Article

Market Interactions for Farmed Fish Species on the Korean Market

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Abstract : This study aims to analyze the market interactions among the main farmed fish species in Korea, using both multivariate and bivariate cointegration analysis. For the analysis of market interactions among farmed fish species, major four farmed fish species, olive flounder (*Paralichthys olivaceus*), black rockfish (*Sebastes schlegeli*), red seabream (*Pagrus major*), and grey mullet (*Mugil cephalus*) were selected as the analytical target species. And their real price data by month from January 2000 to December 2011 were used in the analysis. The results of the multivariate cointegration test for four farmed fish showed that there would be no long-term equilibrium relationships among farmed fish species, and consequently they do not share the same market. The results of bivariate cointegration test indicated that there was little evidence to suggest that all farmed fish species were cointegrated each other. However, it was only analyzed that olive flounder and grey mullet might have a long run equilibrium relationship.

Key words : market interaction, cointegration analysis, ADF test, aquaculture

1. Introduction

After the 1980s, there was rapid growth in the production of aquaculture in Korea; by 2011, the overall amount of production reached 1,478 thousand tons. This constitutes 45% of the total production of seafood in Korea, indicating that aquaculture has grown to be one of the most important sources of seafood supply. Among types of aquaculture industries, particularly fish farming has grown quickly since the 1990s along with the development of farming methods such as land-based and sea-cage fish farming systems. In addition, with the development of farming technologies, an increasing number of fish species have been added to fish farming (Choi 2012; MIFAFF 2011; Park et al. 2012).

There are many existing studies on the subject of farming production, including the development of farming technology in Korea; however, there are almost no studies on the market analysis of farmed seafood. In particular, including the analysis of the demand for farmed seafood, the influence of farmed seafood on the market has been relatively insufficient. This is because if the production of farmed seafood is low, the influence on the market is small; in addition, the increase in demand has been accompanied by an increase in production. However, with the increasing production of farmed seafood and diversification of farmed fish species, market competition among different farmed fish species has been growing harsher. To determine a reasonable production level and make fish farming business stable, demand analysis by species or analysis of market interactions among species is emerging as an important issue.

Market interactions between farmed fish species and wild caught fish species triggered by the increase in production of farmed fish species have already become an important issue and researches have been conducted on this subject worldwide (Asche et al. 2005; Asche et al. 2001; Gordon et al. 1993; Jeffry et al. 2000; Rodriguez et al. 2013). However, with the recent increase in the supply of farmed seafood on the Korean market, there are growing concerns regarding market interactions among farmed fish species. In particular, in Korea, offshore cage aquaculture system has been introduced and commercialized in addition to the conventional methods of sea cage and

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land-based farming systems. The problem of market interactions among farmed fish species caused by the rapid increase in production has emerged as an important issue for the stabilization of fish farming business conditions and sustainable development of fish farming.

This study aims to analyze the market interactions among the main farmed fish species in Korea. In the analysis, we use data on market prices for farmed fish species in order to estimate the impact of price changes associated with an increase in the production of a certain type of farmed fish species on the price of other types of farmed fish species. This analysis will help to determine whether the relationship among farmed fish species is that of no substitution, imperfect substitution, or complete market integration. The results of the study are expected to greatly contribute to stabilizing the farmed markets and ensuring the sound development of fish farming industry.

2. Materials and Methods

Market interactions and cointegration analysis

The most typical method for analyzing market interactions among farmed fish species is to estimate the demand function by species and analyze the cross-price effects for fish species that are potential competitors. If the cross-price effect has a statistical significance, it can be said that the species are competing in the same market. In other words, the change in the price of fish due to an increase or decrease in its output influences the market price of another fish. However, if the cross-price effect does not have statistical significance, it can be said that the types of fish in question do not have a competitive relationship and it can be assumed that each fish species has its own market. However, although the method of measuring the cross-price effect in the demand function is theoretically the most precise and easy, it is practically difficult to obtain real consumption data based on different levels of prices to estimate the demand function (Asche et al. 2001).

Many studies have proposed the cointegration analysis that estimates price interdependencies or market delineation using market prices as a general method for analyzing market interactions (Asche et al. 2005; Asche et al. 1999; Asche et al. 1997; Bose and McIlgorm 1996; Goodwin and Schroeder 1991; Gordon et al. 1993; Jeffry et al. 2000; Rodriguez et al. 2013). As already mentioned in previous studies, this is because cointegration analysis uses data on market prices and verifies price interdependencies by analyzing long-run equilibrium relationships;

the results of such an analysis can help to evaluate whether the concerned products share the same market or have separate markets. In particular, Stigler (1969) defines the market as "the area within which the price of a commodity tends to uniformity, allowance being made for transportation costs" and it means that a stable long run relationship between prices implies those goods to be in the same market. It is exactly related to the concept of cointegration (Asche et al. 2005; Asche et al. 1997; Jeffry et al. 2000; Rodriguez et al. 2013).

