MEASUREMENT OF SUBSTITUTABILITY BETWEEN U.S. DOMESTIC CATFISH AND IMPORTED FISH

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ABSTRACT

This study examines *p*-interdependence and quantifies *q*-substitutability between domestic catfish and different species of imported fish in the U.S. fish market. In doing so, this study uses cointegration analyses for *p*-interdependence and structural analyses for *q*-substitutability. Cointegration analysis identifies the long run price equilibria between U.S. domestic catfish and different species of imported fish. The structural analyses show a degree of *q*-substitutability.

Key words: cointegration, structural analyses, fish, imports, *p*-interdependence, and *q*-substitutability

This study is motivated by two basic questions about the U.S. fish market. The first question is about price interdependence (*p*-interdependence) between domestic and imported fish, which emanates from the issue as to whether both fish types belong to one common market. Secondly, if these two fish groups belong to the same market, how does the quantity and type of imported fish affect the domestic price of fish. Structural analyses based on economic principles leads to the condition that a varying degree of quantity substitutability (*q*-substitutability) among domestic and imported fish exists. In this paper we seek to answer both questions using domestic catfish and representative species of imported fish.

If there is *p*-interdependence between domestic catfish and imported fish in the U.S. fish market, the economic concept of cointegration argues that domestic catfish and imported fish have one long run equilibrium price and deviations from the equilibrium price for two fish species should be stationary (Granger, 1986 and Bose and McIlgorm, 1996). The underlying reason for this is that market forces will play an important role in prohibiting persistent deviation from their relevant long run behavioral path. For example, if the price of domestic catfish is considerably higher than the price of imported catfish, then it is reasonable to think that U.S. fish consumers will shift from domestic catfish to imported catfish because of their budget constraint. Therefore, the price of domestic catfish will decline (Hannesson 1994a). This process should prohibit persistent long run deviations from the equilibrium, although significant short-run deviations may occur. Consequently, cointegration analysis provides a suitable framework within the long run price relationships among domestic catfish and various species of imported fish.

The second question can be answered using inverse demand system analyses because structural analyses can quantify respective q-substitutability among domestic catfish and imported fish.[1] Previous studies provide an overview and comparison of the various specifications for different inverse demand systems, including the Differential Inverse Rotterdam (DIRDS) model, the Differential Inverse Central Bureau of Statistics (DICBS) demand model, the Differential Inverse Almost Ideal Demand System (DIAIDS) model, and the Differential Inverse National Bureau of Research (DINBR) demand model (Anderson, 1980; Barten and Bettendorf, 1989; and Barten, 1993; Kim, 1997). From these four inverse demand systems, the Differential Inverse Generalized Demand System (DIGDS) model can be developed, which nests all four demand systems into one functional form (Barten 1993). These models have often been applied to demand (or import demand) analyses for fish (Eales, Durham, and Wessels, 1997 and Park, Thurman, and Easley, 2004). Related to import demand, previous studies focused on the same products sourced from different origins, thus implying acceptance of the separability assumption between different types of fish in import demand analysis (Yang and Koo, 1994). However, as U.S. fish import data show, there is the possibility of a price linkage among different species of imported fish. Furthermore, the relatively small amount of imports from each individual country makes it difficult to use a source differentiated model. As a result, this study uses aggregated inverse demand models by which we can consistently estimate *q*-substitutability among different types of fish species given utility and budget restrictions.

In order to achieve these objectives, this study proceeds as follows: in the next section the two analytical methodologies, cointegration and structural analyses, are reviewed. This study will then discuss trends in U.S. fish imports and how these trends relate to market behavior. Section four will discuss the empirical results obtained from implementation of the two underlying analytical methodologies. Finally, the paper will concluded with a summary and a discussion of limitations and potential future research opportunities.

Analytical Methodology

Cointegration Analysis

In the time series literature, non-stationarity behavior of time series variables is well established (Bose and McIlgorm, 1996). Thus, prior to examining *p*-interdependence between domestic catfish and imported fish, a test for the stationarity of the individual price series should be performed to avoid spurious results (Granger and Newbold, 1974 and Bose and McIlgorm, 1996). It is also reasonable to expect that monthly price series may contain seasonal components. Therfore, tests for non-seasonal stationarity should be preceded by tests for seasonal stationarity. Combining both seasonal and non-seasonal factors, a univariate price series, of order (*d*, *s*), is integrated in which '*d*' represents a one-period time difference and with '*s*' representing a monthly seasonal component. Incorporating these factors into the price series, p_t, we represent the new series as $p_t \sim \mathrm{I}(d, s)$ (Dolado, et al. 1990).

In testing for seasonal stationarity of a univariate price series this study used the HEGY test procedure provided by Beaulieu and Miron (1993) as follows:

$$(1) \qquad \varphi(B)^{*} y_{13t} = \sum_{k=1}^{12} \pi_k y_{k,t-1} + m_0 t + m_1 + \sum_{k=2}^{12} m_k S_{kt} + \varepsilon_t \,,$$

where y_{kt} is a polynomial of price series in the backshift operator, t is a time trend, m_1 is a constant, and S_k is a seasonal dummy. Appendix I shows that each y_{kt} can be written as a series of lag price.

