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Competition between Different Farmed and Wild Species: The US Tilapia Market

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Abstract *This article is an extension of previous work on tilapia in the US market (Norman-López and Asche 2008). This study investigates the degree of market integration between fresh farmed tilapia fillets and fresh fillets of farmed catfish, wild sea dab, wild blackback flounder, and wild whole fresh red snapper in the US market. The literature suggests farmed and wild fish of alternative species do not compete. However, this may be changing as new farmed species are introduced to new markets. The results indicate no relationship between prices of fresh tilapia and catfish. Hence, there is no evidence that fresh tilapia fillets compete in the same market as catfish fillets. Conversely, fresh farmed tilapia fillets compete with wild whole red snapper, wild fresh fillets of sea dab, and blackback flounder. The implications are important for managing these overexploited wild fish species, as prices will most likely decline with increased imports of fresh tilapia fillets. This could lead to lower investments in fishing fleets and a reduction in fishing effort over time.*

Key words Tilapia, market integration, competition, wild fish, farmed fish.

JEL Classification Codes D12, Q11, Q22.

Introduction

While aquaculture production is rapidly increasing, harvests of commercially important wild species are either stagnant or declining.[1] One would expect this to result in keen competition between farmed and wild-caught fish. However, the evidence so far indicates little substitution between wild and farmed fish, unless they are of the same species (Asche, Bjørndal, and Young 2001). There are a number of reasons for this divergence: differing consumer perceptions towards tastes, safety, etc; wild and farmed species typically have different characteristics in the market; and rapid increases in supply have meant that farmed fish are often observed to quickly shift market position from consumers willing to pay a premium for gourmet products to those only willing to pay lower prices for similar products. Yet, as farmers adapt to changes in demand by providing a wider variety of species and product forms, wild and farmed fish are increasingly likely to compete more directly in the market. This situation will probably occur in those cases where the substantial decline in wild landings is pushing many intermediaries to find new sources of fish in order to stay in business.

For most successful aquaculture species, such as salmon, shrimp, and sea bream, rapid increases in production have been accompanied by substantial reduction in prices

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[1] From 1990 to 2005, aquaculture production has increased annually from 13 million tonnes to 47.7 million tonnes, while wild production has remained stable at around 90 million tonnes. (This data excludes non-edible invertebrates, mammals, and reptiles [FAO 2007a,c]).

(Asche 1997; Asche, Bjørndal, and Young 2001; Anderson 2003). This indicates that a large part of production growth has found a market by moving down the demand schedule and accepting lower prices, rather than winning market share from competing goods. One can regard this as an indication that farmed species can only compete strongly with similar species of fish. This is not surprising since seafood markets seem to be highly segmented (Asche, Bjørndal, and Gordon 2007). In this article, the relationship between fresh farmed tilapia fillets and several wild species in the US will be investigated. Although fresh tilapia imports to the US have increased substantially during the last decade, fresh fillet prices have remained fairly constant over time. This indicates fresh tilapia fillets must be winning market share in some existing markets, and are therefore, a clear candidate for a farmed fish product that competes against other wild species.

This study is of interest for two reasons. First, during the last decade tilapia has become an important traded species with exports rising even faster than production, yet limited research has been undertaken on these markets. Second, this study provides a contribution to the unsettled issue relating to the competition between farmed and wild species. This is important as the overfishing of wild stocks coupled with the expansion of a wide variety of aquaculture products in the market, could lead to farmed fish competing more directly with wild fish. This has been the case in the study by Nielsen *et al.* (2007) who identified a relationship between farmed trout and wild cod, halibut, redfish, and mackerel in Germany.

This study focuses on the US market, as this is the most important international market for tilapia. Two decades ago tilapia was primarily consumed by ethnic markets and imports were limited. During the last decade, growth in demand has been fast because it meets the typical preferred requirements for fish in the US market: the meat is white, odourless, easy to fillet, and has a mild flavour (Vannuccini 2001). This has resulted in imports increasing from virtually nothing in the early 1990s to 134,869 tonnes in 2005 (NMFS 2007).

The fast increase in US imports has prompted the literature to suggest several wild and farmed species from which tilapia could be gaining market share. Harvey (2002) and Josupeit (2005) proposed US farmed catfish may be one of these species. The main reason is that the increase in tilapia imports has coincided with a reduction in Vietnamese imports of farmed Pangasius (catfish) in 2002 and 2003 following trade disputes between the US and Vietnam. Also, Muir and Young (1999) and Anderson (2006) have argued high-quality tilapia may be competing with higher-valued species such as snapper, grouper, and flatfish, as well as other whitefish. In particular, tilapia is likely to be a closer substitute for snapper and grouper, as it generally has a firmer flesh when compared to flatfish.

In this study we investigate the competition between fresh fillets of imported tilapia (*Oreochromis niloticus*) and several wild and farmed fish in New York's Fulton Fish Market; namely, farmed fresh catfish fillets (*Ictalurus punctatus*); wild fresh whole red snapper (*Lutjanus campechanus*); and fresh fillets of two wild flatfish species, blackback flounder (*Pseudopleuronectes americanus*) and sea dab (*Hippoglossoides platessoides*). These species were chosen based on suggestions in the literature (Muir and Young 1999; Harvey 2002; Josupeit 2005; Anderson 2006) and their reduced landings in the last decade, giving buyers the incentive to find substitutes.

Evidence of competition between tilapia and other wild species would indicate a new development in the demand for seafood products in the US. This situation would have important implications for the US market and fishermen. Changing consumer lifestyles, where less time is allocated to eating and food preparation, have led to consumers eating out more and creating a higher demand for convenience food when at home (Murray and Fofana 2002; O'Dierno, White, and Garfield 2003). Farmers are catering for this shift in consumption by supplying an increasing variety of value-added products and species that can sit in the fridges/freezers of fish counters beside long-established wild fish processed products. When combined with successful marketing campaigns, farmed fish is likely to be able to compete more directly with wild fish (Gempesaw *et al.* 1995; Kinnucan and

Miao 1999). In addition, supermarkets' and restaurants' preference for consistency in quantity and price may reinforce this competition by influencing the products that reach the consumer (Murray and Fofana 2002).