As Jaffry et al. (2000) already mentioned, cointegration between non-stationary price series implies the existence of a long run equilibrium to which that while short term fluctuations in prices of individual farmed fish species exists, the proportional relationship between prices of farmed fish species that form part of a cointegrated system tend to remain the same over the longer term. Even if two or more variables in themselves are non-stationary in their levels, linear combinations, cointegration vectors, which are stationary may exist. From this, it can be assumed that a long run price equilibrium condition exists resulting from the variables forming parts of the same market.

Multivariate cointegration model

As an analytical method for cointegration, Johansen's cointegration test method has been widely utilized (Johansen 1991a; 1991b). For the multivariate Johansen cointegration analysis, the basic statistical model can be represented as the p-dimensional vector autoregressive (VAR) model with Gaussian errors.

$$X_t = A_1 X_{t-1} + \ldots + A_k X_{t-k} + \Phi D_t + \varepsilon_t,$$
$$t = 1, 2, 3, \ldots, n \tag{1}$$

where $X_0, \ldots, X_{-k+1}$ are fixed, ε_t are identically and independently distributed residual with zero mean and contemporaneous covariance matrix Ω. D_t is a vector of deterministic variables such as a constant, linear trend, and seasonal- or intervention dummies. D_t can also contain stationary stochastic variables that are weakly exogenous, or that can be excluded from the cointegrating space.

The purpose of the cointegration analysis is to distinguish between stationary created by linear combinations and stationary created by differencing. Therefore the model can be reformulated in the error correction form as follows.

$$\Delta X_t = \Pi X_{t-1} + \Gamma_1 \Delta X_{t-1} + \Gamma_{k-1} \Delta X_{t-k+1} + \Phi D_t + \varepsilon_t$$
$$t = 1, 2, 3, \ldots, n \tag{2}$$

where $\Pi = \sum_{i=1}^{k} A_i - I_p$ and $\Gamma_i = \sum_{i=i+1}^{k} A_i$. The properties of

the error correction model are determined by the properties of the characteristic polynomial of the process given by

$$A(z) = (1-z)I_p - \Pi z - \sum_{i=1}^{k-1} \Gamma_i (1-z) \quad (3)$$

It is well-known, that if we assume that all roots of A have modulus larger than one then X_i is stationary, but we will also allow A to have unit roots so that X_i can be $I(1)$. If $z = 1$ is a root, then Π has reduced rank $r < p$ since $|A(1)| = |\Pi| = 0$. This implies that Π can be written as $\Pi = \alpha\beta'$ where α and β are $p \times r$ matrices of full column rank, and hence the hypothesis of cointegration is formulated as a reduced rank condition on the Π matrix,

$$H_r : \Pi = \alpha\beta' \quad (4)$$

where α is the adjustment parameters and β contains the cointegration vectors. Assuming a technical condition on the derivatives of A is satisfied, the condition H_r implies that the processes ΔX_t and $\beta'X_t$ are stationary whereas X_i is non-stationary.

Johansen suggests two tests for the number of significant cointegration vectors with two different test methods (Johansen 1991b). The first is the maximum eigenvalue test (ε), which is a test of the relevance of column $r + 1$ in β; $\xi_r = -T(1-\lambda_{r+1})$. The second is the trace test (η_r) and is a likelihood ratio test for at most, r cointegration vectors. This is given by $\eta = -T \sum_{i=r+1}^{N} \ln(1-\lambda_i)$.

One problem with using cointegration analytical methods in order to delineate markets is that variables might be shown to cointegrate even though one or more of the variables do not significantly contribute to the long run relationship. For instance, so called weak cointegration might be identified between variables that normally have independent processes, but are subject to similar demand shock or sticky prices. In order to correct for any weak cointegration exclusion tests can be undertaken (Jeffry et al. 2000). The hypothesis of long run exclusion of the variable X_i is formally given as

$$H_0 : R_i'\beta = 0 \quad (5)$$

where $R_i = e_i$ and $1 \le i \le p$. Under the null, the test is asymptotically distributed as $\chi^2(r)$. The test is performed for each $i = 1, \ldots, p$ and $r = 1, \ldots, p-1$ and provides useful information about which variables can or can not be excluded.