In order to test the null hypotheses about various seasonal unit roots, we estimate (1) by Ordinary Least Squares and then compares the OLS test statistics to the critical values provided by Beaulieu and Miron (1990). For frequencies 0 and π, this study examines the relevant *t*-statistic for $\pi_k = 0$ against the alternative that $\pi_k < 0$. For other frequencies, this study follows the test procedures suggested by Beaulieu and Miron (1993) for monthly data in which the null hypothesis of I(1,1) is tested against the alternative hypothesis of I(1,0). Critical values of tests statistics are given in table A.1 of Beaulieu and Miron (1993).

To test for non-seasonal unit roots, this study considers the Augmented Dickey-Fuller (ADF) test procedure using the following regression:

$$(2) \qquad \Delta p_t = \alpha + \beta t + \gamma p_{t-1} + \sum_{i=1}^{k} \delta_i \Delta p_{t-i} + v_t \,,$$

where p_t represents the proposed price variable, *t* stands for time, and v_t is the white noise residual. To detect non-seasonal price series stationarity, this study considers the hypotheses H_0: $\gamma = 0$ (non-stationary) and Ha: $\gamma \neq 0$ (stationary). The *t*-statistics obtained from equation (2) for the estimated coefficient 'γ' are compared to the tabulated critical values given in Fuller (1976, p.373). Sufficient lag terms of the dependent variables are included in the regressions to simulate the residual white noise. In addition to the ADF of level form of price series, this study has also tested for first differencing form of price series. To satisfy the prerequisite condition for the cointegration test, the null hypothesis for level form price series should not be rejected, while the null hypothesis of first differencing form for price series should be rejected.

Now, consider two price series, p_{it} and p_{jt}, each of which is non-stationary in itself and requires seasonal and/or a non-seasonal differencing transformation to produce a stationary series. However, a linear combination of the two price series,

(3) $$e_t = p_{it} - \alpha - \beta p_{jt},$$

produces a residual series, e_t. If e_t is stationary, the bivariate price series, p_{it} and p_{jt}, are said to be cointegrated. The cointegrated prices, p_{it} and p_{jt}, exhibit a long run equilibrium relationship defined by $p_{it} = \alpha + \beta p_{jt}$ and the equilibrium error, e_t, represents short term deviations from the long run relationship. Thus, the cointegration of p_{it} and p_{jt} can be tested to determine whether e_t is stationary as follows:

(4) $$\Delta \hat{e}_t = \alpha_0 + \gamma \hat{e}_{t-1} + \sum_{i=1}^{k} \delta \Delta \hat{e}_{t-i} + v_t,$$

where $\Delta \hat{e}_t = \hat{e}_t - \hat{e}_{t-1}$. In testing for cointegration, the null hypothesis is $\gamma = 0$, under which one time period differencing residuals are non-stationary. To reject the null hypothesis, we examine the *t* (or *tau*) statistic for the cointegration of p_{it} and p_{jt}. If the *t*-statistic is less than that of the critical value, we reject the null hypothesis and conclude that prices p_{it} and p_{jt} are stationary, indicating that there is a long run equilibrium relationship between p_{it} and p_{jt}.

This idea could also be extended to a multivariate context. This study uses the same ADF test procedure outlined above to examine the residuals from the multivariate cointegrating regressions. Although the ADF test procedure for a multivariate cointegrating regression is computationally simple, it fails to identify the number of cointegrating vectors in the multivariate cointegration regression. To supplement this drawback, Johansen (1988) and Johansen and Juselius (1990) developed the likelihood ratio (LR) test procedure. This study will use the likelihood ratio (LR) test procedure to test for both bivariate and multivariate cointegration. The proposed LR test for the hypothesis that there are at most '*r*' cointegrating vectors is given by:

$$(5) \qquad LR = -T\sum_{i=r+1}^{N}\ln\left(1-\hat{\lambda}\right),$$

where $\hat{\lambda}_{r+1}\ldots\hat{\lambda}_{N}$ are the $N - r$ smallest squared canonical correlation coefficients between the residuals obtained by first regressing $\Delta p_t\,(t = 1,2,\ldots,T)$ on its lagged differences, Δp_{t-1}, Δp_{t-2}, $\ldots, \Delta p_{t-11}$ and then regressing p_{t-12} on the same regressand. Full details of theoretical backgrounds and application guide of the Johansen's test procedure are provided in Dickey and Rossana (1994).