The substitutability between wild and farmed species would lead to a fall, or at least limit any increase in wild fish prices, and hence fishermen's revenues. This is likely to have consequences for effort and capacity use in the fishing fleet (Anderson 1985). The potential consequences that aquaculture can have on wild fisheries management have already been highlighted by Anderson (2002). The author criticised fisheries experts for not considering aquaculture as a solution to overfishing, despite aquaculture representing the majority of the growth in fish supply over the past two decades. Furthermore, in the long term, farmed fish is likely to become more competitive in the commodity market, pushing wild fish towards niche markets (Muir and Young 1998). In contrast, if no competition is found, the results will indicate that fresh tilapia fillets, like other farmed fish products, will increase quantity by moving down the demand schedule and winning market share from a number of other products. This is similar to what Asche, Bjørndal, and Young (2001) found for salmon. This outcome would reinforce the lack of relationship between different wild and farm species.

The Fulton Fish Market is the main wholesale market for seafood on the eastern seaboard of the US, and competition in this marketplace should reflect the extent to which tilapia competes with these species. However, only fresh price data is available from this market for the different species considered in the study. This is not an issue as, unlike frozen tilapia products, fresh tilapia fillets have greatly expanded in the US market whilst maintaining stable prices. Hence, fresh tilapia fillets are most likely to be taking market share from other products. The tool used when investigating the relationship between the species investigated is market integration analysis. This method is less data intensive than demand analysis as it only requires price data, and it has been used in a number of studies of the seafood market during the last decade (Asche, Bjørndal, and Gordon 2007).

This article is organised as follows. In the next section, the situation of farmed tilapia as a worldwide produced species is discussed. Then the data used in this analysis are presented along with an analysis of their time series properties. This is followed by a description of the methodology, the empirical results, and some concluding remarks in the final section.

Background to Tilapia Production and Trade

Tilapia originates from Africa and the near East, but it has been successfully introduced in Asia, Oceania, South America, North America, and Europe. In the 1930s and 40s, biologists and missionaries introduced tilapia throughout the tropics with the intention of growing it in small ponds to supplement the diet of impoverished people (Young and Muir 2002). However, since then, tilapia has become a profitable species that is not only consumed in the producing countries themselves, but is also increasingly traded internationally.

Farmed tilapia production has become an important component of the international tilapia industry. Figure 1 shows world farmed tilapia production split into Africa, America, Asia, and Europe from 1980 to 2005. As can be seen, world farmed tilapia production has increased from 107,459 tonnes in 1980 to 2,025,559 tonnes in 2005. In contrast, wild tilapia production has only increased from 250,354 tonnes to 669,935 tonnes (FAO 2007a). This means world farmed tilapia production has increased from 30% in 1980 to 75% in 2005 of the total world tilapia production.

Also, figure 1 indicates the largest producers of farmed tilapia are located in Asia, followed by Africa, America, and Europe.[2] The production of farmed tilapia has increased

[2] Africa includes the Middle East. Asia includes several islands in Oceania. America includes North, South, and Central America.

in the four continents, although in Europe tilapia production was negligible at 578 tonnes in 2005. As a result, European production is not easily appreciated in figure 1. In contrast, Asian tilapia production has increased from 86,937 tonnes in 1980 to 1,589,495 tonnes in 2005, representing around 80% of world farmed tilapia production. In 2005, the seven largest producers of farmed tilapia were China, Egypt, Indonesia, the Philippines, Thailand, Taiwan, and Brazil representing 48%, 11%, 9%, 8%, 5%, 4%, and 3% of world farmed tilapia production, respectively.

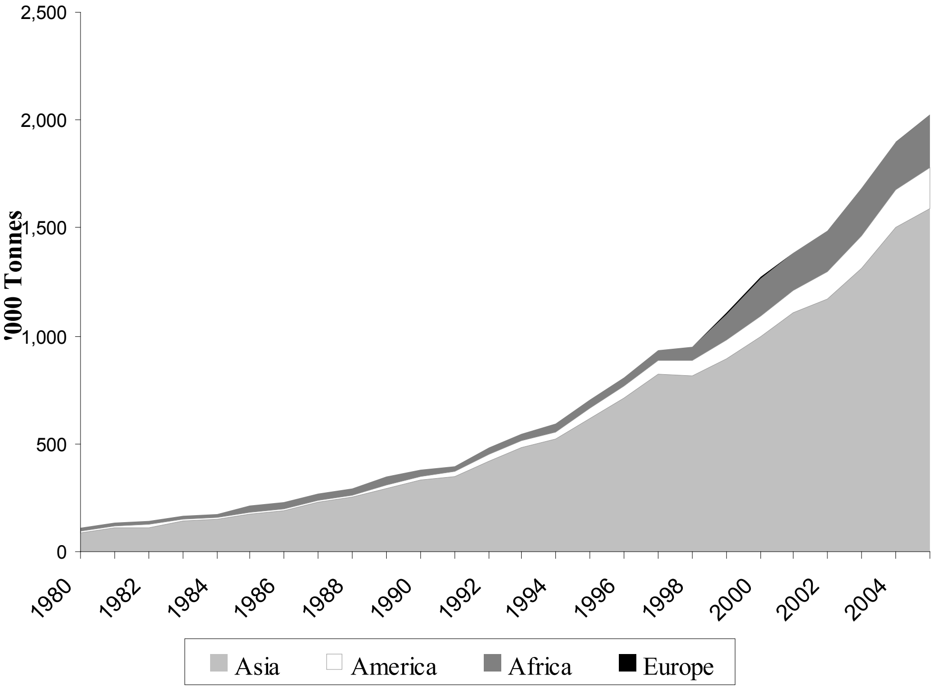

Figure 1. Annual Quantities (tonnes) of World Farmed Tilapia Production 1980–2005

Source: FAO (2007c).

The variability between countries in terms of the quantities of tilapia they produce is related to differences in production costs. Overall, Asian tilapia producers face lower production costs than other continents because they require a lower technological investment to produce it (Urch 2001). In general, tilapia production costs are higher in temperate regions because together with feed and fingerling costs, they face higher labour wage rates and require production systems that maintain the high water temperatures needed to farm this tropical fish (Alceste and Jory 2002).

