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Competition between farmed and wild salmon: the Japanese salmon market

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Abstract

This article examines the Japanese market for salmon. This market is of interest, since it is the largest and most diversified salmon market in the world with wild and farmed species, from Europe and South and North America, competing in the same market. In contrast to the European Union (EU)- and U.S.-markets, there have been neither trade conflicts nor trade restrictions. The Japanese market can hence provide information about the impact of bringing substantial quantities of a new product into a market, and the effect of large-scale aquaculture on traditional fisheries. In this article, market integration between wild and farmed salmon on the Japanese market is examined, using both bivariate and multivariate cointegration analysis. Tests for the Law of One Price are also conducted. The results indicate that the species are close substitutes on the market, and that the expansion of farmed salmon has resulted in price decreases for all salmon species.

JEL classification: Q11, Q17

Keywords: Aquaculture; Salmon markets; Market integration

1. Introduction

Salmon has recently overtaken the number one spot from shrimps as the most successful species in modern large-scale aquaculture (Anderson and Fong, 1997). Production has grown to over a million tons during the last two decades farmed salmon has been a commercial product. The growth is a result of substantial productivity growth (Asche, 1997; Guttormsen, 2002; Tveteras, 2002) that has reduced the production costs to about a third of the costs in the early 1980s. Furthermore, the growth has been amplified by market growth that at least partly is due to generic marketing programs (Bjørndal et al., 1992; Kinnucan and Myrland, 2000, 2002). However, such a large increase in production has significantly changed the structure in several markets, and this has led to a number of trade conflicts. Norway, the largest producer, has been the main target in these conflicts. More recently, also Chile has been subject to dumping complaints in the United States and the EU, and the Faroe Islands have been targeted in an anti-dumping complaint in the EU.[1]

The impact of new products in a market and the effect of trade-restricting measures depends on the size of the market. The literature indicates that there is a global market for salmon where all species of salmon compete, while other seafood species such as cod and hake do not seem to be a part of this market (Asche, 2001; Asche et al., 1999, 2002; Gordon et al., 1993; Jaffry et al., 2000). The focus so far has been on farmed Atlantic salmon and wild North American salmon, and because of the trade issues, the focus has been on the European and U.S. markets.[2] However, farming of the Pacific salmon species coho is a substantial part of the Chilean industry, and salmon trout (large rainbow trout) is important both in Chile and in several European countries.[3] All these species are present together with wild salmon of similar species in the Japanese market, the

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[1] See Anderson and Fong (1997), Asche (1997, 2001), and Kinnucan and Myrland (2000, 2002) for studies and discussions of several of these cases.

[2] Wessells and Wilen (1994) and Eales et al. (1997) investigate demand for salmon in demand systems containing a number of other goods, but does not differentiate by species.

[3] Chile is currently the largest producer of salmon trout. However, Norway and Finland, where substantial quantities still are produced, have also held this

largest and most diversified salmon market in the world.[4] The fact that there have been no trade conflicts related to salmon in the Japanese market allows us to investigate the impact on the relative prices of the large increase in the supply of a new product, and also to investigate the relationship between wild and farmed products. In particular, there are substantial imports of farmed coho from Chile and wild-caught coho from North America, as well as considerable quantities of wild sockeye, a species regarded as a close substitute to coho and a previous with market leader. With all these species belonging to the same market, the market has now changed from being exclusively served by wild salmon to a market dominated by farmed species. The wild salmon, mostly from North America, dominated the market until the late 1980s, but during the farmed salmon's take over in the 1990s, the wild salmon's market share declined to 31% in 2000.

The results are also of general interest, as salmon is not only the largest modern farmed species, but it is the first farmed species that is sold globally in potential competition with its wild cousins in all main markets. The results can therefore offer some insights into the future development of species such as sea bass, sea bream, and cod in Europe, and tilapia, catfish, and a number of other species in the rest of the world as production increases. Moreover, as new regions take up farming of similar species for which a market already exists, comparable shifts in market shares are likely also between different farmed species.

