tilapia, because imported, farmed produce competes with domestic produce in the United States market, as well as studies on seabass and seabream in the Mediterranean area.

Figure 2. Share of seafood imports in value by products analysed (2011)



Source: FAO (2015a).

3.1. Salmon and trout

There are six commercially relevant salmon species: Atlantic salmon (*Salmo salar*) is the only salmon species native to the Atlantic Ocean. The other five salmon species are native to the Pacific Ocean, all of them from the *Oncorhynchus* genus (Asche and Bjørndal, 2011).[5] All salmon species occur in nature only in the northern hemisphere. Nevertheless, salmon aquaculture has spread more widely and is present in countries in Europe, North and South America, Asia and Australia. Aquaculture has developed for three salmon species: Atlantic salmon and two Pacific species, chinook and coho.[6] However, a substantial part of wild-capture salmon landings from Canada (mainly chum and pink), Japan and the United States of America come from CBF (Asche and Bjørndal, 2011).

Farmed salmon trout (*Oncorhynchus mykiss*) is also produced in large quantities at a size that makes it comparable to salmon. It is sold mainly in Japan in competition with salmon (Asche *et al.*, 2005; Asche and Bjørndal, 2011). Substantial quantities of rainbow trout (814 000 tonnes in 2013) and other trout varieties are also farmed. However, these fish are produced at a smaller size (weighing less than 0.5 kg) and appear not to compete with the salmon species (Asche and Bjørndal, 2011).

Clayton and Gordon (1999) found that farmed Atlantic salmon (*Salmo salar*) and wild-caught chinook (*Oncorhynchus tshawytscha*) and coho salmon (*Oncorhynchus kisutch*) were substitutes in the United States market. It should be noted that in the 1980s and into the 1990s Atlantic salmon was still a luxury product, but currently this is no longer the case. Thus results based on old data may have little relevance to the current market situation, and outcomes from those studies should be considered carefully and may not be comparable to more-recent studies.

In France, Gordon, Salvanes and Atkins (1993), using Engle-Granger and Johansen cointegration tests (Engle and Granger, 1987; Johansen, 1988), found that farmed Atlantic salmon (*Salmo salar*) prices were not related to whitefish wild-caught turbot (*Psetta maxima*) and Atlantic cod (*Gadus morhua*) in Rungis, the wholesale market of Paris, during the period 1981–1990.

In the United Kingdom of Great Britain and Northern Ireland, Clay and Fofana (1999) found that the farmed Atlantic salmon (*Salmo salar*) price was not linked to the prices of wild-caught whitefish, such as Atlantic cod (*Gadus morhua*), saithe (*Pollachius virens*) and haddock (*Melanogrammus aeglefinus*).

Jaffry *et al.* (2000), using quarterly import prices for the period 1984–1996 and the Johansen cointegration test, examined the extent to which farmed salmon competes with the main traditional wild-caught fish species in the Spanish market. They found that farmed salmon was only a weak substitute for wild-caught tuna, hake and whiting, but no significant interaction could be found.

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[5] Global wild capture production of pink salmon (*Oncorhynchus gorbuscha*) was 563 000 tonnes in 2013, chum salmon (*Oncorhynchus keta*) almost 200 000 tonnes, sockeye salmon (*Oncorhynchus nerka*) almost 137 000 tonnes, coho salmon (*Oncorhynchus kisutch*) 29 000 tonnes, chinook salmon (*Oncorhynchus tshawytscha*) 9 000 tonnes and Atlantic salmon 2 000 tonnes. Very small quantities of masu salmon (*Oncorhynchus masou*) are harvested (FAO, 2015a).

[6] Global aquaculture production of Atlantic salmon was 2.1 million tonnes in 2013, coho salmon 157 000 tonnes and chinook salmon almost 13 000 tonnes (FAO, 2015a).