According to Steen's suggestion (1995), this study undertakes exclusion tests on the long run cointegrating parameter, $\hat{\beta}$, in (3) to ensure the robustness of the cointegration relationship between price series. Hence, to conclude that all fish belong to the same market it is also required that all the price series contribute significantly to the long run relationship. Given cointegration, exclusion tests are imposed as null restrictions on the long run cointegrating parameter, $\hat{\beta}$. For example, if prices for domestic and imported catfish are cointegrated and we want to test the significance of imported catfish in the cointegration regression, the null restriction is H_0: $\hat{\beta}_{cam} = 0$ in which the imported catfish market is separated from the domestic catfish market. The alternative is Ha: $\hat{\beta}_{cam} \neq 0$ in which there is one common market for both domestic and imported catfish.

Structural Analyses

As this study previously mentioned, the second objective of this study is to quantify the economic impact of imported fish on the price of domestic catfish. This study assumes weak separability in order to use structural analysis based on microeconomic principles. As many former studies have indicated, we can formalize a structural model for measuring the impact of quantity on price. Gorman (1960) provided a theoretical basis for the price formation of perishable or semi-perishable goods such as fish. Studies for fish, thereafter, developed similar types of inverse demand systems. The features of these inverse demand systems are that quantity is exogenous which provides *q*-substitutability, and that the system of equations of endogenous price is expressed using budget shares. This study uses inverse demand systems to measure the impact of quantity of imported fish on the price of domestic catfish. In particular, domestic catfish price equations in the systems are more focused to measure *q*-substitutability between domestic catfish and imported fish.

As former studies have stated, a fish consumer's problem can be summarized as follows:

$$(6) \qquad \max_q U(q) \quad \text{s.t. } \textstyle\sum_i p_i q_i = m .$$

By using duality, the solution of (6) leads to the following inverse specification, known as the DIGDS:

$$(7) \qquad w_i d \ln \pi_i = g_i d \ln Q + \sum_j g_{ij} d \ln q_j ,$$

where $g_i = h_i - \theta_1 w_i$ and $g_{ij} = h_{ij} - \delta_{ij}\theta_2 w_i - \theta_2 w_j$ (θ_1 and θ_2 are nesting parameters, δ_{ij} is the Kronecker delta), w_i is the budget share for good *i*, $\pi_i = \frac{p_i}{m}$ is the normalized price of good *i*, and $d\ln Q = \sum_i w_i d\ln q_i$ is the Divisia volume index. The other nested models can be obtained by restricting one or both nesting parameters as follows:

(6) $w_i d\ln \pi_i = h_i d\ln Q + \sum_j h_{ij} d\ln q_j$ DIRDS for $\theta_1 = 0$ and $\theta_2 = 0$,

(7) $w_i d\ln \frac{p_i}{P} = c_i d\ln Q + \sum_j h_{ij} d\ln q_j$ DICBS for $\theta_1 = 1$ and $\theta_2 = 0$,

(8) $dw_i = c_i d\ln Q + \sum_j c_{ij} d\ln q_j$ DIAIDS for $\theta_1 = 1$ and $\theta_2 = 1$,

(9) $dw_i - w_i d\ln Q = h_i d\ln Q + \sum_j c_{ij} d\ln q_j$ DINBR for $\theta_1 = 0$ and $\theta_2 = 1$,

where $c_i = h_i + w_i$ and $c_{ij} = h_{ij} + w_i\delta_{ij} - w_i w_j$ and $d\ln P = \sum_i w_i d\ln p_i$ is the Divisia price index. The quantity elasticity parameters, g_{ij}, h_{ij} and c_{ij}, and scale elasticity parameters, g_i, h_i and c_i, can be converted into elasticity forms. Table 1 shows compensated and uncompensated elasticity forms for the cross quantity elasticity parameters.

U.S. Fish Imports

In 2006, U.S. imports of edible fishery products were valued at \$13.4 billion, amounting to \$6.7 billion more than 1996 imports, implying that a 100% increase in value of imports took place over the past decade. The quantity of edible fish imports was 2.45 million metric tons, an increase of 1.01 million metric tons from the quantity of fish imported in 1996. This increase in imports amounts to a 70% increase in volume of imports over the same ten year span. Since the rate of increase for import value is greater than import quantities, imported price has increased from \$4.65/kg in 1996 to \$5.47/kg in 2006. In 2006, edible fish imports consisted of 2 billion kilograms of fresh and frozen products valued at $11.7 billion, 328 million kilograms of canned products valued at $1.3 billion, 40 million kilograms of cured products valued at $206.5 million, 3.3 million kilograms of caviar and roe products valued at $32.4 million, and 24 million kilograms of other products valued at $119.4 million.