To investigate if farmed and wild coho, sockeye, and salmon trout compete in the same market in Japan, we study the relationship between their prices. While testing hypotheses about market integration, using only price data, has a long history, several developments during the last decade have made the link to economic theory clearer and therefore the results more useful. In particular, one can distinguish between no substitution, imperfect substitution, and complete market integration (the Law of One Price [LOP]holds). One would also suspect a close link between market integration and aggregation, as, for instance, it should be possible to aggregate several similar products from different producers to a generic commodity. Indeed, the Generalized Composite Commodity theorem of Lewbel (1996) indicates that this is the case, as goods with stable relative prices can be aggregated under this theorem. However, as a stable relative price is equivalent to a situation in which the LOP holds, one can test the theorem by testing the LOP (Asche et al., 1999). Furthermore, Asche et al. (1999) and Gonzàlez-Rivera and Helfand (2001) have clarified the relationship between bivariate and multivariate cointegration tests in a market integration context.

This article is organized as follows. In the next section we give a brief background on the Japanese salmon market and a presentation of the data set. In the third section the empirical methods are presented. The empirical results are reported in section 5, before some concluding remarks are provided in the last section.

2. Background

The Japanese salmon market is one of the three major markets for salmon together with the EU and the United States, and practically all high-value salmon is imported.[5] Moreover, it is the only market in which fish from all the major producing regions are present and where both farmed and wild-caught salmon hold substantial market share. At the beginning of the salmon-farming era, Japan was the only large market for high-valued salmon, as most high-valued North American salmon were exported to this market (Knapp et al., 1993). Hence, the Japanese market was the place for potentially large changes in an existing market structure because of the introduction of farmed salmon. Until the late 1980s the demand for salmon in the Japanese market was mainly concentrated on wild sockeye salmon from North America, especially Alaska, as wild salmon primarily has been available in the northern Pacific. Significant quantities of coho were imported from the same sources. In 1988, the Japanese imports were dominated by the United States with a share of 85%, while the Canadian share was around 9%.[6] The remaining was mostly imports of wild salmon from other countries in Northeast Asia.

During the 1980s, salmon farming became commercially viable after several technological breakthroughs (Bjørndal, 1990). As the pioneers were European, the preferred species was Atlantic salmon, although operators quickly started farming salmon trout and (in the Pacific) coho, targeting the Japanese market.[7] These species are suitable for Japanese tradition because of their deeply red flesh.[8] The market shares for imported farmed coho and salmon trout were close to zero as late as 1990, but in the early 1990s Japanese imports of these species increased rapidly. The import statistics do not allow us to separate the species until 1994, when the market shares were 67% for sockeye, 14% for trout, 11% for farmed coho, and 8% for wild coho. In 2000, on the other hand, the market shares were 32% for salmon trout, 37% for farmed coho, 1% for wild coho, and 30% for sockeye.

World production of salmon increased substantially from about 500,000 tons in 1980 to about 1.8 million tons in 2000,

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position. Salmon trout is also produced in substantial quantities in other North European countries.

[4] However, it should be noted that the EU is the largest importer, and importing almost exclusively Atlantic salmon makes EU the largest market for Atlantic salmon.

[5] Domestic landings, often based on hatchery production, consist mostly of low-value chum salmon, and will not be investigated further here, as it is consumed in different product forms as a final product.

[6] The categories in the import statistics do not allow us to separate the species. Our knowledge of the species composition from the United States stems from the U.S. export statistics.

[7] The main producers of salmon trout are Chile, Finland, and Norway. Chile is virtually the only producer of farmed coho, a species that was pioneered in Japan in the early 1980s.

[8] Sockeye is the salmon species with the deepest red color, favored by Japanese consumers. However, sockeye is not as biologically feasible to farm on a commercial basis.

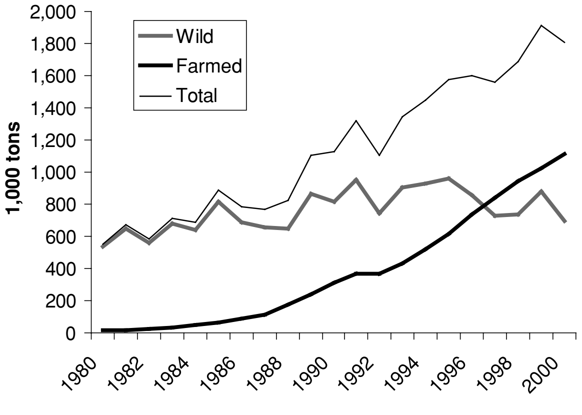

Fig. 1. Production of wild and farmed salmon.