In Finland, imported farmed Atlantic salmon (*Salmo salar*), wild-caught salmon (*Salmo salar*) and farmed salmon trout (*Oncorhynchus mykiss*) were close substitutes. Using the Johansen cointegration test, it was found that imported farmed Atlantic salmon determined the price of wild-caught salmon and farmed salmon trout (Mickwitz, 1996; Setälä *et al.*, 2003; Virtanen *et al.*, 2005). Results between imported farmed Atlantic salmon and farmed salmon trout were sensitive to the period under investigation (Setälä *et al.*, 2003). Similarly, imported farmed Atlantic salmon (*Salmo salar*) and wild-caught Atlantic salmon (*Salmo salar*) from the Baltic Sea, perch (*Perca fluviatilis*), pikeperch (*Sander lucioperca*), European whitefish (*Goregonus lavaretus*) and pike (*Exos lucius*) were part of the same market (cointegrated) in Finland (ibid.). Finnish and Swedish markets for Atlantic salmon, whitefish, pikeperch and perch were partially integrated, while pike markets appeared to be national (Setälä, op cit.).

The German trout market[7] has been analysed by Nielsen *et al.* (2007), using import data and the Johansen cointegration methodology, for the period 1998–2003. Results show that imported farmed frozen trout was perfectly integrated with imported farmed Atlantic salmon (*Salmo salar*) and imported wild-caught Atlantic cod (*Gadus morhua*), and partially integrated with imported wild-caught Atlantic mackerel (*Scomber scombrus*) and imported wild-caught redfish (ocean perch, *Sebastes marinus*). For the same period, imported smoked farmed trout was perfectly integrated with imported smoked wild-caught Atlantic halibut (*Hippoglossus hippoglossus*) and Atlantic mackerel (*Scomber scombrus*), but not with imported smoked farmed Atlantic salmon (*Salmo salar*). However, imported fresh-farmed trout and fresh-farmed trout fillet prices were not related to imported fresh fillets of wild-caught Atlantic cod (*Gadus morhua*) and imported wild-caught redfish (*Sebastes marinus*).

Blomquist (2015) examined the situation in Sweden using 1996–2013 monthly import prices of frozen fillets of 12 different fish species and a bivariate Engle and Granger cointegration procedure. He found that Alaskan pollack and saithe were integrated and that hoki was integrated with hake, and cod with plaice. Imports of farmed Atlantic salmon (*Salmo salar*) were not integrated with any of the imports of wild-caught whitefish species.

Nielsen, Smit and Guillen (2009), using European import data for the period 1995–2005 and the Johansen cointegration methodology, found that fresh and frozen farmed Atlantic salmon (*Salmo salar*) imports were integrated with each other, but not with other fresh and frozen capture species imports. They also found evidence of: a fresh pelagic fish market consisting of herring, mackerel, anchovy and swordfish; a fresh whitefish market consisting of sole, cod, hake, whiting, monkfish and lemon sole; and a frozen whitefish market consisting of hake, cod, pollack, plaice and haddock. These results confirm previous work by Nielsen (2005), which used European import data for the period 1992–2000 and the Johansen cointegration methodology. Nielsen identified a partially integrated, European first-hand market for whitefish, with a perfectly spatially integrated cod market. Previously, Asche, Gordon and Hannesson (2004), using French import prices for the period 1983–1995 and the Johansen cointegration methodology, found evidence of a French whitefish frozen fillets market including cod, haddock and saithe, while redfish frozen fillets were loosely integrated with whitefish frozen fillets.

The Japanese market is the largest and most diversified salmon market in the world, where wild and farmed species from Europe and South and North America compete. Asche *et al.* (2005), using monthly import data for the period 1994–2000 and the Johansen cointegration methodology, found that wild-caught sockeye (*Oncorhynchus nerka*) and coho salmon (*Oncorhynchus kisutch*) and farmed coho salmon (*Oncorhynchus kisutch*) and salmon trout (large rainbow trout, *Oncorhynchus mykiss*) were close substitutes in the Japanese market. Thus the expansion of farmed salmon has led to decreased prices for all salmon species.

[7] Mostly small, portion-sized trout with white meat.