The increase in tilapia production is leading to a rapid rise in its world trade. Until 1992, tilapia was not registered separately from other freshwater fish; however, by the year 2000, 76,452 tonnes were traded globally, increasing to 263,345 tonnes in 2005 (FAO 2007b). As most of the tilapia is exported as fillets, and the fillet percentage is less than 40%, this represents more than 650,000 tonnes live weight and about a third of the total production. The demand for tilapia is increasing with the appearance of new markets, mainly in the US and slowly in Europe. Asia, along with South and Central America, are the major exporters of tilapia to the US.

The US imports tilapia in three main product forms: fresh fillets, frozen fillets, and whole frozen. Of these three products, Asia mainly exports whole frozen tilapia and frozen tilapia fillets, while South and Central America mainly export fresh tilapia fillets. The geographical proximity of South and Central America to the US gives producers a competitive advantage, as they are able to export fresh tilapia in a shorter time and at a lower cost. For frozen tilapia products, Asian countries are able to out-compete other producers because of the lower technological investment required to produce it (Urch 2001). This situation implies that the market for different tilapia products may be segmented due to varying production and transportation costs between different producer countries (Norman-López and Asche 2008).

Import quantities to the US have increased for all product forms: however, prices of all product forms of imported tilapia do not show the same pattern. Only fresh fillets have experienced stable prices, whereas prices for the other two products have declined with increasing quantities. This further suggests that the different product forms of tilapia compete in different market segments (Norman-López and Asche 2008). Figure 2 shows annual tilapia fresh fillet import volumes and prices in US dollars from 1992 to 2006. Tilapia fresh fillet imports have increased steadily from 184 tonnes in 1992 to 23,101 tonnes in 2006. Nominal prices have also increased over time from 5.1 US$/kg in 1992 to 6.4 US$/kg in 2006.

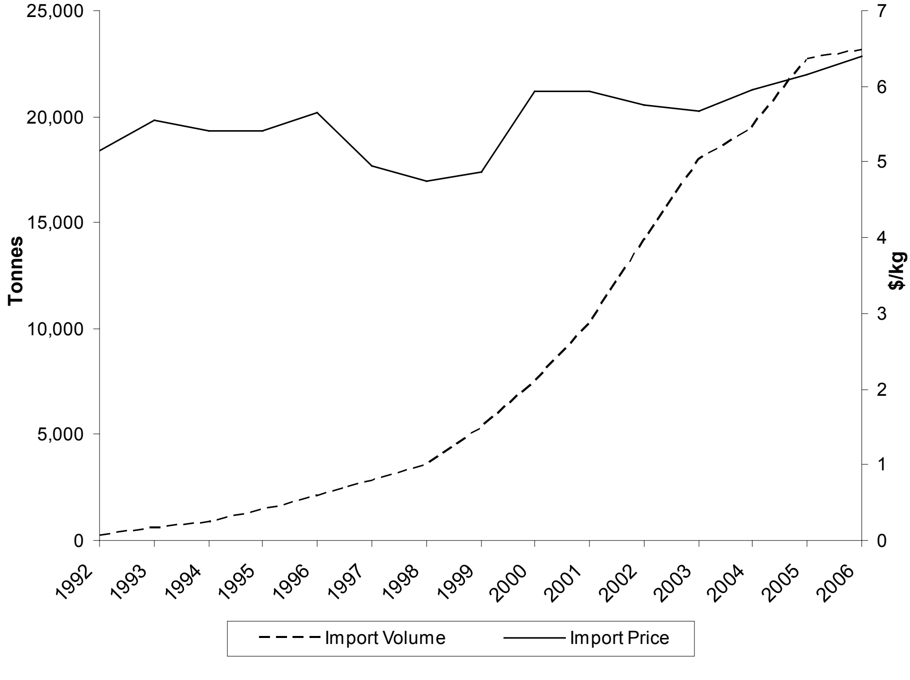

Figure 2. Annual Quantities (tonnes) and Prices (US$/kg) of Fresh Imported Tilapia Fillets, 1992–2006

Source: NMFS (2007).

Data

The data used for econometric analysis are monthly wholesale prices from the Fulton Fish Market. The data were obtained from the fisheries statistics division of the National Marine Fisheries Survey (NMFS 2007). The Fulton Fish Market is viewed as a good place to investigate the competition between wild and farmed species, as worldwide it is the second largest seafood wholesaler in size after the Tsukiji Market in Tokyo. Wholesalers, seafood retailers, supermarkets, restaurateurs, and customers from around the country purchase fresh and frozen seafood daily (New Fulton Fish Market). In this market, fish is sold fresh, frozen, salted, cured, smoked, breaded, in portions, and in different product forms (whole and fillets). However, despite the variety of fish products, the Fulton Fish Market voluntarily provided only the annual summary of monthly fresh fish and seafood prices until December 2004.

This study investigates market integration for the same product (fresh fillets) for different wild and farmed species with the exception of red snapper, which was whole.[3] Red snapper is wild and supplied by a variety of countries (US, Brazil, Ecuador, Mexico, Trinidad, and Venezuela). Tilapia is farmed and imported from the major exporters of fresh tilapia to the US (Ecuador, Costa Rica, and Honduras). Catfish is farmed and produced in the US. Sea dab and blackback flounder are wild and caught in the US. Our data analysis starts in January 1998 because whole red snapper prices are not continuous before this month. The analysis ends in December 2004, as price data could not be obtained after this date.

Figure 3 presents the prices of tilapia fillets, catfish fillets, sea dab fillets, blackback flounder fillets, and whole red snapper in US$/kg.[4] The left vertical axis represents the wild species and the right vertical axis the farmed species. Overall, a higher fluctuation in prices for wild species can be observed. This may be due to the strong seasonal fluctuation of wild catches compared with the more regular production of fish farms. Also, all prices declined from 1998 until around 2002, when prices started to rise again. This is a different pattern than anticipated. We expected wild fish prices to increase and farmed fish prices to decrease over time. However, prices in 2004 did not exceed the annual average price in 1998 independently of whether the species was farmed or wild.