mostly because of increased farmed salmon production, as shown in Fig. 1. The increase in production has been accompanied by declining real prices, primarily because of a substantial productivity growth for farmed salmon (Asche, 1997; Guttormsen, 2002; Tveteras, 2002). However, in addition to the influence of farmed salmon, a number of hypotheses have been forwarded for the causes of price declines for wild salmon. In Alaska the Exxon Valdez oil spill in 1989 and alleged collusive behavior among Japanese buyers in the early 1990s have been blamed for adverse effects on Alaskan salmon prices. To what extent the price decline for Alaskan salmon can be blamed on the oil spill, collusion among Japanese buyers, and increased farmed salmon production is unknown. However, given that there was no significant market share of farmed salmon in the Japanese market until the 1990s, a high degree of market integration in this main market for sockeye and coho salmon would indicate that the presence of farmed salmon in the Japanese market to a large extent is influencing the prices for wild salmon from Alaska.

While the market for salmon is of interest in itself, it is of general interest to investigate the impact of farmed fish in traditional seafood markets. There have been theoretically based analyses, such as Anderson (1985), but there are no analyses based on actual data. Salmon is the first large-scale farmed species to hit the market, and the Japanese market is the first market where a major seafood market has seen a substantial increase in supply of farmed product to a large market segment for a similar wild species (e.g., in Europe, the salmon consumption was very low before farmed salmon became available).[9] Hence, the results are of interest, as aquaculture is expected to be the main source for further growth in seafood production (Anderson, 2002).

3. Methodology

In general microeconomic theory one assumes that there exists a market constituted by a group of commodities. The commodities compete in the same market when the goods are substitutable for the consumer or the producer. Whether goods are substitutes can be measured by estimating demand and/or supply equations and by testing whether there are cross-price effects. If cross-price effects exist, the goods compete in the same market, whereas if there are no cross-price effects, the goods do not compete. If the relative price is constant, the goods are perfect substitutes. The most common measure of a cross-price effect is cross-price elasticities, which can be derived empirically if one estimates a demand equation. However, in many cases, obtaining the necessary data to estimate demand equations is a problem. Often, prices are available while quantities are not. Moreover, while one can often find a price that is a good proxy for the market price, it is hard to get reliable estimates of demand and supply equations if data are not available for the full quantity consumed in a market. While measuring the degree of substitution is the preferred way of measuring to what extent goods compete, the development of prices is easier to observe. Therefore, economists early started defining markets only based on observations of prices (Stigler, 1969).

Based on the observation that most price series seem to be nonstationary, cointegration analysis has been established as a preferred tool when analyzing relationships between prices. Evidence of how price changes in one market generate price changes in another so as to bring about long-run equilibrium relationship can be represented as

$$p_t^1 - \beta_0 - \beta_1 p_t^2 = e_t, \tag{1}$$

where p_t^i is the logarithm of the price observed in market i at time t, β_0 is a constant term (the log of a proportionality coefficient) that captures transportation or transaction costs and quality differences, and β_1 gives the relationship between the prices. If $\beta_1 = 0$, there is no relationship between the two price series, while if $\beta_1 = 1$, the LOP holds, and the relative price is constant. Note that some researchers separate between the strong LOP where $\beta_0 = 0$ and the weak LOP where β_0 is different from zero. If β_1 is different from zero but not equal to one there is a relationship between the prices, but the relative price is not constant, and the markets are not fully integrated. If $\beta < 0$ the goods will be complements. If p_t^1 and p_t^2 are cointegrated, the error term e_t will be stationary. This observation forms the basis for the Engle and Granger test for cointegration, where e_t is tested for stationarity by performing Augmented Dickey–Fuller (ADF) unit root tests. The Engle and Granger methodology has several serious shortcomings, however, and is mostly replaced by the Johansen framework today. If one perceives there are adjustment costs in the system, lags are added to Eq. (1). The long-run relationship will then have the same form as Eq. (1). The adjustment costs imply that the response to changes in the price in one market will be less in the short run,

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[9] There is also substantial production of aquacultured products in small-scale operations, particularly in China, that reaches the world market only to a very limited extent.

making markets less integrated in the short run than in the long run.