From 1996 to 2006, the amount of U.S. fish imports continuously increased with relatively little fluctuation in total volume and value and unit price of individual imported fish. Shrimp imports were $4.1 billion and 0.590 million metric tons in 2006, representing increases of 67% for value and 123% for quantity from 1996. The unit price of imported shrimp decreased from $9.30/kg to $6.97/kg during this period of time (1996-2006). Shrimp imports accounted for 31% of the value and 24% of the quantity of total edible fish imports in 2006. Salmon imports were $1.5 billion and 0.242 million metric tons in 2006, representing increases of 278% for value and 190% for quantity from 1996. Unlike that of shrimp, the unit price of imported salmon increased from $4.93/kg to $6.43/kg during this ten year period of time. Salmon imports accounted for 11% of the value and 10% of the quantity of total edible fish imports in 2006. Tuna imports were $0.9 billion and 0.275 million metric tons in 2006. Although the value of tuna imports increased by 48% during this ten year period, the quantity of tuna imports was steady or had slightly decreased. Consequently, the unit price of imported tuna increased from $2.28/kg to $3.39/kg during this period. Tuna imports accounted for 7% of value and 11% of quantity of total edible fish imports into the U.S. in 2006.

Even though the import quantity and value of other fishery products are relatively small, U.S import trends for catfish, tilapia, and trout were shown to be similar to that of salmon imports, which represent both import value and quantity increase but the increase in value is greater than the increase in quantity so that the unit price of imports have increased during this time period. Faced with this increase in fish imports, this study will analyze the *p*-interdependence and *q*-substitutability between domestic catfish and imported fish such as catfish, trout, tuna, tilapia, salmon, and shrimp.

Data Sources

This study uses monthly data from January 1989 to December 2007. Our analysis includes not only five fin fish species such as catfish, trout, tuna, tilapia, and salmon, but also includes one crustacean species (shrimp). Data of price and quantity for domestic catfish come from the National Agricultural Statistics Service (NASS). Price and quantity data for domestic catfish is for round weight processed catfish. Quantity and value data for imported fish are obtained from the National Marine Fisheries Service (NMFS). The unit prices of imported fish are obtained by dividing the total value by volume of imports. Domestic catfish and imported fish prices are used for cointegration analysis in order to identify the long run equilibrium relationship. Price and quantity data are transformed into differential logarithmic form for structural analyses.

Empirical Results

Table 2 presents the results of the seasonal unit root tests for the individual price variable. The regression equations include an intercept, time trend, and eleven seasonal dummy variables. To test seasonal individual price series unit roots at zero and π frequency, we use the *t*-statistics obtained by equation (1). Based on our tests results, we reject the null hypothesis of seasonal unit roots for frequency π at the 1% level of significance, but we fail to reject the null hypothesis in the case of zero frequency because all π_1 statistics are greater than the critical values. We also use the '*F*' test suggested by Beaulieu and Miron (1993) to test seasonal unit roots of individual price series at frequency $\pi/2$, $2\pi/3$, $\pi/3$, $5\pi/6$, and $\pi/6$. The test results strongly reject the null hypothesis because all calculated *F*-values are higher than the critical values, implying that at least one member of each of the following subsets of test statistics $\{\pi_3, \pi_4\}$, $\{\pi_5, \pi_6\}$, $\{\pi_7, \pi_8\}$, $\{\pi_9, \pi_{10}\}$, and $\{\pi_{11}, \pi_{12}\}$, are significantly different from zero. Thus, overall test results indicate that for most series we reject unit roots at most frequencies, and there is no series for which we fail to reject unit roots for at least one of the seasonal frequencies. The strongest evidence for a seasonal unit root of individual fish price series is found at zero frequency.

To detect non-seasonal stationarity on all of the individual price series, we test the null hypotheses, H_0: $\gamma = 0$ (non-stationary). For the null hypotheses tests, the *t*-statistics obtained from equation (3) for γ are compared to the tabulated critical values given in Fuller (1976, p. 373). Sufficient lag terms of the dependent variable have been added to obtain the white residual. The results of the non-seasonal unit root tests on all the fish price variables are presented in Table 3. For the level form of all price variables, test results do not allow us to reject the null hypothesis of non-stationarity at the 5% level of significance. For example, ADF tests for level forms of price variables of domestic catfish, and imported catfish, trout, tuna, salmon, and shrimp failed to reject the null hypotheses. Even though the ADF test result for level form of price variable of imported tilapia rejects the null hypothesis, the *t*-statistics obtained from the first difference form of the price variable were greater than those of the level form. In the first difference case, the null hypothesis of non-stationarity is rejected at the 1% level in favor of the alternative of stationarity for all price variables. Thus, based on our test results, we can say that all price variables are stationary in their first differences. In conclusion, the fish prices used in this study are integrated as I(1,1).

