The Economics of Aquaculture with respect to Fisheries

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MARKET INTERACTIONS IN AQUACULTURE

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Abstract

During the last two decades there has been a tremendous growth in the production of intensively farmed fish. This growth has been accompanied by a substantial reduction in prices. As this enhances the competitiveness of farmed fish, concerns are often raised with respect to the market impact of new aquaculture species. Of particular interest is the relationship to wild species in the output market as well as in the input market because of the demand for feed. In this paper we investigate what we know about market interactions based on two simple market models, where the difference between the two models is whether the competing product is wild-caught seafood or a traditionally produced product.

Keywords: Aquaculture, market interaction, fishmeal trap

Jel classification:

Introduction

During the past 20 years, new production technologies have allowed farmed fish to become an important segment of the world fish market. Since 1970, production has increased from about 3.5 million tonnes to more than 50 million tonnes in 2003. Moreover, most of this growth is taking place in the developing world as this makes up more then 80 percent of total production. At the same time, landings of wild fish have been stagnant while demand for fish and seafood has been perceived to increase. Farmed seafood is now among the most important species in the largest seafood markets in the world, the European Union, Japan and the United States (Anderson, 2002). Moreover, it is obvious that many of the new species are perceived to be competitors from the number of anti-dumping and trade restricting measures that has been implemented. As such, it is clear that aquaculture products are perceived to be substitutes for wild-caught seafood. At the same time, several authors have observed that several farmed species are using marine inputs as feed, and based on this fact,

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argue that increased aquaculture production leads to increased fishing pressure for species that are used in the feed. This hypothesis is known as the fishmeal trap. Hence, aquaculture production also interacts with wild stocks through the markets for its feed inputs.

In this paper, we look at some of the impacts of the additional supplies of farmed seafood on the world's fish markets. Asche, Bjørndal and Young (2001) provide a number of hypotheses with respect to these potential interactions. These are: a) increased supplies of farmed fish depress the prices of wild-caught fish destroying fishermen's livelihoods2, b) increased supply of farmed fish is necessary to maintain the supply of fish protein as populations grow and landings stagnate, c) farming enhances wild stocks as reduced prices lead to lower fishing effort, d) farmed fish increase the demand for fish in general as stable fish supplies with reliable quality also allow for more outlets with seasonally supplied wild fish. In addition, there is the hypothesis of the fishmeal trap. Depending on your stand, these hypotheses indicate that increased farmed seafood production may be positive or negative. Moreover, while the market impact from farmed fish is likely to be closest for "similar" species, it may also be important with respect to other types of fish and seafood products and different types of meat. Although many observers have been most concerned with the impact of farmed fish on wild-caught fish, market structure is also important for the farmers. If their product competes in large market, increased aquaculture production will have only a limited price effect. This may make it easier for the industry to grow than in the case where there are few or no substitutes, and the farmers have to create the market for their product. In addition, there are a number of issues related to growing aquaculture production, such as environmental issues and coastal use.

In this paper, the focus is on the market impact of farmed fish, or how the increased supplies and reduced prices of farmed fish affect demand for potentially competing products. As these questions are largely related to market structure, the discussion is mainly about what is known about the market structure for these types of farmed fish. As noted by Anderson (1985), this problem becomes particularly interesting for a subset of the potentially competing goods, other fish. This is because the biological constraint on the supply of wild-caught fish makes the supply schedule for these products backward-bending. However, since catching wild fish and fish farming are very different methods of producing fish, farmed fish will have a number of unique attributes compared to the wild-caught fish even if the meat sold is largely the same. Our empirical examples will focus on salmon, for two main reasons. The most important is that salmon is clearly the most studied seafood species when it comes to market knowledge. In fact, it is the only species where there is a substantial academic literature on this topic. Moreover, it is also in many ways the species for which most innovations have taken place technologically as well

[2] This hypothesis apparently led to riots in France in 1993-1994; see e.g. Peridy, Guillotreau and Bernard (2000).

as market-wise. Hence, salmon is the species which has most likely experienced most of the potential market interactions that can take place.

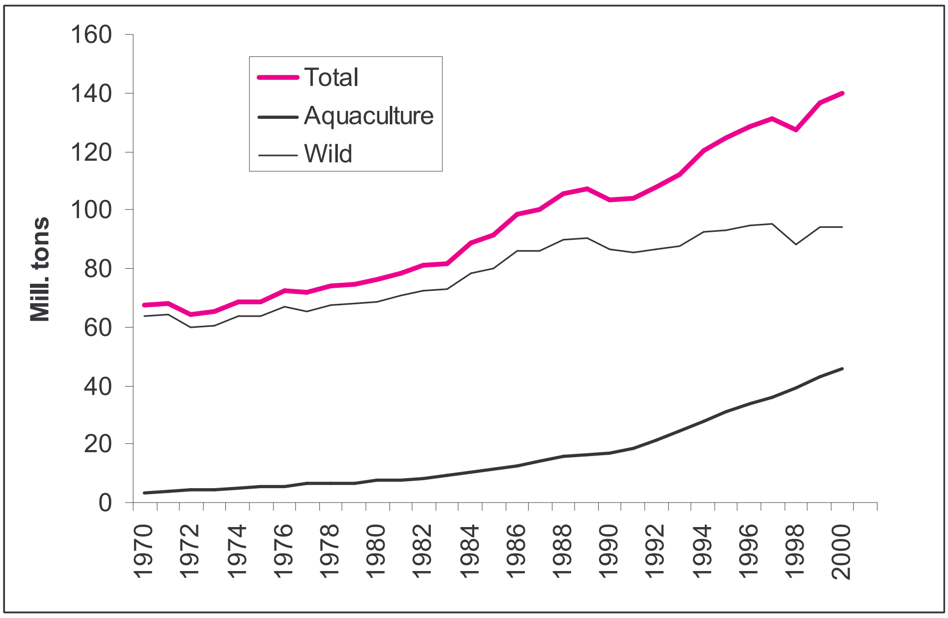
The paper is organised as follows: Section 2 presents some background information on aquaculture. In Section 3 a brief account of market interactions, using a simple economic model is given, while methods for measuring market interaction are discussed in Section 4. In Section 5, market interactions of the three groups of species are studied; this is followed in Section 6 by a discussion of the fishmeal trap. In Section 7 some concluding remarks are provided.

Aquaculture production

Aquaculture is an old production technology that can be dated back at least two millennia in China, and it has more than a hundred years of history in many other parts of the world. Depending on species and region, there is also a wide variety in production methods from freshwater ponds to mussel stakes. However, there are also several common features, which can most easily be described as very extensive production technologies. In most cases, fingerlings, fries or small individuals collected from wild stocks are placed in an environment where they can feed themselves, but where the farmer has sufficient control to be able to harvest them.