Froot and Rogoff (1995) indicate that relationships such as Eq. (1) can be extended to any number of goods. However, with the structure of the model, one does not obtain any additional information by providing multivariate relationships. A multivariate test for the LOP only means that the cointegration vector must sum to zero, or, in a single equation specification, that the right-hand side variables' coefficients must sum to one. Without loss of generality, one can then normalize the model so that the parameters on all but one right-hand side price series are zero. It follows from the identification scheme of Johansen and Juselius (1994) that this also is true for nonstationary data series with this data structure; thus, no structural information is lost by modeling only bivariate relationships. It should also be noted that in models where all pairs of variables are cointegrated, the multivariate system is driven by one common stochastic trend, and therefore that multivariate systems should have $n - 1$ cointegration vectors (Hall et al., 1992).

Multivariate models are, however, of interest for at least two reasons. With n data series there can at most be $n - 1$ cointegration vectors. However, there are $(n^2 - n)/2$ possible pairs. Hence, all but $n - 1$ pairs will be redundant (Asche et al., 1999; Gonzàlez-Rivera and Helfand, 2001). A potential problem, therefore, is that one might obtain different conclusions, depending on which pairs one chooses in applied work.[10] This problem is avoided in a multivariate specification, as one then only can estimate $n - 1$ cointegration vectors. Moreover, while all structural information is contained in the cointegration vectors, one needs the full system to find out if there are any exogenous variables.[11] While this might suggest that one, in all cases, should estimate multivariate systems, the reason for not doing so is the sensitivity of the results to the dimensionality of the system. In particular, the reliability of the results is a decreasing function of the number of parameters to be estimated with a given number of observations. This is what Hendry (1995) refers to as "the curse of dimensionality." There is no clear answer to what is the correct strategy. A multivariate analysis is to be preferred if one is not exposed to a dimensionality problem, but as that often seems present, bivariate specifications can also be valuable tools. Because of the dimensionality problem and since bivariate Johansen systems contain all structural information, some studies only report results from the bivariate systems.

3.1. The Johansen test

The multivariate Johansen approach can be represented as follows. Let X_t denote an $n \times 1$ vector, where the maintained hypothesis is that X_t follows an unrestricted vector autoregression (VAR) in the levels of the variables

$$X_t = \Pi_1 X_{t-1} + \cdots + \Pi_k X_{t-k} + \Phi D_t + \mu + e_t, \tag{2}$$

where each of the Π_i is a $n \times n$ matrix of parameters, μ a constant term, and ε_t are identically and independently distributed residuals with zero mean and contemporaneous covariance matrix Ω. The VAR system in Eq. (2) written in error correction form (ECM) is

$$\Delta\mathbf{X}_t = \Gamma_1 \Delta\mathbf{X}_{t-1} + \cdots\cdots\cdots + \Gamma_{k-1}\Delta\mathbf{X}_{t-k+1} + \Pi\mathbf{X}_{t-k} + \psi\mathbf{D}_t + \varepsilon_t, \tag{3}$$

with $\Gamma_i = -I + \Pi_1 + \cdots + \Pi_i, i = 1, \ldots, k-1$ and $\Pi_i = -I + \Pi_1 + \cdots + \Pi_k$. Hence, Π is the long-run "level solution" to Eq. (2). If X_t is a vector of I(Eq. (1)) variables, the left-hand side and the first $(k - 1)$ elements of Eq. (3) are $I(0)$, and the kth element of Eq. (3) is a linear combination of $I(1)$ variables. Given the assumptions on the error term, the kth element must also be $I(0)$; $\Pi X_{t-K} \sim I(0)$. Hence, either X_t contains a number of cointegration vectors, or Π must be a matrix of zeros. The rank of Π, r, determines how many linear combinations of X_t are stationary. If $r = n$, the variables in levels are stationary; if $r = 0$ so that $\Pi = 0$, none of the linear combinations are stationary. When $0 < r < n$, there exist r cointegration vectors—or r stationary linear combinations of X_t. In this case one can factor Π; $\Pi = \alpha\beta'$, where both α and β are $n \times r$ matrices, and β contains the cointegration vectors (the error correcting mechanism in the system), and α the adjustment parameters. Johansen suggests two tests for the number of cointegration vectors in the system, the *maximal eigenvalue* test and the *trace* test.