Table 4 reports the results of the bivariate cointegrating regressions and the associated stationary tests of the residuals. The set of regressions examines the cointegration relationships between domestic catfish and imported fish. We used two types of ADF tests. The first includes only a constant and the second includes both a constant and a trend. For all the bivariate cointegrating regressions, the first and second types of the ADF test results are significant at the 5% level. Furthermore, LR statistics indicate the existence of one cointegrating vector at the 1% level. Thus, the null hypothesis of non-cointegration can be rejected in favor of the alternative of cointegration. Given cointegration between the prices of domestic catfish and individual imported fish, this study provided the *t*-statistics of the long run cointegrating parameter, $\hat{\beta}$, obtained from each bivariate cointegrating regression as the results of an exclusion test. As the *t*-statistics show, all the null hypotheses indicate that domestic catfish and individual imported fish consist of a separated market were rejected at the 5% level of significance because the cointegrating parameters of imported catfish, trout, tuna, tilapia, salmon, and shrimp are significant at the 5% level. Thus, the exclusion test results indicate that domestic catfish and individual imported fish have one common market (we also obtained the same result from a multivariate cointegrating regression which is not provided in the paper). To examine the direction and strength of cointegration between domestic catfish and different imported fish, we compare the cointegrating parameters, $\hat{\beta}$. All cointegrating parameters are shown to be positive. The strength of relationship between different combinations of the price variables is that the combinations (P_{dca}, P_{mca}), (P_{dca}, P_{mtr}), (P_{dca}, P_{mtu}), (P_{dca}, P_{mti}), (P_{dca}, P_{msa}), and (P_{dca}, P_{msh}) are 0.10783, 0.20208, 0.21652, 0.11858, 0.35987, 0.12821, respectively. In consequence, the relative magnitude between price variables indicates that *p*-interdependence between domestic and imported catfish is weaker than those of any combination of domestic catfish and imported fish, while the combination of domestic catfish and imported salmon is the strongest. This result deviated from expectations because imported catfish is expected to be the closest substitute for domestic catfish.

In order to measure *q*-substitutability of these cointegrated fish, this study used inverse demand system models rather than a single equation model. Table 5 summarizes the complete sets of quantity elasticity parameters in domestic catfish equations of the five different inverse demand system models with statistical results of *t*-ratios and R^2 for goodness-of-fit of the system models. The system R^2 is 0.8752 for DIRDS, 0.9648 for DICBS, 0.1933 for DIAIDS, 0.9984 for DINBR, and 0.9459 for DIGDS. Except for the DIAIDS model, the other four models show a desirable R^2 value, indicating that these models well explain the variation of the price dependent variable. The *t*-statistics show that most estimated quantity elasticity parameters are significantly different from zero at the 2.5% level. As expected, all cross quantity elasticity parameters are estimated as negative, implying an increase in quantity of individual imported fish decreases domestic catfish price. The relative magnitude of the cross quantity elasticity parameter of each imported fish is different depending on the model used in the estimating procedure. In all five models, however, the magnitude of the cross quantity elasticity parameter of imported shrimp is shown to be largest, while those of imported catfish or trout are shown to be smallest. As in the result of the cointegration analysis, this result is somewhat surprising, because imported catfish is often regarded as the most influential fishery product on domestic catfish price.

The estimated cross quantity parameters can be transformed into elasticities for easy interpretation of effect of quantity on price. By using elasticity formulae shown in table 1, we calculated compensated and uncompensated quantity elasticity of each model. As expected, most compensated and uncompensated quantity elasticities are negative; indicating that individual imported fish is substitutable for domestic catfish. For compensated quantity elasticity, however, imported tilapia in DIRDS, imported tuna, salmon, and shrimp in DIAIDS, imported catfish, tuna, tilapia, and salmon in DINBR, and imported tilapia in DIGDS are shown to be net complements to domestic catfish. For uncompensated quantity elasticity, imported catfish, trout, tuna, and tilapia in DIRDS, imported catfish, tuna, tilapia, salmon, and shrimp in DINBR, and imported tilapia for DIGDS are shown to be gross complements to domestic catfish. Among the five different models, the DICBS model for compensated quantity elasticity provides consistent results with economic principle and the DICBS and DIAIDS models for uncompensated quantity elasticity are the case. For example, all quantity elasticities in the models are estimated to be negative. The compensated quantity elasticity estimated in the DICBS model is -0.0037 for imported catfish, -0.0045 for imported trout, -0.1388 for imported tuna, -0.0050 for imported tilapia, -0.1033 for imported salmon, and -0.5108 for imported shrimp. The uncompensated quantity elasticities estimated in the DICBS and DIAIDS are -0.0064 and -0.0072 for imported catfish, -0.0062 and -0.0048 for imported trout, -0.2708 and -0.408 for tuna, -0.0246 and -0.259 for tilapia, -0.2172 and -0.424 for salmon, and -1.0265 and -0.1497 for shrimp. The results of the DICBS model show that imported shrimp is the most substitutable goods for domestic catfish among six imported fish, while imported catfish is the least substitutable goods. The compensated quantity elasticities estimated in the five different models range from -0.0043 to 0.0008 for imported catfish, from -0.0045 to -0.0013 for trout, from -0.1388 to 0.1287 for tuna, -0.0050 to 0.0250 for tilapia, from -0.1438 to 0.0795 for salmon, and from -0.6404 to 0.4025 for shrimp. The uncompensated quantity elasticities estimated in the five different models ranged from -0.0064 to 0.0033 for imported catfish, -0.0062 to 0.0002 for trout, from -0.2708 to 0.2517 for tuna, from -0.0259 to 0.0433 for tilapia, from -0.2172 to 0.1094 for salmon, and from -1.0265 to 0.3802 for shrimp.