3.2. Catfish and tilapia

Most tilapia and catfish production comes from aquaculture. Farmed tilapia[8] production reached 4.8 million tonnes in 2013. Production of farmed catfish-like species[9] in the same year reached almost 4.2 million tonnes, including 2.0 million tonnes of pangassius family catfishes (FAO, 2015a).[10] Farmed catfish from *Ictalurus* family production reached 419 000 tonnes, all of it belonging to channel catfish (*Ictalurus punctatus*) (FAO, 2015a). To protect the United States domestic catfish industry, the United States Congress passed a law in December 2001 restricting use of the label 'catfish' in the United States market to only the species from the *Ictalurus* family farmed in the United States of America (Narog, 2003).

A significant part of catfish and tilapia wild capture catches come from culture-based fisheries (see Soto *et al.* [2012] for more details). In 2013, wild tilapia production reached 715 000 tonnes, while catfish from *Ictalurus* family production reached 13 000 tonnes – 667 000 tonnes when we apply a less-strict definition of catfish (so that other species are included, such as those from the pangassius family) (FAO, 2015a).

International tilapia trade has expanded significantly, from less than 1 000 tonnes in 1995 to almost 800 000 tonnes (live weight equivalents) in 2011,[11] valued at about US$1.4 billion (FAO, 2015a). China is the main exporter, with more than 80 percent of world exports in 2011, while the United States of America is the main importer with almost 80 percent of global imports (FAO, 2015a).

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[8] Includes Nile tilapia (*Oreochromis niloticus*), tilapias nei (*Oreochromis* (=*Tilapia*) spp.), blue-Nile tilapia, hybrid (*Oreochromis aureus x O. niloticus*), Mozambique tilapia (*Oreochromis mossambicus*), three-spotted tilapia (*Oreochromis andersonii*), blue tilapia (*Oreochromis aureus*), longfin tilapia (*Oreochromis macrochir*), redbreast tilapia (*Tilapia rendalli*), tilapia shiranus (*Oreochromis shiranus*), sabaki tilapia (*Oreochromis spilurus*), blackchin tilapia (*Sarotherodon melanotheron*), Cichla (*Cichla* spp.), Oreochromis tanganicae (*Oreochromis tanganicae*), banded jewelfish (*Hemichromis fasciatus*), mango tilapia (*Sarotherodon galilaeus*), redbelly tilapia (*Tilapia zillii*) and jaguar guapote (*Cichlasoma managuense*).

[9] Includes pangas catfish nei (*Pangasius* spp.), torpedo-shaped catfish nei (*Clarias* spp.), amur catfish (*Silurus asotus*), channel catfish (*Ictalurus punctatus*), striped catfish (*Pangasius hypophthalmus*), yellow catfish (*Pelteobagrus fulvidraco*), North African catfish (*Clarias gariepinus*), African bighead catfish, hybrid (*Clarias gariepinus x C. macrocephalus*), Chinese longsnout catfish (*Leiocassis longirostris*), pangas catfish (*Pangasius pangasius*), Philippine catfish (*Clarias batrachus*), Asian redtail catfish (*Hemibagrus nemurus*), upsidedown catfish (*Synodontis* spp.), stinging catfish (*Heteropneustes fossilis*), wels(=Som) catfish (*Silurus glanis*), bagrid catfish (*Chrysichthys nigrodigitatus*), Amazon sailfin catfish (*Pterygoplichthys pardalis*), South American catfish (*Rhamdia quelen*) and African catfish (*Heterobranchus bidorsalis*.

[10] Striped catfish or tra (*Pangasius hypophthalmus*), pangas catfish or basa (*Pangasius pangasius*) and pangas catfishes nei (*Pangasius* spp.).

[11] FAO Fisheries Commodities Production and Trade statistics for 2011 (FAO, 2015a) indicate exports of: 192 000 tonnes of fresh and frozen tilapia fillets, 63 000 tonnes of tilapia prepared or preserved, not minced, and 146 000 tonnes of whole, fresh and frozen tilapia. The live-weight equivalents were then calculated at 1.0 times the weight of whole tilapia, 2.03 times the weight of tilapia prepared or preserved, not minced, and 2.7 times the weight of fillets (Cao *et al.*, 2015).