The Johansen procedure allows a wide range of hypothesis testing on the coefficients α and β, using likelihood ratio tests (Johansen and Juselius, 1990). When the LOP hypothesis is of interest, it is the restrictions on parameters in the cointegration vectors β we wish to test. In the case where there are two price series in the X_t vector, and provided that these series cointegrate, the rank of $\Pi = \alpha\,\beta'$ is equal to 1 and α and β are 2×1 vectors. A test of LOP is then a test of whether $\beta' = (1, -1)'$. However, if a group of goods are to be in the same market, all the prices must be pairwise cointegrated. This also allows a multivariate test of the LOP, because it implies that there is only one common stochastic trend in the system, and hence with n prices in the system there must be $n - 1$ cointegration vectors (Asche et al., 1999; Gonzàlez-Revera and Helfand, 2001). In general, in a system with n data series and r cointegration vectors, there will be $n - r$ different stochastic trends (Stock and Watson, 1988). As the cointegration vectors are identified only up to a nonsingular transformation, any set of restrictions that makes the columns of β sum to zero will do. A natural procedure is to

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[10] Note that the theory is asymptotic.

[11] For instance, bivariate systems can indicate that data series *a* is exogenous for series *b*, but that *c* is exogenous for *a*, but not for *b*. A multivariate test will then be able to resolve which variables are exogenous in the system, if any.

normalize upon one price. This makes all cointegration vectors $(1, -1)$ with respect to this price.[12] In this case

$$\beta = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ -1 & 0 & \cdots & 0 \\ 0 & -1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & -1 \end{bmatrix}. \tag{4}$$

The α vector (matrix) contains information about price leadership, as a parameter (row) of zero(s) makes the data series in question weakly exogenous in this system. This price will then be determined outside of the system and therefore be the price leader. As there has to be at least as many endogenous variables in the system as cointegration vectors, there can at most be one exogenous variable when there is only one common stochastic trend in the system. Hence, there can at most be one price leader.

3.2. Aggregation

The Composite Commodity theorem of Hicks (1936) and Leontief (1936) states that for a bundle of goods, if individual prices move proportionally over time (i.e., the relative prices are constant), the bundle can be characterized using a single composite price index. Hence, a test for proportionality of prices over time, i.e., a test for the LOP, provides evidence of whether the goods can be aggregated. In this case one does not need information about consumer preferences as with different separability concepts. A problem with the Composite Commodity theorem in empirical work is that for the theorem to hold, the prices must be exactly proportional. However, Lewbel (1996) provides an empirically useful generalization of the theorem that allows for some deviations from proportionality.[13] There are several ways to test for the Generalized Composite Commodity theorem. One method is to investigate whether the LOP holds in a market delineation context when prices are nonstationary (Asche et al., 1999). If so, aggregation can occur according to the Generalized Composite Commodity theorem. This is consistent with our intuition that goods that are equivalent for consumers or producers can be treated as one good. Moreover, this is interesting because it provides a clear link between aggregation theory and market integration.

4. Data

Our data are based on Japanese import data on a monthly basis from 1994 to 2000. These data contain import values and quantities for salmon trout, coho, and sockeye. Since all coho in Chile is farmed and all North American coho is wild caught, we label Chilean coho as farmed coho and North American coho as wild coho. All production of salmon trout is farmed, while all North American sockeye are wild-caught. For wild coho there are two missing observations that are interpolated, as are three outliers for sockeye. The price data used in empirical testing are shown in Fig. 2. Note that for most of the period, farmed coho prices were higher than the prices of wild caught. The main reason for this is that farmed coho can be imported fresh throughout the year, while wild salmon reach the market only in certain periods of the year. The wild coho must hence be stored in Japan, and are therefore of lower quality, on average.