Conclusions

This paper examined the effect that imported fish supply had on domestic fish price. In doing so, this paper first focused on examining *p*-interdependence between domestic catfish and imported fish to confirm whether or not domestic catfish and imported fish belong to one common market. For this, we used cointegration analysis. Then, to measure *q*-substitutability between domestic catfish and cointegrated imported fish, we used five different inverse demand system models for structural analyses.

In cointegration analyses, this study tested seasonal and non-seasonal stationarity before testing cointegration due to the seasonal and non-seasonal unit roots of the monthly time series data. For the seasonal unit root test, this study used the HEGY test procedure. The test results show that the price series does not contain any seasonal unit roots at any seasonal frequency other than zero. For the non-seasonal unit root test ADF tests were used. Results from the ADF tests show that we are not able to reject the null hypothesis of non-stationarity for level form of price series. However, we are able to reject the null hypothesis for the first difference form of price series at the 5% level. With both seasonal and non-seasonal unit root test results, this study is assured that the monthly price series satisfy the prerequisites of cointegration test which require non-stationarity of level forms of price series and stationarity of first difference form of price series. Cointegration analyses showed that there were long run price equilibria between domestic catfish and imported fish such as imported catfish, trout, tuna, tilapia, salmon, and shrimp, indicating that these fish have one common market. However, contrary to expectations, *p*-interdependence between domestic and imported catfish was the weakest estimate.

As expected, the structural analyses show that imported fish negatively influences the domestic catfish price. As in cointegration analyses, the magnitude of *q*-substitutability of imported shrimp was largest, while that of imported catfish or trout were smallest. Thus, this result is somewhat surprising, because imported catfish is often regarded as the most influential fish on the domestic catfish price.

To determine the net and gross q-substitutability between domestic catfish and cointegrated imported fish, this study calculated the compensated and uncompensated quantity elasticities. As expected, the majority of cross quantity elasticities turned out to be substitutes in all five models. In particular, the DICBS model provided consistent results with economic theory in both compensated and uncompensated quantity elasticities.

Table 1. Compensated and Uncompensated Quantity Elasticity Formulae

	DIRDS	DICBS	DIAIDS	DINBR	DIGDS
f_{ij}^{*}	$\frac{h_{ij}}{w_i}$	$\frac{h_{ij}}{w_i}$	$\frac{c_{ij}}{w_i} + w_j$	$\frac{c_{ij}}{w_i} + w_j$	$\frac{g_{ij}}{w_i} + \theta_2 w_j$
f_{ij}	$\frac{h_{ij} - h_i w_j}{w_i}$	$\frac{h_{ij} - (c_i + w_i) w_j}{w_i}$	$\frac{c_{ij} - c_i w_j}{w_i}$	$- h_i \frac{w_j}{w_i} + \frac{c_{ij}}{w_i} + w_j$	$\frac{g_{ii} - g_i w_j}{w_i} + (\theta_2 - \theta_1) w_j$

f_{ij}^{*} : Compensated own quantity elasticity.

f_{ij} : Uncompensated cross quantity elasticity.

Table 2. Results of tests for seasonal unit roots in monthly aggregate series[a]

	0	π	π/2		2π/3		π/3		5π/6		π/6		π/2	2π/3	π/3	5π/6	π/6
	π_1	π_2	π_3	π_4	π_5	π_6	π_7	π_8	π_9	π_{10}	π_{11}	π_{12}	$F_{3,4}$	$F_{5,6}$	$F_{7,8}$	$F_{9,10}$	$F_{11,12}$
P_{cad}	3.37	-5.54	-2.65	-5.48	-4.85	3.54	-0.44	-5.45	-5.80	1.75	0.34	-10.6	20.05	19.12	15.74	17.9	57.51
P_{cam}	-1.65	-4.32	-7.13	-0.08	-6.67	-0.99	-4.54	0.76	-6.29	0.67	-4.58	-2.63	25.42	23.73	10.63	19.8	16.89
P_{trm}	-1.81	-5.08	-5.93	-3.65	-6.79	2.16	-6.22	-1.24	-6.89	1.15	-2.45	-4.74	26.45	25.64	20.33	24	17.84
P_{tum}	-1.82	-3.20	-4.74	-1.67	-4.69	-0.23	-4.49	-2.38	-4.11	-0.7	-3.55	-4.22	13.03	11.07	14	9.23	18.95
P_{tim}	-0.65	-3.81	-5.96	-4.73	-5.27	1.06	-3.23	-2.68	-6.01	4.11	-3.91	-4.55	33.26	13.96	10.76	27.68	23.55
P_{sam}	4.41	-5.33	-4.22	-4.66	-5.29	3.64	-3.56	-5.98	-6.77	2.35	0.91	-7.62	21.72	21.67	28.88	25.37	29.28
P_{shm}	3.68	-5.01	-4.69	-5.84	-5.36	4.81	-1.88	-6.49	-4.9	4.27	0.68	-7.95	31.91	29.06	25.06	21.92	32.44

[a] 1. P_{cad}, P_{cam}, P_{trm}, P_{tum}, P_{tim}, P_{sam}, and P_{shm} represent the prices of domestic catfish, and imported catfish, trout, tuna, tilapia, salmon, and shrimp, respectively.