Similarly, international catfish trade has expanded significantly, from less than 2 000 tonnes in 2001 to almost 1.5 million tonnes (live weight equivalents) in 2011,[12] with a value of about US$0.6 billion (FAO, 2015a). Viet Nam is the main exporter, with more than 90 percent of world exports in 2011, while imports are more-widely distributed, with the United States of America being the main importer with 36 percent, Spain with 12 percent, Germany with almost 10 percent, the Netherlands with 8 percent, and Italy with almost 5 percent (FAO, 2015a).

The United States of America is not only the main international market for catfish and tilapia, but also the only developed country with a significant national production of one of these species. It produced 163 000 tonnes of channel catfish (*Ictalurus punctatus*) in 2013 (FAO, 2015a). However, United States catfish producers have often complained that imports of catfish and tilapia affect their prices in the United States market. Following complaints from the Association of Catfish Farmers of America (CFA) regarding unfair trade involving the massive import of cheap catfish, the United States of America imposed an anti-dumping tariff ranging from 44.66 percent to 63.88 percent on all Vietnamese catfish imports in 2003 (Duc, 2010).

Ligeon, Jolly and Jackson (1996) investigated the effects on United States domestic catfish of imported catfish from other North American Free Trade Agreement (NAFTA) member countries, in particular Mexico and, early on, also Canada, using Ordinary Least Squares regressions for double log functions. Outcomes of the study indicate that imported catfish behaves as an inferior good (there is a negative relationship between United States average income and imported volumes of catfish). Moreover, they demonstrate that the quantity of imported catfish decreases when the United States domestic price declines, owing to a decrease in import prices that makes the United States market less attractive to exporters. At the same time, an increase in imports from NAFTA countries would not have a significant effect on the domestic industry, owing to the low level of catfish imports at that time. Kennedy and Lee (2005), using Ordinary Least Squares and Seemingly Unrelated Regressions, found that imports of catfish have a negative effect on United States domestic catfish prices. In addition, they indicate that catfish and income consumption have a positive relationship, showing that catfish behaves as a normal product, contradicting the previous results from Ligeon, Jolly and Jackson (1996). Catfish prices in the United States of America are also affected by trout, clam and chicken supplies. Hong and Duc (2009), using a Linear Approximate Almost Ideal Demand System (LA/AIDS), found that demand for United States domestic catfish is price inelastic and demand for imported frozen catfish fillets is price elastic for the period 1999–2007. They also found substitution relationships between imported catfish and domestic catfish, domestic catfish and tilapia, domestic catfish and salmon, tilapia and salmon, and salmon and imported catfish. Quagrainie and Engle (2002), using a bivariate Engle and Granger cointegration procedure, found that catfish producer prices play an important role in determining the price of domestic frozen catfish fillets – and the price of domestic frozen catfish fillets in determining the price of imported frozen catfish fillets.

Norman-López and Asche (2008), using the Johansen cointegration test, found that there is a single United States market for domestic catfish for fresh and frozen catfish fillets for the period 1997–2006. Conversely, results also show that the markets for fresh and frozen tilapia fillets are separate. This is explained, at least in part, by varying production technologies, quality, and/or transportation costs among tilapia producer countries. In fact, fresh tilapia fillets are mainly shipped from Latin America, while the frozen products are primarily imported from Southeast Asia. Moreover, none of the forms of tilapia product was found to compete with catfish. Norman-López and Bjørndal (2009) confirm these results, showing that imports of farmed tilapia products from the largest producing regions in Asia, Africa and South and Central America are not perceived as similar products (i.e. are not cointegrated) in the United States of America for the period 2002–2006. Similarly, no relationship was found between different tilapia products: between imports of whole, frozen tilapia and frozen tilapia fillets in

[12] FAO Fisheries Commodities Production and Trade statistics for 2011 (FAO, 2015a) indicate exports of: 468 000 tonnes of fresh and frozen catfish fillets, 85 000 tonnes of catfish steaks frozen, and 2 000 tonnes of whole, fresh and frozen catfish. The live-weight equivalents were then calculated at 1.0 times the weight of whole catfish, 1.67 times the weight of catfish steaks, and 2.86 times the weight of fillets (Cao *et al.*, 2015).

the United States market, as well as between the highest quality, whole, fresh tilapia (grade 1) and frozen tilapia fillets in Egypt.