It can be seen from figure 3 that blackback flounder and sea dab fillet prices follow each other closely over time. The average annual price of blackback flounder and sea dab fillets has fallen from 6.08 US$/kg and 6.28 US$/kg in 1998 to 5.31 US$/kg and 5.39 US$/kg, respectively, in 2001. Since then, prices have increased to 5.48 US$/kg and 6.10 US$/kg, respectively, in 2004. Whole red snapper prices show a smaller fluctuation than prices of the flatfish species. This may be because red snapper is supplied not only by the US but also by several export countries. The average annual price in 1998 was 3.44 US$/kg. Later, this price declined to a minimum average price of 3.33 US$/kg in 2003. Afterwards, the price increased to an average of 3.44 US$/kg in 2004.

Figure 3 shows that the prices of catfish fillets and tilapia fillets have fluctuated very little over time. The price of catfish fillets declined from a maximum price in March 1998 of 3.29 US$/kg to a minimum price of 2.75 US$/kg in December 2001. Prices remained constant until March 2003, when they increased to 2.85 US$/kg. Prices have remained stable since then. For tilapia fresh fillets, prices declined from 4.10 US$/kg in January 1998 to 3.73 US$/kg in April 2004. Since then, prices have increased to 3.86 US$/kg in December 2004.

In order to avoid spurious results, it is important that the time-series properties of the data are understood before performing the analysis. If a data series contains a unit root

[3] Fresh red snapper was only supplied whole to the Fulton Fish Market during the study period.

[4] For commodities like seafood, one would expect that changes in exchange rates are rapidly reflected in prices. The two studies that investigate exchange rate transmission for seafood products, Asche, Menezes, and Dias (2007) and Asche and Tveterås (2008), indicate there is complete exchange rate transmission.

(I (1)), it is non-stationary. Thus, unless it combines with another non-stationary series to form a stationary cointegration relationship, its mean, variance, and covariance will change over time. In this study, we tested for unit roots[5] using the most common approach available, the Augmented Dickey–Fuller (ADF) test (Dickey and Fuller 1979, 1981). ADF tests for each series, in nominal values, were performed in levels and first differences with a constant as well as with a constant and a trend. The null hypothesis in the ADF test is that each series is non-stationary (I (1)). Table 1 presents the ADF tests on nominal prices. The values in parentheses represent the chosen number of lags by the Schwarz information criteria for each ADF test. The large number of lags chosen for the wild price series is due to their high seasonal variability in the market. The ADF tests have indicated that the price series were non-stationary in levels and stationary in first differences.

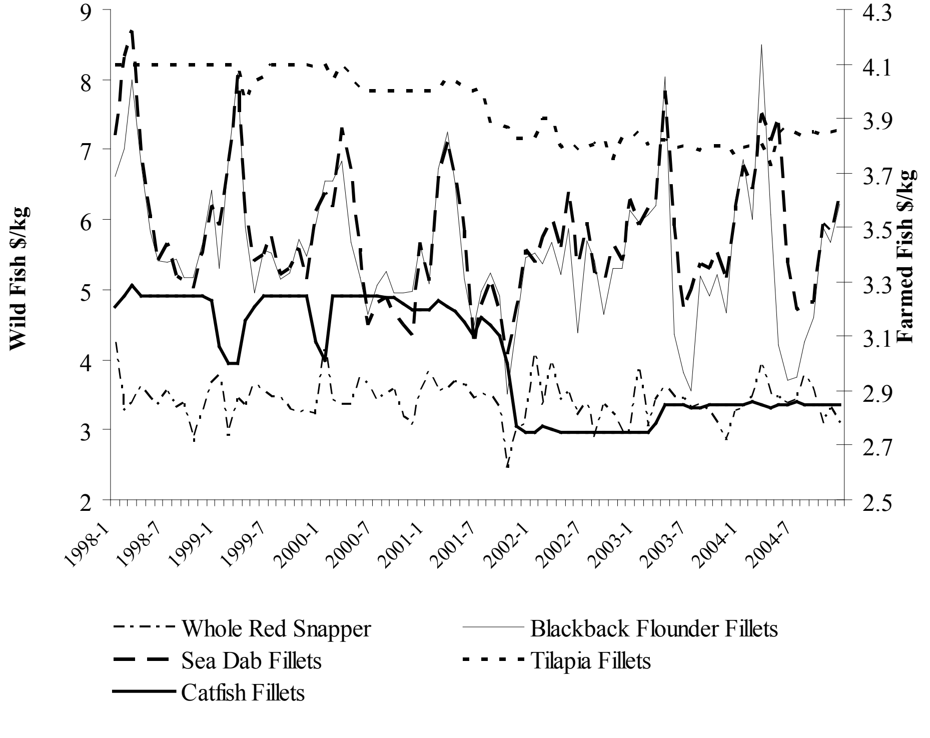

Figure 3. Monthly Prices of Wild and Farmed Fish in the Fulton Fish Market Jan. 1998–Dec. 2004

Source: NMFS (2007).

[5] All unit root tests were performed with the econometric software package EViews version 5.0.

Table 1
Unit Root Tests (Augmented Dickey–Fuller) of Logged Nominal Fresh Prices
Jan. 1998–Dec. 2004 (n = 84)

	Levels		First Differences	
Variable	Constant	Trend+Constant	Constant	Trend+Constant
Tilapia, fillets, P	–1.300 (1)	–2.977 (0)	–12.041** (0)	–11.994** (0)
Catfish, fillets, P	–1.209 (0)	–2.437 (1)	–7.265** (0)	–7.223** (0)
Sea dab, fillets, P	–2.366 (9)	–2.951 (8)	–7.434** (10)	–7.864** (10)
Blackback, fillets, P	–2.042 (10)	–2.495 (10)	–8.443** (9)	–8.404** (9)
Red snapper, whole, P	–2.686 (10)	–3.037 (10)	–5.811** (11)	–5.778** (11)

The values in parentheses indicate the number of lags.
Prices are in US$/kg.
** Indicates significance at the 1% level.