2. Seasonal unit roots are tested in log levels of prices.

3. The estimation equations include a constant, eleven seasonal dummies, and a time trend.

4. Standard errors are OLS standard errors.

5. Critical values of the test statistics are given in table A.1 of Beaulieu and Miron (1993, pp.325-26).

Table 3. Results of tests for non-seasonal unit roots in monthly aggregate series[a]

	P_{cad}	P_{cam}	P_{trm}	P_{tum}	P_{tim}	P_{sam}	P_{shm}
Level Form							
with constant	-1.91	-2.36	-0.85	-0.08	-3.32	-2.01	-1.67
with constant and trend	-2.00	-2.52	-0.87	-0.43	-4.29	-1.99	-1.94
First Difference Form							
with constant	-2.52	-5.82	-6.42	-4.69	-4.14	-3.48	-4.03
with constant and trend	-2.41	-5.86	-6.46	-4.75	-4.36	-3.54	-4.27

[a] 1. Critical values of ADF statistic at 1% and 5% levels are -3.46 and -2.88 for regression including constant, respectively.

2. Critical values of ADF statistic at 1% and 5% levels are -3.99 and -3.43 for regression including both constant and trend, respectively, (Fuller 1976, p. 373).

Table 4. Results of the Bivariate Cointegrating Regressions[a]

Between Domestic Catfish Price and the Imported Fish Prices		Unit Root Test for the Residual			
		ADF Test With		LR Test	
		Constant	Constant & Trend	r = 0	r = 1
$P_{cad} = 1.51618 + 0.10783 P_{cam}$: (4.56)	$R^2 = 0.0841$	-2.83	-2.90	66.98	0.14
$P_{cad} = 1.38143 + 0.20208 P_{trm}$: (9.32)	$R^2 = 0.2776$	-2.97	-2.87	66.73	0.07
$P_{cad} = 1.42792 + 0.21652 P_{tum}$: (9.09)	$R^2 = 0.2675$	-3.65	-3.570	89.65	4.82
$P_{cad} = 1.53957 + 0.11858 P_{tim}$: (7.72)	$R^2 = 0.2088$	-4.15	-4.06	67.31	2.38
$P_{cad} = 1.02970 + 0.35987 P_{sam}$: (8.07)	$R^2 = 0.2237$	-3.33	-3.48	71.67	6.80
$P_{cad} = 1.40181 + 0.12821 P_{shm}$: (3.90)	$R^2 = 0.4935$	-4.33	-4.48	77.14	8.66

[a]1. *t*-statistics for exclusion tests are in the parentheses.

2. Critical values of LR test at 5% levels of significance for r = 0 and r = 1 are 20.168 and 9.094, respectively, (Johansen and Juselius 1990, p. 209).

Table 5. Quantity Elasticity Coefficients[a]

	Catfish(M)	Trout	Tuna	Tilapia	Salmon	Shrimp	System R^2
DIRDS	-0.0005	-0.0003	-0.0005	0.0021	-0.0314	-0.1161	0.8752
	(-2.63)	(-1.57)	(-6.55)	(4.69)	(-24.26)	(-62.16)	
DICBS	-0.0008	-0.0010	-0.0303	-0.0011	-0.0226	-0.1116	0.9648
	(-4.29)	(-5.13)	(-30.73)	(-2.26)	(-15.99)	(-74.95)	
DIAIDS	-0.0015	-0.0010	-0.0067	-0.0053	-0.0074	-0.0242	0.1933
	(-2.80)	(-4.04)	(-2.08)	(-4.40)	(-1.93)	(-3.36)	
DINBR	-0.0013	-0.0010	-0.0064	-0.0058	-0.0084	-0.0283	0.9984
	(-2.27)	(-3.91)	(-1.96)	(-4.33)	(-2.07)	(-3.89)	
DIGDS	-0.0004	-0.0009	-0.0006	0.0012	-0.0240	-0.1340	0.9459
	(-2.76)	(-4.93)	(-8.32)	(3.41)	(-21.85)	(-104.79)	

[a] 1. Critical value of *t*-statistic is -1.96 at 2.5% level.