Norman-López (2009) investigated the degree of market integration, using the Johansen cointegration test, between fresh-farmed tilapia fillets, fresh fillets of farmed catfish, wild sea dab, wild blackback flounder and wild, whole fresh red snapper in the United States market. The results indicate no relationship between the prices of fresh-farmed tilapia and catfish, so fresh tilapia fillets do not compete in the same market as catfish fillets. However, fresh-farmed tilapia fillets do compete with wild whole red snapper, wild fresh fillets of sea dab and wild blackback flounder.

In Uganda, Bukenya and Ssebisubi (2014), using monthly price data from 2006 to 2013 and the Johansen cointegration test, showed that domestic farmed and wild-harvested North African catfish (*Clarias gariepinus*) form part of the same market. Gordon and Ssebisubi (2015) found a similar pattern, using monthly price data from Uganda for the period 2006–2010 and the Johansen cointegration test. They demonstrated that farmed and wild-caught North African catfish (*Clarias gariepinus*), farmed and wild-caught Nile tilapia (*Oreochromis niloticus*) and wild-caught Bagrus form one market, while wild-caught Nile perch (*Lates niloticus*) and wild-caught mukene (silver cyprinid, *Rastrineobola*) follow separate and individual trends. However, Singh *et al.* (2015), using monthly price data from Thailand for the period 2001–2010 and the Johansen cointegration test, showed that prices of Nile tilapia (*Oreochromis niloticus*), walking catfish (*Clarias* spp.), vannamei shrimp (*Penaeus vanamei*) and Asian seabass or barramundi (*Lates calcarifer*) are not related.

In Nigeria, Bada and Rahji (2010) used the Johansen cointegration test and annual data for the period 1970–2005 and discovered that the price of domestic farmed North African catfish (*Clarias gariepenus*) is determined by the imports of hake (Panla/stockfish), mackerel (*Mackerel* spp.) and sardinella (*Sardinella eba*). However, they also found that the prices of imported species do not depend on Nigerian domestic species.

3.3. Shrimp and prawn

Annual worldwide production of wild shrimp and prawn has been oscillating over time between 3.1 and 3.4 million tonnes since the beginning of the century. A list of the species of Decapoda and Natantia (i.e. shrimp and prawn) of interest to fisheries is presented by Holthuis (1980). In 2013, global production reached 3.4 million tonnes, with China responsible for 37 percent of production, followed by India (11 percent), Viet Nam (8 percent), Indonesia (7 percent), Canada (4 percent) and the United States of America (4 percent) (FAO, 2015a). Worldwide production of farmed shrimp and prawn increased to 4.5 million tonnes in 2013. China is responsible for 38 percent of production, followed by Indonesia (14 percent), Viet Nam (12 percent) and Ecuador, India and Thailand with 7 percent each (FAO, 2015a). The shrimp species that have proved best suited to aquaculture are located mainly in tropical and semi-tropical regions (Béné, Cadren and Lantz, 2000).

Shrimp and prawn are one of the most internationally traded seafood commodity groups, representing 15 percent of the total seafood value traded (FAO, 2015a). Some 2.7 million tonnes of shrimp and prawn, valued at US$19.5 billion, were commercialized internationally in 2011 (FAO, 2015a). The main exporting countries were Thailand, with 14 percent of total exports, Viet Nam (13 percent), China (11 percent) and India (10 percent). The main importers were the United States of America, with 24 percent of total imports, Japan (12 percent), Spain (7 percent), and France, Denmark and the United Kingdom of Great Britain and Northern Ireland with 4 percent each. Thus the United States of America, European Union (Member Organization) and Japan are the main international markets for shrimp and prawn. Vinuya (2007) documents the existence of a global farmed shrimp market.

Most United States consumption comes from imported farm-raised shrimp (Anderson, 2003). Domestic production, including both wild fisheries and aquaculture, reached slightly more than 143 000 tonnes, while imports represented 577 000 tonnes and exports less than 15 000 tonnes of shrimp and prawn in 2011 (FAO, 2015).