During recent decades, a revolution has taken place with respect to the production technology that is available in aquaculture, as semi-intensive and intensive production technologies have been invented. This has led to a substantial increase in production. In Figure 1, we show total global seafood production from 1970 together with wild and aquaculture production. As can be seen, aquaculture was relatively insignificant in 1970, making up only about 5% of total seafood production with a production volume of about 3.5 million tonnes. In 2003, this had increased to about 55 million tonnes so that aquaculture constitute about a third of the total seafood supply. Moreover, while landings of wild fish has been stagnant since the late 1980s, aquaculture production has increased so much that it more than makes up for this and in fact keep up the rate of increase in the supply of seafood. Supply of seafood has been increasing more rapidly then the global population growth, so that per capita supply of seafood has increased in all of the three previous decades. Hence, it is clear that aquaculture already plays a very important role in the global supply of food.

Figure 1: Global production of seafood, wild and aquaculture



Source: FAO.

China is clearly the largest aquaculture producer, with different species of carp and scallops, oysters and mussels as the most important product forms. However, although exports of tilapia and shrimps have become significant in recent years, most of the production is for domestic use. The same is true for much of the other low valued farmed seafood that is produced. We will here focus on the high valued species that are traded, with shrimp and salmon as the leading species. Shrimps and salmonids combined makes up just about 5% of total production, but makes up as much as 20% of production value. Moreover, it is among the top five species consumed in the three main import markets, the EU, Japan and the US. These are the largest seafood markets in the world by value, and the targeted markets for many new aquaculture species.

All successful new aquaculture species, when success is measures as a significant quantity produced, has at least one common feature. The price declines significantly as production increase. This is only natural, as this is necessary to make the product competitive in the market. This is shown for shrimp in Figure 2, and for salmon in Figure 3. In the following we give some attention to salmon, to illustrate the mechanisms involved.

Figure 2: Global aquaculture production of shrimp and real prices (2003=1)

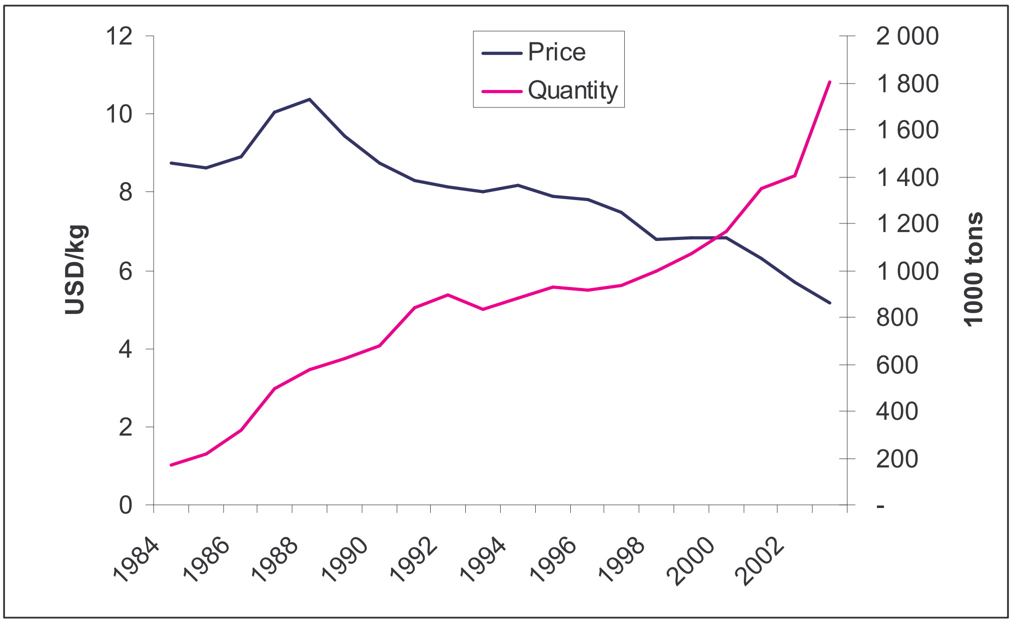
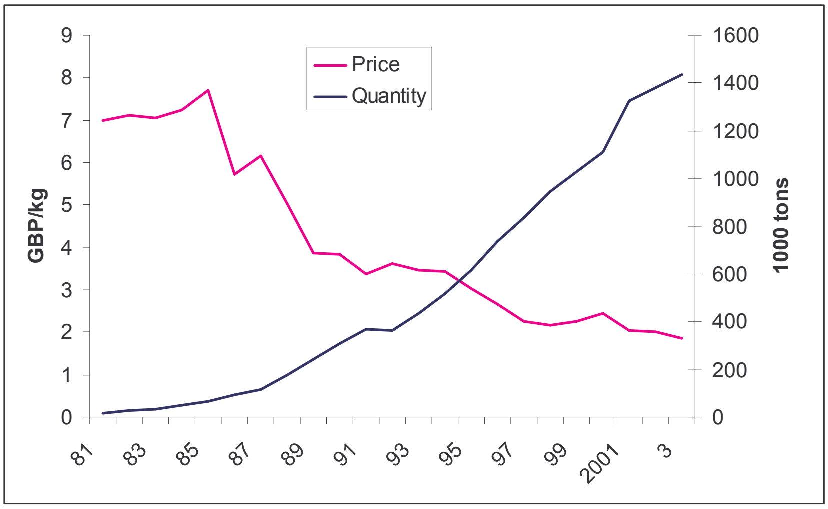


Figure 3: Global aquaculture production of Atlantic salmon and real price (2003=1)



The term 'farmed salmon' refers to Atlantic salmon, coho and salmon trout, which are very similar species and seem to be highly substitutable.3 Salmon is the most successful of the intensively farmed species when measured by the quantity produced. Salmon aquaculture became commercially interesting in the early 1980s. From then on, the availability of salmon increased substantially. In 1980 the total supply of salmon was about 500,000 tonnes, of which only

[3] About 80% of the farmed salmon were Atlantic, and its share seems to be increasing. It should also be noted that in Canada about 10 000 tonnes of farmed chinook are produced each year.