Methodology

Stigler (1969) defined a market as: "the area within which the price of a commodity tends to uniformity, allowance being made for transportation costs." Other definitions of a market apply this concept not to a geographical space, but to product space, so quality differences will take the place of transportation costs (Stigler and Sherwin 1985). Following these definitions, prices may deviate from each other in the short run, but in the long run, arbitrage and substitutability will ensure that prices form an equilibrium relationship. Therefore, products will be in the same market when prices hold an equilibrium relationship (that is, they are cointegrated). A variety of seafood studies have examined the market relationship between different goods by analysing their prices with tests for cointegration. Examples of seafood studies include Bose and McIlgorm (1996); Gordon and Hannesson (1996); Asche, Bremnes, and Wessells (1999); Jaffry *et al*. (2000); Asche, Gordon, and Hannesson (2004); Nielsen (2005); Asche *et al*. (2005); and Nielsen *et al*. (2007).

Testing for market integration is an appropriate method for testing the long-run relationship between products based on price data. Demand analysis is another suitable method to test competition between products in a market. In particular, the error correction model has been popularized by Engle and Granger (1987) to investigate the long- and short-term relationship between products. Nevertheless, demand analysis has the drawback that it requires information on quantities as well as prices.

Cointegration analysis uses non-stationary series.[6] This is very useful, since most price series are non-stationary. There are several approaches to test for cointegration, the most common being the Engle and Granger test (1987) and the Johansen test (Johansen 1988; Johansen and Juselius 1990). We use the Johansen test in the market integration analysis, as it allows hypothesis testing (such as the 'law of one price' [LOP]).

In this study, we test for market integration between two (bivariate) and multiple (multivariate) price series at a time. The Johansen test is based on a vector autoregressive (VAR) system. To start, we set a vector $\mathbf{z_t}$ containing the *(N)* price series we are investigating. Then, we model $\mathbf{z_t}$ as an unrestricted vector autoregression (VAR) model with "k

[6] A series is stationary if it oscillates around a constant value over time. Therefore, its mean, variance, and autocovariance will be the same whenever it is measured. The series is non-stationary when its mean, variance, and autocovariance are not constant in time. Therefore, a non-stationary series will show a general trend upwards or downwards over time.

lags" containing these variables in levels, where z_t is (n × 1) and each of the Π_i is an (n × n) matrix of parameters. The system is in reduced form, with each variable in $\mathbf{z_t}$ regressed on only lagged values of both itself and all other variables in the system. In order to use the Johansen test, the vector autoregression (VAR) representation needs to be turned into a vector error correction model (VECM) of the following form:

$$\mathbf{\Delta z}_t = \Gamma_1 \mathbf{\Delta z}_{t-1} + \ldots + \Gamma_{k-1} \mathbf{\Delta z}_{t-k+1} + \Pi \mathbf{z}_{t-k} + \mu_t, \quad (1)$$

where $\Gamma_i = -(I - \Pi_1 - \ldots - \Pi_i)$, $(i = 1, \ldots, k-1)$, and $\Pi = -(I - \Pi_1 - \ldots - \Pi_k)$. The Johansen test centres on an examination of the Π matrix. Π_k is the long-run "level solution" to equation (1), because in equilibrium, all the first differences of the price series ($\mathbf{\Delta} z_{t-i}$) will be zero, and setting the error terms, u_t, to their expected value of zero will leave $\Pi z_{t-k} = 0$. Furthermore, $\mathbf{\Pi = \alpha\beta'}$, where $\boldsymbol{\alpha}$ represents the speed of adjustment, while $\boldsymbol{\beta}$ is a matrix of long-run coefficients. Both $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are (N × r) matrices.

There are two asymptotically equivalent tests for cointegration in the Johansen framework: the likelihood ratio test and the trace test. The test for cointegration between the $\mathbf{z_t}$ is calculated by looking at the rank of the $\mathbf{\Pi}$ matrix via its eigenvalues. The rank of $\mathbf{\Pi_k}$, $\mathbf{r}$, determines how many linear combinations of $\mathbf{z_t}$ are stationary. If $r = N$, the variables in levels are stationary. If $r = 0$, none of the linear combinations are stationary ($\mathbf{\Pi_k} = 0$). When $0 < r < N$, there exist r linear stationary combinations of $\mathbf{z_t}$, or r cointegration vectors. In this instance, we need to determine how many $r \leq (n-1)$ cointegration vectors exist in $\boldsymbol{\beta}$. As there are no deterministic trends in the data, the cointegration tests are carried out with an intercept but no trend in the cointegrating equation. If the series are cointegrated, we further investigate whether the two price series are imperfect substitutes or whether they are perfect substitutes (LOP) so their relative price is constant. We test for the LOP by imposing the restriction $\boldsymbol{\beta}' = (1, -1)'$. Furthermore, if the series are cointegrated, we will further test whether it is the price of a single species that influences the other species in the long run. This test is know as weak exogeneity, and it is tested for each of the prices on the $\boldsymbol{\alpha}$ matrix by imposing the restriction that all the parameters in the corresponding row on the $\boldsymbol{\alpha}$ matrix are zero (Johansen and Juselius 1990).

Results

In this study, we expect fresh farmed tilapia fillets, whole fresh red snapper, and fresh fillets of farmed catfish, wild sea dab, and wild blackback flounder to be in the same market, following suggestions in the literature (Muir and Young 1999; Harvey 2002; Josupeit 2005; Anderson 2006). To test this hypothesis, the market integration analysis was carried out in two steps. First, the relationship between tilapia and each of the other two species was investigated in bivariate tests. Then, as bivariate tests are not necessarily consistent for different pairs of prices, systems were investigated.

Bivariate Cointegration Test

The Schwartz information criteria (SIC) for bivariate VAR systems indicated that 1 lag was appropriate for all the pairwise relationships investigated. The results from the bivariate cointegration tests are reported in table 2. With the exception of the test for fresh tilapia fillets and fresh catfish, the null hypothesis of no cointegration or rank = 0 is rejected at the 1% significance level in all cases. These results indicate fresh tilapia fillets are in the same market as the three wild species: fresh whole red snapper, fresh blackback flounder fillets, and fresh sea dab fillets. On the other hand, the test for fresh tilapia fillets and fresh catfish fillets fails to reject the null hypothesis of no cointegration vector with rank = 0 at the 5% significance level. Therefore, market integration was not found between domestic catfish fillets and imported tilapia fillets. This means that imported tilapia fillets do not take market share from domestic catfish fillets, as consumers regard catfish and tilapia as unrelated products. This also implies that catfish does not compete in the same market as the wild species.