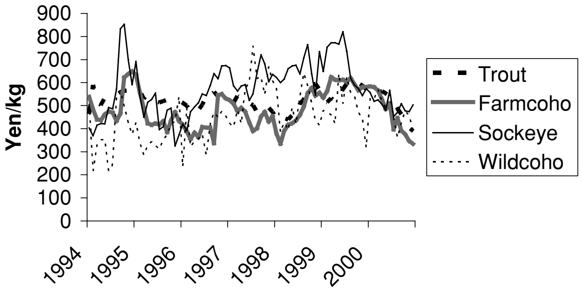

Fig. 2. Japanese import prices for salmon.

When investigating market integration, the first priority is to examine the time series properties of the price series. We use the most common approach, the ADF test for this purpose.[14] The lag length, k, is set to achieve white noise in the error term, as suggested by Banerjee et al. (1993), by starting with a generous parameterization and then removing insignificant lags. Using the level forms of each series, the null hypothesis is that each data series is nonstationary. If the hypothesis is not rejected, the test is repeated using the first differences of each price series. In this case, the null hypothesis is nonstationary in first differences. In Table 1, the results of the ADF test for individual prices are reported both for the prices in levels and for the prices in first differences. For all prices in levels, we cannot reject the null hypothesis of nonstationarity. However, for all prices in first differences we can strongly reject the null hypothesis of nonstationarity. These conclusions are independent of the number of lags chosen and whether or not a trend variable is included in the measurement. Hence, we conclude that all four prices are integrated of order one (i.e., stationary in first differences).

5. Empirical results

We next test whether the prices are cointegrated. We start by investigating a multivariate system containing all prices with

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[12] This is often done when testing the unbiased expectation hypothesis (e.g., Hall et al., 1992), which is carried out in a similar fashion.

[13] As always, there is some cost involved. Aggregates constructed using the Generalized Composite Commodity theorem cannot be used in welfare comparisons.

[14] We also conducted the tests with seasonal dummies. However, these did not lead to any changes in the results.

Table 1
Dickey–Fuller tests

Variable	Test statistic, levels	Test statistic, first differences
Trout price	−1.951	−3.820*
Farmed coho price	−1.878	−4.538*
Sockeye price	−1.841	−4.520*
Wild coho price	−2.788	−5.960*

*indicates significant at a 5% level. Critical value at the 5% level is −3.467.

Table 2
Multivariate Johansen test

H_0:Rank $= p$	Max Test statistic	Critical value at a 5% level	Trace test statistic	Critical value at a 5% level
$p == 0$	53.18*	28.1	103.10*	53.1
$p <= 1$	29.45*	22.0	49.90*	34.9
$p <= 2$	14.60**	15.7	20.45*	20.0
$p <= 3$	5.85	9.2	5.85	9.2

*indicates significant at the 5% level; **indicates significant at the 10% level.

two lags.[15] This seems sufficient to model the dynamics in the system, as Lagrange-Multiplier (LM) tests against up to 12th order autocorrelation in each equation gave the following test statistics with p-values in parentheses: Salmon trout, 1.350 (0.213), Farmed coho, 1.584 (0.118), Sockeye, 1.062 (0.406), Wild coho, 0.711 (0.736). The results from the cointegration tests are reported in Table 2. As one can see, there are three cointegration vectors, and accordingly one common stochastic trend in the system. Hence, these four products seem to belong to one market in Japan. Furthermore, a test for the LOP gives test statistic of 3.073, and has a p-value of 0.381. Hence, the LOP holds, and the relative prices are stable in the long run.

Johansen and Juselius (1994) indicate that if there are $n - 1$ cointegration vectors in a system with n variables, these relationships can be normalized, so that all structural information is contained in bivariate relationships. Bivariate cointegration tests in our case are reported in Table 3. All bivariate tests indicate one cointegration vector and hence one common stochastic trend. This is as expected, given the results from the multivariate system. Furthermore, the LOP also holds in all relationships.

These results indicate that the Japanese salmon market is a single market consisting of both wild and farmed species. The market is highly integrated, as the relative prices are stable over time and the LOP holds. As this implies that the Generalized Composite Commodity theorem holds, we can say that it is not meaningful to distinguish between wild-caught and farmed salmon, or between the different species in this market. This also means that the prices of wild and farmed salmon are set in the same market, and hence that the same factors influence both. Hence, Alaska salmon prices seem to be influenced by the same factors that influence salmon production worldwide. However, it should be noted that the adjustment speed towards equilibrium is slow. Moreover, there seem to be consumers who do not regard the different species as fully substitutable. In particular, in seasons with very low quantities of the wild species, the price can deviate from the long-run relationship over a full season.