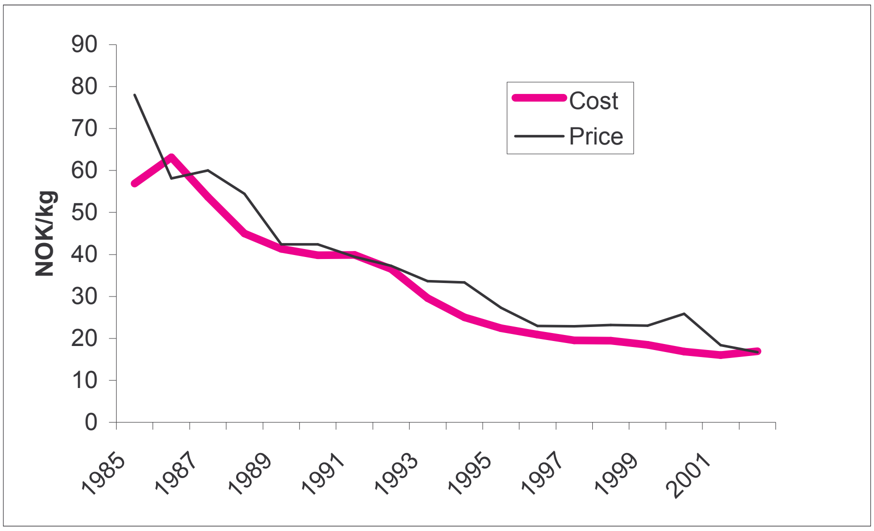
13,000 tonnes were farmed. During the 1980s the landings of wild Pacific salmon increased substantially to historically high levels; in the 1990s, these have been about 800,000 tonnes, although with much variation. However, the most significant change in the salmon market is the huge increase in the supply of farmed fish. From 13,000 tonnes in 1980, farmed production increased to about 1.4 million tonnes in 2004, making the total supply of salmon over 2 million tonnes, or more than a quadrupling since 1980.

Figure 4 shows total aquaculture production, the real Norwegian export price and production cost.4 It is evident that the increase in production has been accompanied by a substantial reduction in prices; in real terms, the price at the turn of the century was only one third that of 1982. However, production costs have also declined, hence expansion has been possible because of substantial productivity growth (Asche, 1997). Although this suggests that a large part of the growth in salmon aquaculture has been a move down along the demand schedule, there is also evidence that this has been amplified by market growth, partly due to generic advertising programmes (Bjørndal, Salvanes and Andreassen, 1992; Kinnucan and Myrland, 1998). There is also a substantial productivity development taking place in the supply chain as the predictability of the supply is much larger for farmed seafood. This is shown for catfish by Zidack, Kinnucan and Hatch (1992). A measure that provides evidence with respect to the magnitude is that Norwegian salmon farmers are paid almost 50% of retail value for whole fresh salmon. For cod fishermen, the same percentage is between 10 and 15%. The increased share of retailed fish that is sold through supermarket chains (Murray and Fofana, 2002) is also beneficial to aquaculture with a higher degree of control in the supply chain.

It is also worthwhile noting that farmed salmon is produced in large quantities in only a few countries. With their 2004-share in parentheses, Norway (37%), Chile (36%), the UK (10%) and Canada (8%) make up more than 90% of the total quantity produced. Given that Canada and the UK are members of respectively NAFTA and the EU, this has led to a number of trade conflicts (Asche, 1997, Anderson and Fong, 1998). The main target has been Norway, not surprisingly given its dominant share of production, but recently Chilean producers have also been found guilty of dumping in the US, and they also face penalties on their exports.

[4] The markets for different species and product forms of salmon seem to be highly integrated (Asche and Sebulonsen, 1998, Asche, Bremnes and Wessells (1999) and Asche (2000). Therefore, there should be no problem in interpreting the Norwegian export price as the global price of salmon.

Figure 4: Real production cost and producer price, 1985-2002 (2002=1)



Theory

Market interactions, such as the ones considered here, are the core of microeconomic theory. A formal albeit simple model of market interactions will be developed to highlight some of the relationships under investigation. In particular, an interesting relationship is due to the fact that an important subset of the potentially competing goods to farmed fish, captured fish, has a backward-bending supply schedule (Anderson, 1985). Moreover, as many of the world's fish stocks are reported to be fully or overexploited, it is likely that the market equilibrium for many of the world's fish stocks is on the backward bending part of their supply schedule.

Consider a very simple model with two goods, the aquaculture product and a potentially competing product. Let q_i^D be the quantity demanded, pi and pj the prices of the two products and I consumer expenditure or income. The demand for the two products can be written as:

$$q_i^D = a_i - b_i p_i + c_j p_j + d_i I \qquad (1)$$

where i=A and j=O if it is the demand for the aquaculture product, and i=O and j=A if it is the demand for the competing product. For the interaction between farmed and other products, the parameter cj is of key interest, as this gives the strength of the substitution effect. In particular, if cj=0, there is no substitution effect and therefore no market interaction.

The supply of farmed fish, q_i^S, is a function of output price, pi, and input price(s), wi, as is the supply of the competing product if it is a traditionally produced product. This can be written as

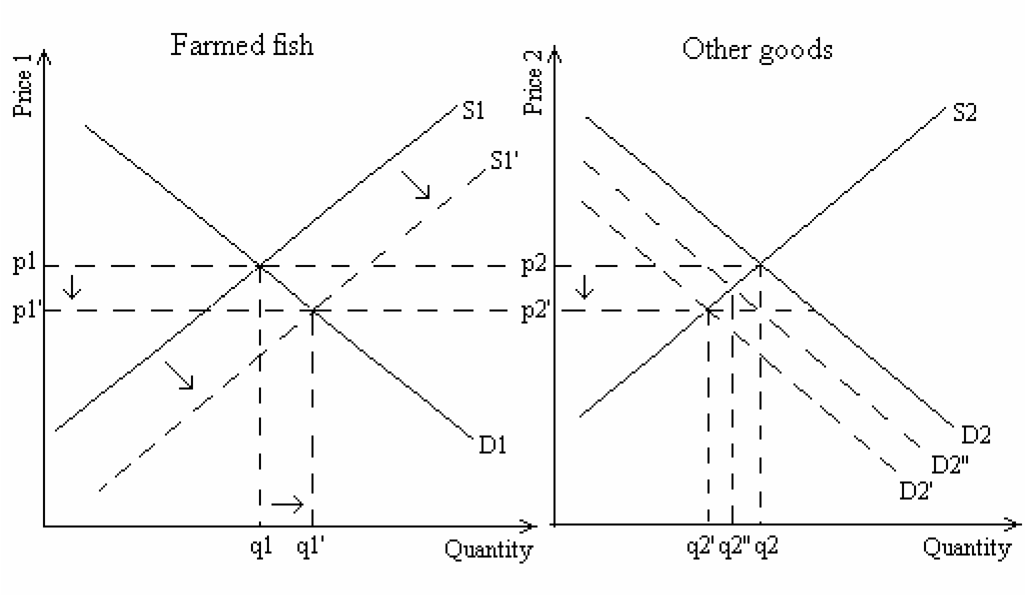
$$q_i^S = m_i + n_i p_i + o_i w_i \qquad (2)$$

The main cause for the increased supply of farmed fish is productivity growth. This may take two forms, productivity growth in the farming operation and productivity growth for the suppliers of input factors.5 The first corresponds to a reduction of mi, while the second results in reduced input price(s), wi. Productivity growth leads to a downward shift in the supply schedule.