Given that prices for tilapia fillets and the other three wild species were found to be related, we have also tested whether the LOP holds in each of these relationships. As shown in the last column of table 2, the LOP was rejected for each relationship at the 1% significance level. Hence, we conclude that the market for tilapia fillets and whole red snapper, blackback flounder fillets, and sea dab fillets is not fully integrated.

Table 2
Bivariate Johansen Test for Cointegration: Jan.1998–Dec. 2004 (n = 84)

	Null Hypothesis[a]				
	Rank (ρ) = 0		Rank (ρ) ≤ 1		Law of One Price
Nominal Prices	Max[b]	Trace[c]	Max[b]	Trace[c]	(LOP)
Tilapia fillets/catfish fillets	5.73	6.49	0.76	0.76	—
Tilapia fillets/whole red snapper	30.28*	31.38*	1.10	1.10	24.73*
Tilapia fillets/blackback flounder fillets	24.44*	25.39*	0.95	0.95	20.17*
Tilapia fillets/sea dab fillets	20.08*	21.04*	0.96	0.96	16.83*

Results from Schwarz IC.

[a] The null hypothesis is that the number of cointegrating vectors is equal to ρ; [b] Maximum eigenvalue test; [c] Trace test.
* Indicates significance at the 1% level.

Multivariate Cointegration Test

A multivariate system was initially undertaken that included all the species in the system. This VAR system was estimated with one lag since the SIC indicated this was the optimal lag length. The results of the multivariate Johansen cointegration test are reported in table 3. The results show three cointegration vectors in the multivariate system, indicating either that four out of the five species in the system are within the same market or that there are two different markets. The bivariate test for fresh tilapia fillets and fresh catfish fillets suggested that catfish does not belong to this market. Therefore, from these results, we proceeded estimating a multivariate system including all the species with the exception of catfish fillets (table 4). The multivariate VAR system with all the species except catfish was estimated; again with one lag since the SIC indicated this was the optimal lag length. The results also indicated three cointegration vectors in this system, signifying that all the species in this system compete in the same market. The LOP was rejected at the 5% significance level. This result agrees with the results from the bivariate cointegration tests. Hence, while tilapia fillets, whole red snapper, blackback flounder fillets, and sea dab fillets compete in the same market, the market is not fully integrated. This indicates that the different species are imperfect substitutes.

Given that there is an integrated market, exogeneity tests can be used to test the price leadership of one of the species in the system. Such tests were conducted for the system consisting of tilapia, red snapper, blackback flounder, and sea dab. The results are reported in table 5. The exogeneity tests are distributed as a Likelihood Ratio (LR) test with three degrees of freedom. The null hypothesis of weak exogeneity is rejected for all the wild species at the 1% significance level. However, we cannot reject the null hypothesis that farmed fresh tilapia fillets are weakly exogeneous, even at the 10% significance level.

From the results, it seems that in the long run, the price of farmed tilapia determines the price of the wild species: red snapper, sea dab, and blackback flounder. Therefore, given that imports of fresh tilapia fillets are likely to continue rising, it seems unlikely that whole red snapper prices and fresh fillet prices of sea dab and blackback flounder are going to increase in the future. This result is similar to that of Asche, Bremnes, and Wessells (1999) and Asche *et al.* (2005). Both of these studies found farmed and wild salmon are close substitutes and that the expansion of farmed salmon has resulted in price decreases for all salmon species.

The impact of lower prices of red snapper, sea dab, and blackback flounder on the supply of these species can be explained using the model formulated by Anderson (1985) on the interaction between farmed and wild fish. The model identifies the supply response of the industry depending on the biology of the stock. It indicates that the position of the wild stock in the backward bending supply schedule and the competitiveness of the aquaculturist will have different effects on the supply of the wild stock, overall price, and total supply to the market. The Atlantic stocks of sea dab and blackback flounder and the stocks from the Western Atlantic and the Gulf of Mexico are on their backward bending portion of the supply schedule, since these stocks are overfished (Waters 2001; Stevens 2006). Therefore, a fall in wild fish prices as indicated by our exogeneity tests is likely to cause a movement down the back-bending portion of the supply schedule. This situation could then lead to lower investments in fishing fleets and, therefore, a reduction in fishing effort over time. Nevertheless, the effect that farmed tilapia is likely to have on the stocks of the wild fish investigated will be weaker, since farmed tilapia is considered to be an imperfect substitute (Ye and Beddington 1996).

Table 3

Multivariate Johansen Test for Cointegration between Tilapia, Sea Dab, Blackback Flounder, Red Snapper, and Catfish: Jan. 1998–Dec. 2004 (n = 84)

Null Hypothesis[a]	Max[b]	95% Critical Value	Trace[c]	95% Critical Value
$\rho = 0$	43.58*	30.44	107.96*	60.06
$\rho \leq 1$	31.02*	24.16	64.37*	40.17
$\rho \leq 2$	26.79*	17.80	33.36*	24.28
$\rho \leq 3$	5.79	11.22	6.57	12.32
$\rho \leq 4$	0.79	4.13	0.79	4.13

Results from Schwarz IC.

[a] The null hypothesis is that the number of cointegrating vectors is equal to ρ; [b] Maximum eigenvalue test;
[c] Trace test.
* Indicates significance at the 1% level.

Table 4
Multivariate Johansen Test for Cointegration between Tilapia, Sea Dab, Blackback Flounder, and Red Snapper, Jan. 1998–Dec. 2004 (n = 84)

Null Hypothesis[a]	Max[b]	95% Critical Value	Trace[c]	95% Critical Value
$\rho = 0$	44.74*	28.59	99.85*	54.08
$\rho \leq 1$	29.12*	22.30	55.11*	35.19
$\rho \leq 2$	23.01*	15.89	25.98*	20.26
$\rho \leq 3$	2.97	9.16	2.97	9.16
Law of One Price	10.685**			

Results from Schwarz IC.