Most United States shrimp production comes from capture fisheries, while United States shrimp aquaculture is still minimal, with less than 6 000 tonnes in 2013 (ibid.). The United States of America maintains a significant wild shrimp fishery (Mukherjee and Segerson, 2011). United States domestic capture shrimp production has been relatively stable at 100–150 000 tonnes since the early 1990s (FAO, 2015a). In 2013, United States domestic shrimp production was 128 000 tonnes (ibid.). The three main species were northern brown shrimp (*Penaeus aztecus*), northern white shrimp (*Penaeus setiferus*) and ocean shrimp (*Pandalus jordani*), representing almost 95 percent of the total. However, United States domestic shrimp prices have fallen since the 1980s owing to the increase in imports, resulting in a loss of revenues generated by the fishery (Keithly, Roberts and Ward, 1993; Gillig, Capps and Griffin, 1998; Kennedy and Lee, 2005; Keithly and Poudel, 2008). After United States fishers filed anti-dumping complaints against several shrimp exporting countries at the end of 2003, the United States of America enacted trade restrictions on several shrimp products from six Asian and Latin American countries in 2004 (Keithly and Poudel, 2008).

Keithly, Roberts and Ward (1993), using a Dynamic Simultaneous Equations System (DSES) model, indicated that if there were no shrimp aquaculture, United States wild shrimp prices in 1988–1989 would have been about 70 percent higher. Gillig, Capps and Griffin (1998), using a Three-Stage Least Squares (3SLS) procedure, found that United States domestic ex-vessel prices were influenced by imported landings, the smallest-sized shrimp being the most responsive to import supplies. Kennedy and Lee (2005) confirmed these results, using Ordinary Least Squares and Seemingly Unrelated Regressions to find that imports of shrimp had a negative effect on United States domestic shrimp prices.

Asche, Oglend and Smith (2012), using the Johansen cointegration methodology, proved that United States capture shrimp and imports of farmed ‘shell-on frozen’ shrimp were substitutes in the United States market during the period 1990–2008. Thus United States capture shrimp prices will not increase when domestic production decreases. In fact, decreased shrimp production in North Carolina in 1999–2005, due to hypoxia (low oxygen water), did not lead to price increases (Huang, Smith and Craig, 2010; Huang *et al.*, 2012). Moreover, the existence of market integration for shrimp suggests that trade restrictions mostly lead to changes in trade patterns (e.g. shifting to imports from non-restricted countries or non-restricted shrimp products), with little benefit to domestic producers (Keithly and Poudel, 2008; Asche, Oglend and Smith, 2012).

Farmed production in Europe is almost negligible, so all domestic production comes from capture fisheries. Béné, Cadren and Lantz (2000), using the Johansen cointegration test, found that imports of wild brown shrimp (*Penaeus subtilis*) from the French Guiana fishery were substitutes for imports of cultured Thai black tiger shrimp (*Penaeus monodon*) in the French market in the period 1986–1993. More recent studies are not available.

3.4. Seabream and seabass

Most seabream and seabass production comes from aquaculture in Mediterranean countries. Farmed gilthead seabream (*Sparus aurata*) production reached 173 000 tonnes in 2013; while wild-caught production was 7 000 tonnes. Farmed European seabass (*Dicentrarchus labrax*) production reached 161 000 tonnes in 2013; while wild-caught production was less than 10 000 tonnes (FAO, 2015a).

In Spain, Alfranca, Oca and Reig (2004), using 2000–2001 weekly price data from Mercabarna (Barcelona’s wholesale market) and the Johansen cointegration test, found that farmed gilthead seabream (*Sparus aurata*) prices determine the evolution of wild gilthead seabream (*Sparus aurata*) prices more accurately than do previous wild gilthead seabream prices. Prices of wild sole

(*Solea* spp.), farmed Atlantic salmon (*Salmo salar*), farmed seabass (*Dicentrarchus labrax*) and wild seabass (*Dicentrarchus labrax*) have a rather weak influence on prices of farmed and wild seabream (*Sparus aurata*).