Possible market interactions are illustrated in Figure 5, where demand and supply both for farmed fish and for a potentially competing product are shown. Assume that the prices are normalised so that they initially are equal for the two products, and that the supply of farmed fish shifts downward due to productivity growth. This leads the supply of farmed fish to increase from q1 to q1' and the price to decrease from p1 to p1'. The effect on the market for the potentially competing product depends on the parameter cA in the demand equation for this good, since this parameter determines the cross-price effect of the competing product with respect to a price change for farmed fish. If this parameter is zero, there will be no effect, price and quantity demanded remains at p2, q2, and there is no market interaction. If the parameter is positive, implying substitutes, a price reduction for farmed fish will lead to a downward shift in the demand for the competing product. At most, the demand schedule for the competing product can shift down sufficiently for the relative price to remain constant. This corresponds to the demand schedule D2' in Figure 5, with quantity demanded reduced to q2' and price to p2'. If there is a weaker substitution effect, the demand schedule for this product will shift down to e.g. D2''. This gives a reduction in price and demanded quantity, but the shift in demand is not sufficient to keep the relative price stable.

[5] A decomposition of productivity growth in salmon farming can be found in Tveterås (1999).

Figure 5: Potential market interaction between farmed fish and traditional goods



If the competing product is a wild-caught fish species, the supply will also be a function of the biological characteristics of the stock and/or the regulatory system. In open-access equilibrium, the supply schedule is backward-bending. Using the same bioeconomic model as Anderson (1985), the supply of wild-caught fish can then be written as:

$$q_i^S = \frac{rC}{p_i}\left(1 - \frac{C}{p_i K}\right) \tag{3}$$

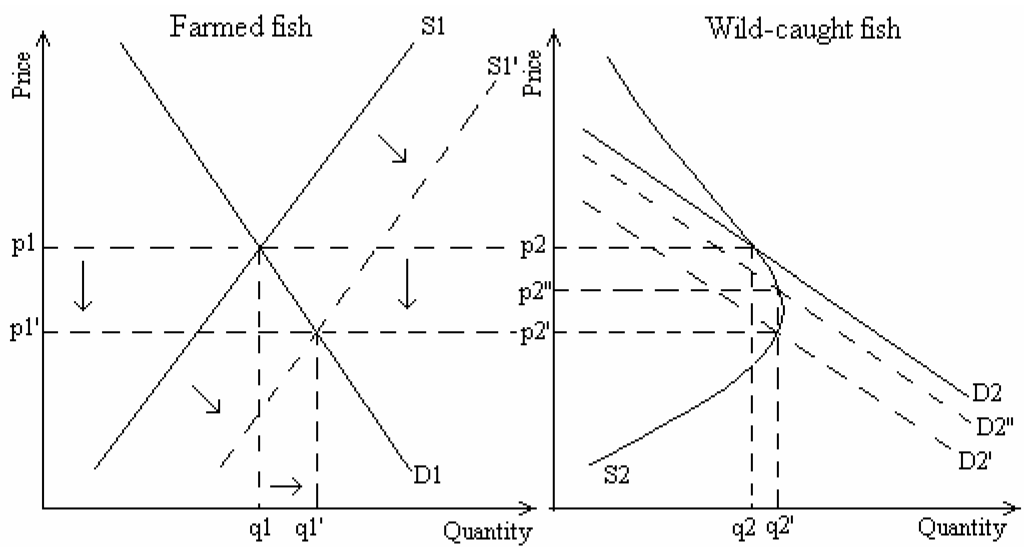
where r is the intrinsic growth rate of the fish stock, C is cost per unit of effort in the fishery and K is the environmental carrying capacity for this fish stock.6 If the fishery is managed with a quota, and in most cases this is based on biological considerations only, this makes the supply schedule vertical.

Market effects are illustrated in Figure 6, which differs from Figure 5 in that that the supply schedule for the competing product, captured fish, is backward-bending. If the fishery is on the upward-bending part of the supply schedule, the description of the effects is as for a conventional product. The most interesting part is if the fishery is on the -bending part of the supply schedule. This may also be most representative with regard to world fisheries, as a large number of wild fish stocks are overexploited (FAO, 2003).

[6] See Anderson (1985) for a discussion of the underlying bioeconomic model and the specific parameters.

Assume again that productivity growth gives a downward shift in the supply schedule for farmed fish, reducing price to p1' and increasing quantity supplied to q1'. The effect on the market for the potentially competing product again depends on the parameter cA, which determines the cross-price effect of the competing product with respect to a price change for farmed fish. As above, if this parameter is zero, there will be no effect, and therefore no market interaction. If the parameter is positive, implying substitutes, a price reduction for farmed fish will lead to a downward shift in the demand for the competing product. At most, the demand schedule for the competing product can shift down sufficiently for the relative price to remain constant. This corresponds to the demand schedule D2' in the figure, which implies that the quantity demanded of this good is increased to q2' while the price is reduced to p2'. If there is a weaker substitution effect, the demand schedule for this product will shift down to e.g. D2''. This gives a reduction in price and an increase in quantity, but the shift in demand is not big enough to keep the relative price stable. The main difference from the case with a conventional product is the quantity effect for wild-caught fish. When the price is reduced, this leads to lower fishing effort, which gives a higher fish stock and higher landings.

Figure 6: Potential market interaction between farmed fish and wildcaught fish



While one of the primary concerns with respect to market structure for farmed fish often is the effect of farmed fish on other products, it may also be worthwhile to comment upon the effect of the market structure for possible growth of aquaculture production. Let us look at conventional products first. If production of farmed fish is increasing relative to the other product, this implies that the productivity for farmed fish production increases faster than for the other product. If the two products are close substitutes, farmed fish can then win market shares from the other product. However, if the goods are not substitutes there are no market effects, and the increase in the supply of the farmed fish will only lead to a move down the demand schedule for farmed fish. Hence, for the producers of farmed fish it is easier to expand when the farmed fish has substitutes in established markets. As observed by Anderson (1985), this situation changes if the potential substitute is fish from a fishery located on the backward-bending part of the supply schedule. The increased supply of farmed fish will then also lead to a higher supply of wild-caught fish, leading to keener competition. Anderson also shows that, in some cases, this keener competition may drive the farmed fish producers out of business.