[a] The null hypothesis is that the number of cointegrating vectors is equal to ρ; [b] Maximum eigenvalue test; [c] Trace test.
* Indicates significance at the 1% level; ** indicates significance at the 5% level.

Table 5
Weak Exogeneity Tests, Jan. 1998–Dec. 2004 (n = 84)

Potentially Exogenous Variable	LR Test Statistic	*p*-value
Tilapia	1.245	0.742
Sea dab	20.530*	0.000
Blackback flounder	22.556*	0.000
Red snapper	28.633*	0.000

* Indicates significance at the 1% level.

Discussion and Conclusions

The purpose of this article has been to investigate whether fresh farmed tilapia fillets compete with several fresh wild and farmed species in the US market. The investigation is particularly interesting for two main reasons. First, little research has been done on the markets for tilapia, since global production and international trade with this species has been substantial only during the last few years. In particular, US imports of fresh tilapia fillets have increased significantly, while prices have remained stable. Therefore, fresh tilapia fillets are likely to have taken market share from other established species in the US market. Second, this study provides a contribution with respect to the issue of competition between farmed and wild fish. This issue remains unsettled, as the degree of competition seems to depend on species and market (*e.g.*, Asche, Bjørndal, and Young 2001; Nielsen *et al*. 2007).

Our results indicate that markets for farmed fresh tilapia fillets and farmed fresh catfish fillets are separate. This concurs with the findings of Norman-López and Asche (2008). On the other hand, fresh farmed tilapia fillets, wild fresh whole red snapper, fresh sea dab fillets, and fresh blackback flounder fillets compete in the same market, although we found that the LOP does not hold. Therefore, these seafood products are imperfect substitutes. In addition, we have tested whether any of these seafood products determine the price of other products in the market using exogeneity tests. Our results indicate that fresh tilapia fillets determine the price of wild fresh whole red snapper, sea dab fillets, and fillets of blackback flounder. Hence, any continued growth of fresh tilapia fillet imports is likely to reduce the prices of the product forms for these wild species.

The most likely cause for the competition between farmed tilapia and wild snapper, sea dab, and blackback flounder is the decline in stocks of these wild species (Waters 2001; Stevens 2006). This has resulted in lower supplies of these wild species to markets. In the US, the annual per-capita consumption of fish and shellfish has remained more or less stable over the last two decades (NFI 2007). Therefore, the increasing production of tilapia is likely to have filled the gap between the declining landings of these wild species and relatively constant US seafood per-capita consumption.

Other possible reasons for competition between wild snapper, sea dab, and blackback flounder and farmed tilapia include increased demand for convenience food following the change in consumer lifestyles (Murray and Fofana 2002) and the positive perceptions of farmed fish following successful advertising campaigns that have familiarised consumers with farmed species such as tilapia (Gempesaw *et al.* 1995; Nauman *et al.* 1995). Furthermore, the competitiveness of farmed tilapia in the commodity market is likely to be enhanced with the increasing importance of retail outlets for the seafood industry and the rising number of chain restaurants (Anderson 2006). In the US Northeast, 30% of total seafood sales go to retailers and supermarkets and 60% to restaurants and foodservice (O'Dierno, White, and Garfield 2003). Restaurants and the retail sector are likely to prefer farmed fish to wild fish because volumes and prices are less volatile. Fish farms can adjust supply in the short run by changing harvesting time and in the long term by altering the number of active farms. On the other hand, fishermen can be prevented from adjusting supply in the short term by fisheries management, and in the long term they are dependent on the biology of the stock.

The relationship between farmed tilapia and the wild fish will have implications for producers, processors, traders, consumers, and other levels of the supply chain. The implications for fishermen can be described in relation to the model formulated by Anderson (1985) on the interaction between farmed and wild fish. Given that the wild fish in this analysis are all currently overexploited, fishermen will be unable to increase supply in the long term due to the biology of the stock. Wild fish supply is also likely to be constrained in the short term depending on the management of the fishery. Therefore, an increase in demand can only be met by increasing the supply of farmed fish, such as tilapia. In addition, the price leadership of tilapia suggests that lower farmed tilapia prices are likely to cause a reduction in the demand for wild fish. This will reduce the price of competing wild species and result in a loss in revenue to the fishers in the short term. As fishers reduce fishing effort due to lower prices, this will create a positive stock effect.

References

Alceste, C.C., and D.E. Jory. 2002. World Tilapia Farming 2002. *Aquaculture Magazine*. http://www.aquaculturemag.com/siteenglish/printed/buyers/web-tilapia.pdf

Anderson, J.L. 1985. Market Interactions between Aquaculture and the Common Property Commercial Fishery. *Marine Resource Economics* 2(1):1-24.

_____. 2002. Aquaculture and the Future: Why Fisheries Economists Should Care. *Marine Resource Economics* 17(2):133-51.

_____. 2003. *The International Seafood Trade,* 240 pp. Cambridge, UK; Woodhead Publishing Ltd.

_____. 2006. The Seafood Industry: 2020. International Boston Seafood Show. Boston, MA. March 12–14. http://seafoodreport.com/uploaded_docs/ Boston_2006_JLA.pdf

Asche, F. 1997. Trade Disputes and Productivity Gains: The Curse of Farmed Salmon Production? *Marine Resource Economics* 12:67-73.

Asche, F., T. Bjørndal, and D.V. Gordon. 2007. Studies in the Demand Structure for Fish and Seafood Products. *Handbook of Operations Research in Natural Resources,* A. Weintraub, C. Romero, T. Bjørndal, R. Epstein, and J. Miranda, eds., pp. 295-314. USA: Springer.

Asche, F., T. Bjørndal, and J.A. Young. 2001. Market Interactions for Aquaculture Products. *Aquaculture Economics and Management* 5:303–18.

Asche, F., H. Bremnes, and C.R. Wessells. 1999. Product Aggregation, Market Integration and Relationships between Prices: An Application to World Salmon Markets. *American Journal of Agricultural Economics* 81:568-81.

Asche, F., D.V. Gordon, and R. Hannesson. 2004. Test for Market Integration and the Law of One Price: The Market for Whitefish in France. *Marine Resource Economics* 19:195–210.