Table 6. Compensated and Uncompensated Quantity Elasticity

	Catfish(M)	Trout	Tuna	Tilapia	Salmon	Shrimp
Compensated (f_{ij}^{*})						
DIRDS	-0.0021	-0.0013	-0.0022	0.0095	-0.1438	-0.5312
DICBS	-0.0037	-0.0045	-0.1388	-0.0050	-0.1033	-0.5108
DIAIDS	-0.0043	-0.0030	0.1006	-0.0050	0.0795	0.4025
DINBR	0.0008	-0.0022	0.1287	0.0250	0.0033	-0.1003
DIGDS	-0.0021	-0.0040	-0.0096	0.0045	-0.1159	-0.6404
Uncompensated (f_{ij})						
DIRDS	0.0004	0.0002	0.1183	0.0273	-0.0400	-0.0608
DICBS	-0.0064	-0.0062	-0.2708	-0.0246	-0.2172	-1.0265
DIAIDS	-0.0072	-0.0048	-0.0408	-0.0259	-0.0424	-0.1497
DINBR	0.0033	-0.0006	0.2517	0.0433	0.1094	0.3802
DIGDS	-0.0024	-0.0042	-0.0278	0.0018	-0.1315	-0.7111

Footnote 1.

See Anderson (1980) and Barten (1993) for theory and application of inverse demand.

Appendix I: Empirical details for y_{kt}

$$\begin{aligned} y_{1t} = {} & p_t + lag1(p_t) + lag2(p_t) + lag3(p_t) + lag4(p_t) + lag5(p_t) + lag6(p_t) + lag7(p_t) + lag8(p_t) \\ & + lag9(p_t) + lag10(p_t) + lag11(p_t), \end{aligned}$$

$$\begin{aligned} y_{2t} = {} & -p_t + lag1(p_t) - lag2(p_t) + lag3(p_t) - lag4(p_t) + lag5(p_t) - lag6(p_t) + lag7(p_t) - lag8(p_t) \\ & + lag9(p_t) - lag10(p_t) + lag11(p_t), \end{aligned}$$

$$y_{3t} = -lag1(p_t) + lag3(p_t) - lag5(p_t) + lag7(p_t) - lag9(p_t) + lag11(p_t),$$

$$y_{4t} = -p_t + lag2(p_t) - lag4(p_t) + lag6(p_t) - lag8(p_t) + lag10(p_t),$$

$$\begin{aligned} y_{5t} = {} & -\frac{1}{2}(p_t + lag1(p_t) - 2lag2(p_t) + lag3(p_t) + lag4(p_t) - 2lag5(p_t) + lag6(p_t) + lag7(p_t) \\ & - 2lag8(p_t) + lag10(p_t) - 2lag11(p_t)), \end{aligned}$$

$$y_{6t} = \frac{\sqrt{3}}{2}(p_t - lag1(p_t) + lag3(p_t) - lag4(p_t) + lag6(p_t) - lag7(p_t) + lag9(p_t) - lag10(p_t))$$

$$\begin{aligned} y_{7t} = {} & \frac{1}{2}(p_t - lag1(p_t) - 2lag2(p_t) - lag3(p_t) + lag4(p_t) + 2lag5(p_t) + lag6(p_t) - lag7(p_t) \\ & - 2lag8(p_t) - lag9(p_t) + lag10(p_t) + 2lag11(p_t)), \end{aligned}$$

$$y_{8t} = -\frac{\sqrt{3}}{2}(p_t + lag1(p_t) - lag3(p_t) - lag4(p_t) + lag6(p_t) + lag7(p_t) - lag9(p_t) - lag10(p_t)),$$

$$\begin{aligned} y_{9t} = {} & -\frac{1}{2}(\sqrt{3}p_t - lag1(p_t) + lag3(p_t) - \sqrt{3}lag4(p_t) + 2lag5(p_t) - \sqrt{3}lag6(p_t) + lag7(p_t) \\ & - lag9(p_t) + \sqrt{3}lag10(p_t) - 2lag11(p_t)), \end{aligned}$$

$$\begin{aligned} y_{10t} = {} & \frac{1}{2}(p_t - \sqrt{3}lag1(p_t) + 2lag2(p_t) - \sqrt{3}lag3(p_t) + lag4(p_t) - lag6(p_t) + \sqrt{3}lag7(p_t) \\ & - 2lag8(p_t) + \sqrt{3}lag9(p_t) - lag10(p_t)), \end{aligned}$$

$$\begin{aligned} y_{11t} = {} & \frac{1}{2}(\sqrt{3}p_t + lag1(p_t) - lag3(p_t) - \sqrt{3}lag4(p_t) - 2lag5(p_t) - \sqrt{3}lag6(p_t) - lag7(p_t) \\ & + lag9(p_t) + \sqrt{3}lag10(p_t) + 2lag11(p_t)), \end{aligned}$$

$$y_{12t} = -\frac{1}{2}(p_t + \sqrt{3}lag1(p_t) + 2lag2(p_t) + \sqrt{3}lag3(p_t) + lag4(p_t) - lag6(p_t) - \sqrt{3}lag7(p_t)$$

$$-2lag8(p_t) - \sqrt{3}lag9(p_t) - lag10(p_t)),$$

$$y_{13t} = (p_t - lag12(p_t)).$$

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