No mention has been made of the possibility that farmed fish and other products may be complementary. This is mostly because it increases the complexity of the model, as there always must be at least one substitute if there is any market interaction on the demand side. However, even though complementarity is a possible effect, it is most likely not a very important one.

Testing for Market Interactions

In general, micro-economic theory assumes that there exists a market place constituted by a group of commodities. The group of commodities competes in the same market because goods are substitutable for the consumer. Whether goods are substitutes, or not, can be measured by estimating demand equations to test whether there are cross-price effects (Triffin, 1940). If there are, the goods compete in the same market, while if there are not, the goods do not compete. The most common measure of a cross-price effect is a cross-price elasticity. The most common research approach is demand analysis, where demand equations are estimated either individually or in a system of demand equations. These studies of the demand structure focus on the price sensitivity of demand, on the degree of substitution between potentially competing products and on income/expenditure effects.

A common problem is obtaining the necessary data to estimate demand equations. Often price data are available but not quantity. Moreover, while one can often find a price that is a good proxy for market price, it is hard to get reliable estimates of demand equations if data are not available for the full quantity consumed in a market at different price levels. This has also led to markets being defined only based on price information. For instance, Stigler (1969) defines a market as:

"the area within which the price of a commodity tends to uniformity, allowance being made for transportation costs."

When looking at Figure 5, the intuition behind this kind of definition can be seen by looking at the effect of shifts in supply and demand schedules from the price differential. When the supply curve for farmed fish shifts, the price changes. This can then have three types of effects on the price of the other good. If there is no substitution effect, the demand schedule does not shift and there is no movement in price. If there is a substitution effect, the demand schedule shifts, and the price shifts in the same direction as the price of farmed fish. At most, the price of the other product can shift by the same percentage as the price of farmed fish, making the relative price constant so that the Law of One Price holds.

Hence there are at least two ways of testing for market integration, or if two or more products are substitutes. One is to estimate the demand function for a product and to test for cross-price effects. Alternatively, one can look at the effects only in the price differential, where one can test whether there is a price effect (i.e., substitution), and if the relative price is constant, i.e., whether the Law of One Price holds.

If consideration is given to the four hypotheses about the impact of farmed fish on wild fish, demand interactions are sufficient to investigate some but not all aspects. In particular, it gives all the information one needs to evaluate hypothesis a, whether increased supplies of farmed fish leads to reduced prices of wild fish, and hypothesis d, whether farmed fish increase fish demand in general. Hypothesis a will be true if there is a substitution effect between farmed and wild fish. To test hypothesis d, there must be at least three goods in the model, because in the case of two goods the products must be substitutes. However, if farmed fish and wild fish are complements, hypothesis d will hold. For farmed fish to enhance wild stocks, i.e. hypothesis c, it must be the case that farmed and wild fish are substitutes. However, although this is necessary, it is not sufficient, since the effect will depend on the regulatory system. Knowledge about demand interaction will not shed light on hypothesis b, that increased supply of farmed fish is necessary to maintain the supply of fish protein.

Market interaction

There are substantial differences with respect to knowledge about market interaction for different species. A number of studies of salmon markets have been conducted and there is also a body of literature for catfish, but very little for sea bass, sea bream and indeed other farmed species. Knowledge about market interaction between farmed fish and other species is therefore to a large extent dependant on what we know about market structure for salmon.

The demand for salmon has often been modelled with different product forms of salmon other fish species, and meats as potential substitutes. These studies include Bjørndal *et al*., (1992), DeVoretz and Salvanes (1993), Herrmann *et al*., (1993), Wessells and Wilen (1993, 1994), Bjørndal *et al*., (1994), Asche (1996, 1997b), Asche and Hannesson (1997), Asche *et al.,* (1997), Eales *et al*., (1997), Salvanes and DeVoretz (1997), Asche *et al*., (1998), Johnson *et al*., (1998), Kinnucan and Myrland (1998), Eales and Wessells (1999), Steen and Salvanes (1999) and Asche and Steen (2000). In addition, several studies have investigated interaction between prices. These include Gordon *et al.,* (1993), Asche *et al*., (1997), Asche and Sebulonsen (1998), Asche *et al.,* (1999), Clayton and Gordon (1999), Asche (2000) and Jaffry *et al.* (2000), Asche *et al.* (2002), Virtanen *et al.* (2005), Asche *et al.* (2005). The results can be divided into three groups: interactions between different species and product forms of salmon, interactions between salmon and other seafood and finally, interaction between salmon and meat.

For different salmon species and product forms of salmon, the results indicate that these are close substitutes. In particular, where tested, the Law of One Price holds, indicating that relative prices are stable. Hence, increased production of farmed salmon has had a substantial impact on the markets and prices for wild Pacific salmon. One could interpret the increased supplies of Pacific salmon as evidence that one has moved down along a backward-bending supply schedule and that salmon farming therefore has been beneficial for wild salmon stocks. However, several factors cast doubt on such an interpretation. As noted above, the landings are now at historically high levels, so if one is moving down the supply schedule this must have had a substantial outward shift. This may be the case since substantial hatching programmes were implemented in the 1980s (Boyce et al, 1993). But these programmes may also be the underlying cause for the increased landings and hence, although number of fishermen and their revenues have decreased, salmon farming may not have had any impact on landings. This is likely to be due to the regulatory structure, because in regulated open access fisheries substantial overcapacity will tend to emerge (Homans and Wilen, 1997). In such fisheries, reduced revenues will reduce overcapacity but as long as this persists, it will have little effect on landings.

For other species, there is some evidence that salmon competes with high-valued fish, and there is also a greater range of fish in Japan. However, salmon does not in general seem to compete with big-volume species of fish as in the global whitefish market. Furthermore, the results from Japan are often for the period prior to the substantial increase in the supply of farmed salmon. Hence, these results are based mostly on lower-valued wild species which are sold, at least partly, in product forms that farmed salmon are not used for. While these results may seem surprising, there are good reasons. In particular, salmon is sold mostly as fresh or smoked, which are product forms that are not very common for most wild-caught species. Furthermore, farmed salmon is not sold as fish fingers, frozen blocks and many other product forms that are important for many wild species, and particularly for big-volume species. A somewhat surprising result is reported by Asche and Steen (2000), who find evidence of several fish species in the EU being complements for salmon, implying that the expansion in the salmon market has made more room for other species as well. Although it is possible that the increased availability of salmon may make it easier to sell other fish, and marketing campaigns for salmon may spill over to other fish, at least in some market segments, it seems less plausible that this is generally the case.