Analytical data

Fish farming in Korea began growing rapidly after the 1990s; by 2011, the total production reached approximately 72,500 tons. Although this accounts for only 5% of the total amount of aquaculture production (1,478,000 tons), it constitutes 43% of the total value of aquaculture production. The farming target species have been gradually diversified from the conventional major fish species, olive flounder (*Paralichthys olivaceus*) and black rockfish (*Sebastes schlegeli*) to new fish species such as red seabream (*Pagrus major*), grey mullet (*Mugil cephalus*), seabass (*Lateolabrax japonicus*), black porgy (*Acanthopagrus schlegelii*), rock bream (*Oplegnathus fasciatus*), and others. Examining the current state of production of farmed fish species, out of the total output of 72,449 tons in 2011, 40,805 tons were olive flounder (56.3%), 17,338 tons black rockfish (23.9%), 4,850 tons grey mullet (6.7%), and 3,498 tons red seabream (4.8%).

For the analysis of market interactions among farmed fish species, major four farmed fish species, olive flounder (*Paralichthys olivaceus*), black rockfish (*Sebastes schlegeli*), red seabream (*Pagrus major*), and grey mullet (*Mugil cephalus*) were selected as the analytical target. And their real price data by month from January 2000 to December 2011 were used in the analysis. As shown in Fig. 1, the prices for olive flounder were slightly higher compared to those of the other three species, trending toward an increase after 2009. The prices for black rockfish and red seabream were approximately the same, trending toward an increase after 2008. The prices of grey mullet were the lowest compared to the other fish and also witnessed a growth tendency after 2008.

As already mentioned above, when presenting analysis methods to test market interactions, a cointegration test must be preceded by a unit root test of the price data to be
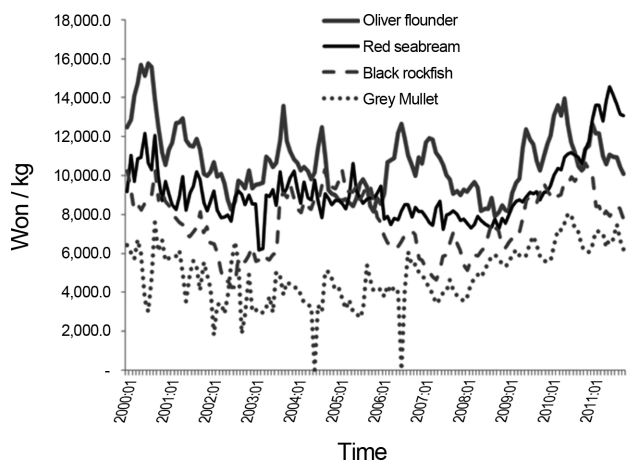
Fig. 1. Real prices for target farmed fish species (January 2000-December 2011)

used in the analysis. A unit root test is conducted to determine the stationarity of the time series data used in the analysis. In long-run analyses, a unit root test needs to be conducted prior to the cointegration test that determines the presence of the cointegration vector. This is because a cointegration test is a long-run equilibrium analysis of non-stationary time series variables; therefore, the non-stationarity of variables needs to be tested first (Gujarati and Porter 2008). This study uses the most widely employed ADF (Augmented Dickey-Fuller) test to conduct the unit root test using price data of farmed fish species before conducting the cointegration test.

3. Results

Results of the unit root test

As shown in Table 1, the results of the ADF unit root test for analytical target four fish species showed that for all types of fish and in all three cases-case including the constant, case including the constant and the trend, and case including neither the constant nor the trend - the null hypothesis could not be rejected for all level variables. Accordingly, all time series price data proved to have unit roots and were estimated to be nonstationary. However, the result of the unit root test for variables in first differences showed that for all fish species and all three abovementioned

cases, the null hypothesis was rejected at the 1% level of significance (5% level of significance for grey mullet, when the constant was included). Consequently, for all prices in first differences, unit roots could be eliminated and they were estimated as being stationary.

Results of the multivariate cointegration test

The multivariate Johansen cointegration test was implemented using the optimal lag structure of the VAR model through the minimization of Akaike Information Criteria (AIC) that selected a model with a number of optimal lags equal to 3. As shown in Table 2, two different test methods were used to test for the number of significant cointegration vectors. First, the trace test results showed that all null hypotheses of r could not be rejected at any statistical levels of significance. This would appear to indicate the existence of no cointegrating vectors. As the same with results of trace test, all null hypotheses of r were not also rejected at any statistical levels of significance.