Asche, F., A.G. Guttormsen, T. Sebulonsen, and E. Sissener. 2005. Competition between Farmed and Wild Salmon: The Japanese Salmon Market. *Agricultural Economics* 33:333-40.

Asche, F., R. Menezes, and J.F. Dias. 2007. Price Transmission in Cross Boundary Supply Chains. *Empirica* 34:477-89.

Asche, F., and S. Tveterås. 2008. International Fish Trade and Exchange Rates: An Application to the Trade with Salmon and Fishmeal. *Applied Economics* 40:1745-55.

Bose, S., and A. McIlgorm. 1996. Substitutability among Species in the Japanese Tuna Market: A Cointegration Analysis. *Marine Resource Economics* 11:143–56.

Dickey, D.A., and W.A. Fuller. 1979. Distribution of the Estimators for Autoregressive Time Series with Unit Root. *Journal of the American Statistical Association* 74:427–31.

_____. 1981. Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root. *Econometrica* 49:1057–72.

Engle, R.F., and C.W.J. Granger. 1987. Cointegration and Error Correction: Representation, Estimation and Testing. *Econometrica* 55:251–76.

FAO. 2007a. *FishStat Plus*. Global datasets, Capture Production. Rome, Italy.

_____. 2007b. *FishStat Plus*. Global datasets, Commodities Production and Trade. Rome, Italy.

_____. 2007c. *FishStat Plus*. Global datasets, Aquaculture Production: Quantities. Rome, Italy.

Gempesaw II, C.M., J.R. Bacon, C.R. Wessells, and A. Manalo. 1995. Consumer Perceptions of Aquaculture Products. *American Journal of Agricultural Economics* 77:1306-12.

Gordon, D.V., and R. Hannesson. 1996. On Prices of Fresh and Frozen Cod. *Marine Resource Economics* 11:223–38.

Harvey, D.J. 2002. Aquaculture Outlook: In 2002, Aquaculture Volumes Higher, but Prices Depressed. October 10, 2002, LPD-AQS-16. Retrieved August 26, 2006, US Department of Agriculture, Economic Research Service website: http://www.ers.usda.gov

Jaffry, S.A., S. Pascoe, G. Taylor, and U. Zabala. 2000. Price Interactions between Salmon and Wild Caught Species on the Spanish Market. *Aquaculture Economics and Management* 4:157–67.

Johansen, S. 1988. Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control* 12:231–54.

Johansen, S., and K. Juselius. 1990. Maximum Likelihood Estimation and Inference on Cointegration–with Applications to the Demand for Money. *Oxford Bulletin of Economics and Statistics* 52:169–210.

Josupeit, H. 2005. Tilapia Market Report – Tilapia Imports Soar in the US Market. April. *Globefish*. FAO. http://www.globefish.org/

Kinnucan, H.W., and Y. Miao. 1999. Media-Specific Returns to Generic Advertising: The Case of Catfish. *Agribusiness* 15(1):81–99.

Muir, J.F., and J.A. Young. 1998. Aquaculture and Marine Fisheries: Will Capture Fisheries Remain Competitive? *Journal of Northwest Atlantic Fisheries Science* 23:157-74.

_____. 1999. Strategic Issues in New Species Development for Aquaculture. *Biofutures Series*. XXXIII International Symposium on New Species for Mediterranean Aquaculture, pp. 85–96. Amsterdam: Elsevier.

Murray, A.D., and A. Fofana. 2002. The Changing Nature of UK Fish Retailing. *Marine Resource Economics* 17:335-39.

National Fisheries Institute (NFI). 2007. US Consumption of Seafood. Retrieved March 5, 2007, National Fisheries Institute website: http://www.aboutseafood.com/ media/top_10.cfm

National Marine Fisheries Service (NMFS). 2007. Fisheries Statistics Division, Foreign Trade Information, National Marine Fisheries Service website: www.st.nmfs.noaa.gov/st1/trade/build_a_database/TradeSelectIndex.html

Nauman, F.A., R. Gempesaw, J.R. Bacon, and A. Manalo. 1995. Consumer Choice for Fresh Fish: Factors Affecting Purchase Decisions. *Marine Resource Economics* 10:117-42.

New Fulton Fish Market. http://www.newfultonfishmarket.com

Nielsen, M. 2005. Price Formation and Market Integration on the European First-hand Market for Whitefish. *Marine Resource Economics* 20:185–202.

Nielsen, M., J. Setälä, J. Laitinen, K. Saarni, J. Virtanen, and A. Honkanen. 2007. Market Integration of Farmed Trout in Germany. *Marine Resource Economics* 22(2):195-213.

Norman-López, A., and F. Asche. 2008. Competition between Imported Tilapia and US Catfish in the US Market. *Marine Resource Economics* 23(2):199-214.

O'Dierno, L., D.S. White, and S. Garfield. 2003. *Aquaculture Marketing Analysis and Opportunities in the Northeast Region*. NRAC Publication No. 03-003. Northeastern Regional Aquaculture Center. University of Massachusetts Dartmouth. North Dartmouth, MA. http://www.nrac.umd.edu/files/Whitepapers/wp_no3_marketing.pdf

Stevens, M.M. 2006. Commercially Important Atlantic Flatfishes. Seafood Report. Seafood Watch. Monterey Bay Aquarium. http://www.seachoice.org/files/ assessment/report/53/MBA_SeafoodWatch_AtlanticHalibutReport.pdf

Stigler, G.J. 1969. *The Theory of Price*. 85 pp. London: Macmillan.

Stigler, G.J., and R.A. Sherwin. 1985. The Extent of a Market. J*ournal of Law and Economics* 28:555–85.

Urch, M. 2001. Tilapia Set for New Markets. *Seafood International* 16(9):29-34.

Vannuccini, S. 2001. Global Markets for Tilapia. *INFOFISH International* 6:16–20.

Waters, J.R. 2001. Quota Management in the Commercial Red Snapper Fishery. *Marine Resource Economics* 16:65-78.

Ye, Y., and J.R. Beddington. 1996. Bioeconomic Interactions between the Capture Fishery and Aquaculture. *Marine Resource Economics* (11):105-23.

Young, J.A., and J.F. Muir. 2002. Tilapia: Both Fish and Fowl? *Marine Resource Economics* 17:163-73.