There is little knowledge about any possible relationship between salmon and meats. In general, the evidence indicates no interaction. However, Eales and Wessells (1999) provide evidence from more recent years in Japan of a shift from no interaction to some competition in the mid-1990s.

Most studies on the demand structure for catfish have been primarily interested in the effect of generic marketing programmes. However, as part of the evaluation process, demand equations are estimated. These studies include Kinnucan and Venkateswaran (1990), Kinnucan and Thomas (1997) and Kinnucan and Miao (1999). Meat products such as poultry have been tested as substitutes, without finding any evidence that these products compete with catfish. In unpublished work, no relationship between an index of fish prices and the demand for catfish has been found.7 However, in recent years imports of catfish have increased, and this fish has been found to be a substitute to the US-raised catfish (Kinnucan and Miao, 1999).

Literature searches suggest that the only study testing the market structure for sea bass and sea bream is Asche and Steen (1998). They investigated the relationship between the price of sea bass/sea bream and a number of other fish species in the EU, and found that sea bass/sea bream may compete with portion trout and several whitefish species. However, there are some problems with the time series properties of the sea bass/sea bream data as they are very close to being stationary. These results do not make too much sense since sea bass/sea bream are consumed to a very limited extent in the areas where these competing species are consumed and vice versa. It is therefore likely that these results indicate that sea bass/sea bream are stationary, and that there is no relationship between sea bass/sea bream and these other species.

The Fishmeal Trap

The 'fishmeal trap' is the name of a hypothesis that claims that aquaculture is environmentally degrading because it leads to increased fishing effort to satisfy

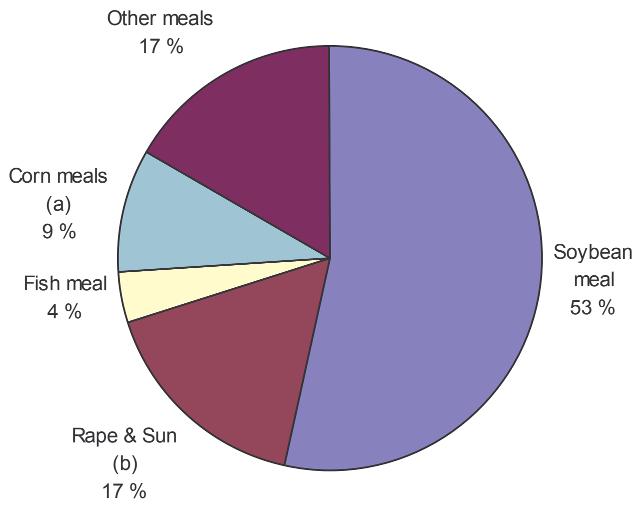
[7] Personal communication, Henry Kinnucan.

increased demand for feed (Naylor et al.). Moreover, it follows that the availability of marine feed will put a limit to how much the aquaculture sector can produce. While the fishmeal trap is mentioned in relation to aquaculture in general, it is clear that it is an issue only in some forms of finfish farming, and does not apply to farming of sea weeds and mussels. Furthermore, it will only apply to species that are fed with feed using marine inputs. This is a substantial part of the sector, as this is the case not only for carnivorous species like salmon and sea bass, but also for omni- or herbivorous species because the use of feed increases the growth rate. However, some conditions must be fulfilled for the fishmeal trap to occur. In this section, this will be discussed following Asche and Tveterås (2004).

To what extent the fishmeal trap associated with aquaculture growth represents an environmental problem can be decomposed into two key issues, one pertaining to the regulation of capture fisheries and one pertaining to the market for protein meals. To what extent increasing demand for fishmeal increases fishing effort is related to the management regime in operation for the fishery in question. Hence, whether growth of aquaculture production can lead to unsustainable capture fisheries is primarily a fisheries management problem. However, as the track record of many fisheries management systems is not too good, this can be a real problem. It does, however, require that aquaculture growth increase total demand for fishmeal.

To what extent increasing aquaculture production increases fishing pressure depends on whether there are substitutes for fishmeal. There is little doubt that the markets for fishmeal are global. In fact, this is a main part of the criticism against the aquaculture industry, as it is the prime example that negative environmental effects are global and not only local. The aquaculture industry is, however, far from the only consumer of fishmeal. Pig and poultry jointly consume 53 percent of the production, while the aquaculture share is 35 percent. Moreover, for most of the species that use fishmeal as feed, this is only one part of their diet. Other protein meals, with soyameal as the most important meal, make up the major share of the diet. If one looks at the total market for protein meals in Figure 7, global fishmeal production is minor compared to the total protein meal production.

Figure 7: World production of protein meals, 1996/97



(a) Corngerm and cornglutenfeed
(b) Rapeseed meal and sunflower seed meal
Source: OW, 1999

When looking closer at the development of fishmeal use, one can also question whether aquaculture's share still really is increasing. In Table 1, total availability of fishmeal as provided by Anderson and Kristofferson (2006) is shown, which as is well known is relatively stable but cyclical, world aquaculture production of finfish and shrimp, their use of aquafeeds and the share of fishmeal going to aquafeed. It is clear that the quantity of fishmeal going to aquafeed was strongly increasing until 1997. However, since then it has stabilised at between 2 and 2.5 million tons. Still, aquaculture production continues to increase. Hence, it is far from obvious that there is a close link between aquaculture production of the species that are thought to be most dependent on fishmeal, and fishmeal use.

Table 1: World aquaculture production of finfish and shrimp, and of fishmeal, and the use of fishmeal in aquafeed

Year	Aquaculture production[1] MMT[2]	Fishmeal Production[3] MMT	Use in aquafeed MMT	Use in aquafeed % of WP	Reference
1988	8.20	6.85	0.69	10.1	New, Shehadeh & Pedini (1995)
1992	10.90	6.25	0.96	15.4	New and Wijkström (2002)
1994	14.06	7.48	1.27	17.0	Pike (1998)
1995	16.10	6.85	1.73	25.2	Tacon (1998)
1996	18.04	6.92	2.00	28.9	Tacon (1999)
1997	19.97	6.54	2.32	35.5	Tacon (1999)
1998	21.24	5.33	2.13	39.9	IFOMA
1999	23.09	6.66	2.10	31.6	IFOMA
2000	24.57	7.04	2.46	34.9	Pike and Barlow (2002)
2001	26.36	6.22	2.49	40.0	Pike and Barlow (2002)
2002	27.94	6.48	2.22	34.2	Barlow (2003)
2003	29.83	5.58	2.00	35.8	GAFTA – 2004

[1] World production of finfish and crustaceans: FISHSTAT, FAO 2004.
2 Million metric tonnes.
3 World production of fishmeal: FISHSTAT, FAO 2004.