These results conclude that there may be no evidence of the existence of cointegrating vectors involving the prices of oliver flounder, black rockfish, red seabream, grey mullet, and that a long run equilibrium relationship may not exist for these prices, suggesting that farmed fish species are not competing in the same market.

For more detailed analysis of cointegration between

Table 1. Results of ADF test

	Variables	Including the constant	Including the constant and the trend	Not including the constant and the trend
Level	Oliver flounder	-1.009400	-1.043002	-0.789813
	Black rockfish	-2.453397	-2.493874	-0.851861
	Red seabream	-0.543371	-0.987620	0.464879
	Grey mullet	-0.999722	-2.42711	0.370085
First difference	Oliver flounder	-6.780820*	-6.833586*	-6.770847*
	Black rockfish	-11.33259*	-11.30456*	-11.36902*
	Red seabream	-9.469943*	-9.807173*	-9.479763*
	Grey mullet	-3.471224**	-7.015906*	-3.444990*

Note: * and ** indicate rejection of the null hypothesis at the 1% level and 5% level, respectively

Table 2. Results of multivariate cointegration test

H$_0$: Rank = r	Trace test			Maximum Eigenvalue Test		
	Test statistic	Critical value (5%)	p-value	Test statistic	Critical value (5%)	p-value
r = 0	39.082	47.856	0.257	21.940	27.584	0.224
r <= 1	17.142	29.797	0.630	8.987	21.132	0.833
r <= 2	8.155	15.495	0.449	7.951	14.265	0.384
r <= 3	0.204	3.841	0.651	0.204	3.841	0.651

Table 3. Results of bivariate cointegration test

	Oliver flounder		Black rockfish		Red seabream	
	trace test	max. eigenvalue test	trace test	max. eigenvalue test	trace test	max. eigenvalue test
Oliver flounder						
Black rockfish	24.23	17.89				
Red seabream	20.90	14.72	17.75	11.21		
Grey mullet	32.34*	22.11*	17.45	10.14	18.17	12.35

Note: * indicate rejection of the null hypothesis at the 1% level

farmed fish species, we additionally conducted the bivariate conintegration test. As shown in Table 3, results of bivariate cointegration test indicated that there was little evidence to suggest that all farmed fish species were cointegrated each other. However, it was only analyzed that olive flounder and grey mullet might have a long run equilibrium relationship. In particular, while oliver flounder and black rockfish appeared to be competing each other in the same market as major farmed fish species, no significant relationship was found. Results of multivariate and bivariate cointegration tests provide that farmed fish species in Korea are not forming a single same market and therefore these species may not be closely substituted each other except oliver flounder and grey mullet.

4. Disscusion

This study used data on fish prices, estimated long-run equilibrium relationships, and analyzed market interactions among farmed fish species in Korea. The results of the multivariate cointegration test for four farmed fish showed that there would be no long-term equilibrium relationships among farmed fish species, and consequently they do not share the same market. The results of the bivariate cointegration test also showed that although there are no equilibrium relationships among farmed fish species, there is a long-run equilibrium relationship between olive flounder and grey mullet, and thus they might share the same market.

The reason for the absence of market interactions for farmed fish species might be presumably the fact that farmed fish species are usually consumed as live raw fish; moreover, for each fish species, there is a clear consumer preference in the Korean market such that farmed fish species could not be easily and/or alternatively substituted for one another in the market. In particularly, while it was expected that olive flounder and black rockfish, the most representative farmed fish species on the Korean seafood market, would be substituted each other, the results showed

no long-run equilibrium relationships, indicating that there is a separate market for each farmed fish species.

The studies on the market interactions for farmed fish species have significance that goes beyond elucidating their substitution relationships. Rather, the usefulness is in its applicability in choosing farmable fish species that would help to increase demand or establish aquaculture policies that reflect the market situation for each fish species. Moreover, through the analyses of market interactions with wild caught fish species, a more effective fish stock rebuilding plans and management policies can be established and implemented. In addition, through the analyses of market interactions between domestic and imported seafood, the extent to which imported seafood influence the domestic market may be evaluated, and effective responsive policy strategies may be implemented.

This study targeted only four farmed fish species. Adding more number of fish species might change the results of cointegration analysis. More analyses that include more number of fish species needs to be actively conducted in the future. Further, more meaningful outcomes regarding market interactions would be generated when cointegration analyses and weak cointegration exclusion tests are conducted effectively together.

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