Finally, to investigate price leadership, exogeneity tests are reported in Table 4. These results are based on the multivariate system, as they imply cross-equation dependencies that are imposed as restrictions if they are carried out in bivariate systems. As one can see, none of the variables are exogenous, indicating that there is no price leader in the Japanese salmon market. This is somewhat surprising given the results of Asche et al. (1999) who find farmed salmon to be price leading in a system with four wild salmon prices. This last result seems reasonable, given that it is productivity growth in the farmed segment that drives the prices down. Hence, we would expect the farmed species to be price leading because of their productivity growth. However, the system does not allow two species to be price leading, one cannot discriminate between the two farmed species, and the conclusion must be that there is no price leadership. The price is thus determined by total supply and demand of all the species and not by the factors that influence only one of the species.

6. Concluding remarks

The purpose of this article has been to examine the Japanese market for salmon. This market is interesting, since it is the most diversified salmon market in the world and the market where the introduction of farmed salmon has changed market structure most. In Japan, different types of farmed salmon are now present together with wild salmon of similar species, and from all major producing regions in the world.

Based on monthly observations of Japanese import data, we find that both wild salmon (sockeye and coho) and farmed salmon (coho and salmon trout) compete in the same market. Furthermore, we find that the LOP holds and hence that the relative prices are stable in the long run, implying that the Generalized Composite Commodity theorem holds. Hence, the market is highly integrated and makes up a single market rather than a set of interlinked market segments. Based on exogeneity tests, we find that none of the prices are exogenous, indicating that there is no price leader in the salmon market. Hence, factors common to all the species influence the price-determining process. This then implies that if certain phenomena in, say, Alaska influence the prices of Alaska salmon, these phenomena will also influence the prices of the other species. Similarly, productivity development of the farmed species will influence the prices of the wild species. Hence, the increased production of farmed salmon is likely to be a main cause of the lower prices

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[15] We also estimated the system allowing for seasonal effect. However, these were not significant. This is as expected, as the literature indicates that there is no seasonality in the levels of salmon prices in the 1990s (Asche and Guttormsen, 2001).

Table 3
Bivariate Johansen tests

Variables in the test	H$_0$:Rank $= p$	Max	Trace	LOP[a]	Autocorrelation[a]
Farmed coho and trout	$p = = 0$	30.73*	37.21*	0.153 (0.695)	1.618 (0.108)
	$p < = 1$	6.473	6.473		0.992 (0.465)
Farmed coho and sockeye	$p = = 0$	17.89*	25.95*	0.948 (0.330)	0.955 (0.499)
	$p < = 1$	8.068	8.068		1.048 (0.417)
Farmed coho and wild coho	$p = = 0$	14.68**	20.7*	2.632 (0.105)	1.038 (0.426)
	$p < = 1$	6.015	6.015		1.018 (0.443)

*indicates significant at the 5% level; **indicates significant at the 10% level.
[a] p-values in parenthesis.

Table 4
Exogeneity tests

	Salmon trout	Farmed coho	Sockeye	Wild coho
Test Statistic	11.879*	28.394*	9.884*	23.807*
p-value	(0.008)	(<0.001)	(0.019)	(<0.001)

*indicates significant at the 5% level.

received by Alaskan fishermen, and accordingly their poor profitability.

The results provide important insights for the development of new farmed species and their impact on existing markets for similar species, both wild and farmed. It is almost remarkable that the relative prices in the Japanese market remain stable, even with substantial short-run variations, given the tremendous shift in market shares. This indicates that new species can go from virtually zero market shares to a dominating one, during a relatively short period of time. In Japan, the market share for farmed salmon made this jump in less than 10 years. It also points towards consumers embracing a new product quickly. This is important in a number of places for long-run market expectations, as new farmed species can change existing market structure substantially for both wild and farmed products, and therefore also the potential revenues for the incumbents. For instance, what will happen to European cod fishermen if cod aquaculture takes off as it seems set to do? Or will this development be stopped to the benefit of fishermen and to the loss for consumers, by trade restrictions if the cod farming in question is not located within the EU?

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