There are two main explanations why fishmeal is used in livestock production. One stresses the uniqueness of fishmeal. Fishmeal has higher protein content than the other protein meals, and also has a different nutritional structure. In particular, this is the case with respect to amino acids which may be positive for the growth and general health of the animals. If fishmeal is unique, increased demand from aquaculture production for fishmeal is likely to increase prices, and therefore increase fishing pressure after poorly managed fish stocks. This might be true even if aquaculture's share of the demand is only 35%, since the additional demand from aquaculture then has to be met partly by aquaculture taking over fishmeal from other consumers that find it too expensive and partly because the higher price increases production. The other explanation emphasizes that fishmeal in general is cheap protein. If fishmeal were demanded primarily because it is cheap protein, one would expect a high degree of substitutability between fishmeal and other protein meals. These two explanations have very different implications for the price formation process for fishmeal. If fishmeal is used because it is unique, the price of fishmeal should be determined by the demand and supply for fishmeal alone. However, if fishmeal is a close substitute for other protein meals, one would not expect the price of fishmeal to be much influenced by increased demand from aquaculture, since the price is determined by total demand for protein meals. If so, increased demand from aquaculture is not a threat to wild stocks.

Fisheries Management

There are a number of management forms in the world's fisheries, but we can group them into three main groups: open access, sole-owner (or optimal management), and restricted open access (where the stock is protected with a quota and potentially additional measures. To what extent increased demand will increase fishing pressure depends on the management regime.

The world's reduction fisheries are mainly based on fisheries for small pelagic species8 used both for human consumption and for reduction, i.e. fishmeal and fish oil, but certain species are only fit for reduction due to their consistency, often being small, bony, and oily. Normal annual catches in the 1990s with the main purpose of reduction to fishmeal amount to approximately 30 MMT (million metric tonnes), giving an average of 6-7 MMT fishmeal. Chile and Peru alone deliver over 50% of the global fishmeal production based on their rich fisheries of Peruvian anchoveta, Chilean jack mackerel, and South American pilchard. Other substantial producers are the Nordic countries Denmark, Iceland and Norway. Combined, their fisheries provide the basis for 15% of the global fishmeal production.

A characteristic of the pelagic fisheries is that while the quantity going directly to human consumption stays relatively stable, the "surplus" that goes to reduction can vary dramatically (Hempel, 1999). Thus, in years when the catches are low, such as in El Niño periods, the fishmeal industry is struck hard. The pelagic fisheries have also generally been described as fully exploited or over-exploited by the FAO (Grainger and Garcia, 1996). A significant expansion of the global fishmeal production, beyond the 6-7 MMT that is normally produced, is therefore not likely unless prices for fishmeal increase substantially.

In the case with optimal management, the size of the landings responds to the increased prices. The biomass will, however, always be higher than the biomass associated with Maximum Sustainable Yield (MSY). One can therefore hardly argue that the fishery poses a threat to the stock under optimal management. If the fishery is regulated by a quota that is set without paying attention to economic factors, the quota remains the same when demand changes, the biomass remains the same, but the value of the catch increases. The obvious conclusion is that if the fishery is not allowed to respond to economic incentives, the increased demand for reduction species will not have much effect other than e.g. reducing season length.

Accordingly, the real problem is in the open access scenario, since increased demand for a species in this scenario might lead to serious depletion of the

[8] Pelagic fish are free migrating fish species that inhabit the surface waters, as opposed to demersal fish that inhabits the sea floor.

stock, and will increase the risk of extinction. The model outlined here allows the stock to be driven down to very low levels, although not to become extinct. It is clear, however, that with very low stock levels, the species also become substantially more vulnerable to changes in other factors such as water temperature, salinity, etc. that are not accounted for in the model. In more general models, one may also increase the probability of extinction.

What is then the management situation for the most important stocks used in industrial fisheries? The stocks of Peruvian anchoveta and Chilean jack mackerel have shown vulnerability both to the weather phenomenon El Niño and because of poor fisheries management. The fisheries management has, however, improved over the last decade, with increasingly stricter regulations on inputs. The most important tools used in Chile and Peru today are Total Allowable Catches (TACs), limited access, input factor regulations and closures that are imposed on the fisheries in certain periods and certain areas.

The industrial fisheries in the Nordic countries are regulated by TACs, often in combination with other restrictions. In the late 1960s and early 1970s, the herring stock collapsed, but the overall state of the fisheries for reduction in the Nordic countries has improved, and several of these stocks have been rebuilt to the levels before the collapses. In the US, the menhaden fishery is the main industrial fishery, and here also the fishery is regulated with a TAC.

A first glance may indicate that the management situations for the most important pelagic fisheries are not too bad, and that open access is not a correct description. However, quotas tend to be high, and one may often question whether the state of the fish stocks is the main priority when the quotas are set. Hence, it is not clear that the situation is very different from what it would be under open access. Whether increased demand for fishmeal from a growing aquaculture industry is harmful for the state of the fish stocks that are targeted in industrial fisheries will thus to a large extent depend on the market structure for fishmeal.