However, Rodríguez, Bande and Villasante (2013), using 2007–2012 monthly price data from Mercamadrid (Madrid's wholesale market) and the Johansen cointegration test, found that wild and farmed gilthead seabream (*Sparus aurata*) are two heterogeneous products and consequently are not substitutes. This could be explained, at least in part, by the negative perception of aquaculture products in Spain compared with wild fish (Fernández-Polanco and Luna, 2010; Claret *et al.*, 2012).

In France, Regnier and Bayramoglu (2014), using 2007–2012 monthly household prices and the Johansen cointegration test, found that fresh whole wild seabream (*Sparus aurata*, *Spondyliosoma cantharus*,
Pagellus bogaraveo, *Coryphaena hippurus*, *Sebastes mentella*, *Sebastes marinus* and *Lithognathus mormyrus*) and farmed seabream (*Sparus aurata*) are partially integrated and that their price relationship is led by farmed seabream, whereas whole wild seabass (*Dicentrarchus labrax* and *Anarhichas lupus*) and farmed seabass (*Dicentrarchus labrax*) are not integrated.

In Italy, Brigante and Lem (2001), using 1991–1998 quarterly ex-vessel and ex-farm prices and a bivariate Engle and Granger cointegration procedure, found that wild and farmed species are not substitutes for gilthead seabream (*Sparus aurata*) and European seabass (*Dicentrarchus labrax*).

3.5. Other species

Park, Davidson and Pan (2012), using a qualitative approach, showed that prices for the most-favoured sashimi species (i.e. olive flounder [*Paralichthys olivaceus*], black rockfish [*Sebastes schlegeli*], red sea bream [*Pagrus major*] and grey mullet [*Mugil cephalus*]), both wild-caught and farmed, declined as farmed production expanded in the South Korean market. Kim (2014), using the Johansen cointegration test, showed no long-term equilibrium relationship (meaning they do not share the same market) between the same four main, farmed fish species in the Republic of Korea: olive flounder, black rockfish, red seabream and grey mullet.

4. CONCLUDING REMARKS

When there is market integration between farmed and wild species, it implies that farmed and wild prices follow the same long-run pattern. Market integration between wild and farmed species often occurs between wild and farmed conspecifics, but it can also occur between different species, in particular when they are similar products. Market integration has been proven for different species and markets, but has been rejected in other cases. This suggests that some species and markets are more likely to be affected than others. Owing to the diversity of the results reported and the low number of studies in the literature, these findings can only be generalized with caution and based on the specific ecological, economic and institutional characteristics of each species studied (Rodríguez, Bande and Villasante, 2013; Villasante *et al.*, 2013).

Results are sensitive to the period being investigated (Setälä *et al.*, 2003). Fish markets are dynamic and are changing continuously. Competition (market integration) between species may take some time to develop once the farmed species reaches the market (e.g. the quality or reputation of farmed production may improve with time). Moreover, consumer preferences change over time, in part because of marketing campaigns and external factors (e.g. the economic crisis). Indeed, frozen and fresh tilapia prices did not follow a similar trend in the United States of America, but the 2008 economic and financial crisis has made consumers more price-sensitive, substituting fresh tilapia from South America with frozen tilapia from Asia, which has a lower price (Tveteraas, 2015). Hence, the economic downturn may have produced changes in demand, strengthening price linkages between some products (Guillen and Maynou, 2015; Tveteraas, 2015).

Consequently, we expect that market interactions between farmed and wild fish may increase in the future, as a larger part of fish supply will come from aquaculture and a larger market share of sales will take place in supermarkets and large retailers. In line with this, Lem, Bjørndal and Lappo (2014) analysed the development in fish markets up to 2030. Outcomes of the study show that, in the future, prices of both capture and farmed fish will be driven largely by the development of aquaculture production, while per capita fish consumption is likely to be maintained, if not increased, in most scenarios, although important differences between regions of the world will remain. In fact, it is expected that some aquaculture species could be integrated (directly compete) with meat products (e.g. chicken) (Eales and Wessells, 1999).

On the other hand, there is growing interest among certain consumers in buying local food – and wild-caught seafood in particular (Asche *et al.*, 2012). Thus it is possible that certain local, wild-caught varieties (e.g. large-sized products) could successfully create or maintain their niche market segment, and not enter the market integration that most wild-caught varieties will enter with imported production.

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