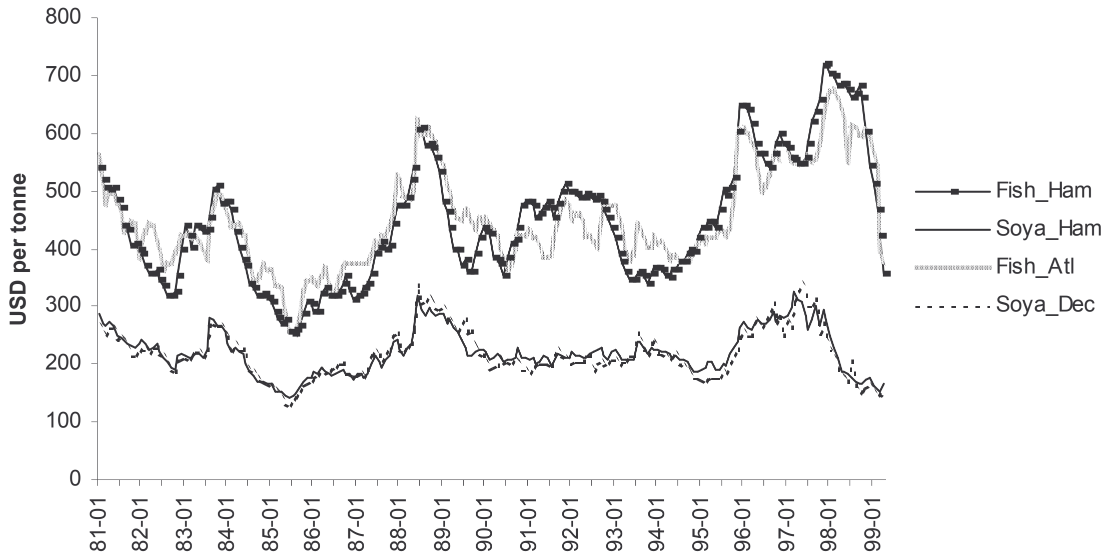
The Market for Oilmeals

We now turn to the market for fishmeal. We need to define the market, since the extent of the market mainly determines whether increased demand from aquaculture affects prices with poor management of the stocks with the current management practices. To determine the position of fishmeal in the protein meal market, Asche and Tveterås (2004) investigated its relationship to soyameal, since this is clearly the largest of the vegetable meals. Their procedure was to analyse the relationships prices from Europe and USA provided by IFOMA (1998), in the period from January 1981 to April 1999. The European prices are reported from Hamburg, and are denoted as Fish Ham and Soya Ham. In addition, they use fishmeal prices from Atlanta, Georgia, denoted as Fish_Atl, and soyameal prices reported from Decatur, Illinois, denoted as Soya_Dec.

The prices are shown in Figure 8. Note that the fishmeal prices are substantially higher than the soyameal prices. This is primarily because of the higher protein content. If one adjusts for the protein content, most of the difference disappears. The period chosen is interesting for at least two reasons. First, there have been some extreme situations for fishmeal production in this period due to low raw material supply, including *El Niños* in 1982-83, 1986-88, 1991-92 and in 1997-98, with the first and the last being the most severe. This makes it interesting to compare how fishmeal and soyameal markets have interacted during these extreme periods. Second, this is the period when most of the growth in intensive aquaculture has taken place. If the fishmeal primarily is demanded due to its special attributes, this should show up as the fishmeal and soyameal being different market segments during this period.

The results suggest that the markets for fishmeal and soyameal are highly integrated and accordingly that the two products are strong substitutes. Total demand for fish and soyameal, possibly together with the demand for other protein meals, thus determines the price of these protein meals. If aquaculture is to influence the price of fishmeal with this market structure, the changes in demand or supply must be large enough to affect demand and supply for fish- and soyameal combined. It is, however, unlikely that increased demand for fishmeal from the aquaculture sector will lead to increased prices for fishmeal, since it has only a negligible share of the market. It is also unlikely that increased demand for fishmeal from the aquaculture sector increase fishing pressure in industrial fisheries.

Figure 8: Monthly fishmeal and soybean meal price data from Hamburg (Ham), Atlanta (Atl) and Decatur (Dec), January 1981 to April 1999



Source: IFFO, 2000.

To conclude, increased demand for fishmeal from a growing aquaculture sector has the potential to increase fishing pressure in industrial fisheries. It does, however, require that the fisheries are poorly managed (or not managed at all) and that there are no close substitutes to fishmeal. The most important fish stocks in reduction fisheries can be described as regulated open access. If this management regime is efficient, increased demand from aquaculture does not pose a threat to the fish stocks. There are, however, many indications that quotas are set higher then biological recommendations and that quotas might be overfished. With such a situation one might not be too far from open access. If so, increased demand for fishmeal may well increase fishing pressure.

Poor fisheries management does not cause increased fishing pressure alone. In addition, there cannot be any close substitutes to fishmeal, since close substitutes would alleviate the pressure on the fishmeal market and consequently the fisheries. Asche and Tveterås (2004) indicate that fishmeal is part of the large protein meal market, and, in particular, that fishmeal is a close substitute to soyameal. With such a market structure, it is total supply and demand for protein meals, of which fishmeal makes up only 4%, which determines prices for fishmeal. One is then led to the conclusion that increased demand for fishmeal from aquaculture cannot have had any significant impact on fishmeal prices in the long run, and accordingly not to increased fishing pressure. However, demand for fishmeal from aquaculture has grown from basically nothing to 35% of total production in only twenty years. If demand for fishmeal from the aquaculture sector continues to grow, it is possible that the market structure may change. However, this does not have to be the case, since it is not clear that even the demand for fishmeal from the aquaculture sector is mainly because of the unique characteristics of fishmeal. What is clear though is that the current market structure prevents increased demand for fishmeal from having a negative impact on industrial fish stocks. Moreover, as productivity grows, lower production costs has been the main engine of growth in the aquaculture sector, and increased prices will follow if there is a shortage of fishmeal and oil will reduce demand. ?? However, the only measure that can ensure that demand for fishmeal does not have a negative impact on these fish stocks due to increased fishing pressure at any time in the future is good fisheries management.

Concluding remarks

In this paper, we look at the market interactions of farmed seafood in the output as well as the input market. The strong reduction in the price for new aquaculture species gives an indication that the markets for these species are not strongly linked to the markets for other products. Since few if any other goods can show a similar development in prices, the relative price between farmed fish and most other goods have changed substantially. As perfect substitutes have a constant relative price and close substitutes have highly correlated prices, this is an indication that farmed fish do not compete too closely with other goods. The limited knowledge we have about the market structure for these species also indicates that market interactions between farmed fish and other fish and meat are very limited, with the exception of the wild supplies of the species that are farmed. However, since the production of these farmed species makes up substantial quantities and there obviously is demand for the fish, it must win market share somewhere. We think it is difficult to find where farmed fish win market shares because farmed fish partly creates new market segments and partly wins market share from such a large variety of goods that the effects are too small to pick up for each good.

There are many possible reasons why new aquaculture products should not interact too much with traditional market segments. Most of these are related to unique attributes of the farmed fish. In particular, relative to other species, and particularly big-volume species, a very large share of the farmed fish is sold in fresh product forms. This is possible because the higher degree of control of the production process gives the farmers the opportunity to decide when to market their product. This allows a supply chain very different from that of wild-caught fish. The changes in food distribution and the retail sector are a further advantage for farmed fish relative to captured supplies, since farmed production is much better suited to this kind of supply chain than landings from traditional fisheries.

Finally, there is little evidence that the fishmeal trap hypothesis has any validity. While it is not rendered invalid by the most obvious reason, that good fisheries management prevents overfishing, it seems to be invalid because of market interactions. In particular, fishmeal seems to be a part of the much larger market for vegetable meals. Furthermore, cost considerations, which are necessary for aquaculture products to stay competitive, make it impossible for aquaculture producers to significantly increase demand for fishmeal by bidding up the price.

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