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**TESTS FOR MARKET INTEGRATION AND  
THE LAW OF ONE PRICE:**

**THE MARKET FOR WHITEFISH IN FRANCE**

by

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# **TESTS FOR MARKET INTEGRATION AND THE LAW OF ONE PRICE: THE MARKET FOR WHITEFISH IN FRANCE**

## **Abstract**

This paper examines the relationship between causality models and cointegration models in testing for price integration and the Law of One Price (LOP). In our review, we show that cointegration models, which allow for nonstationarity in prices, are a natural extension of the traditional causality methods and not an alternative approach. Hence, the two approaches investigate the same economic hypotheses however, the choice of modeling method depends on the times series properties of the data. An empirical analysis is provided using prices for the whitefish market in France. With nonstationary price data the causality approach over rejects the hypothesis of the LOP whereas, cointegration models provide evidence for a well-integrated whitefish market. What is more, a generalized version of the composite commodity theorem holds and prices of most whitefish species can be aggregated into a single commodity price index. Salmon does not belong to the whitefish market in France.

Keywords:

Causality, Law of One Price, Cointegration, Fish Prices

Running Head:

Testing the Law of One Price: Whitefish in France

# 1. Introduction

What constitutes a market is an important economics question as virtually all microeconomics analysis is based on some definition of a market (see, Stigler and Sherwin, 1985; Cournot, 1971; Marshall, 1947; Cassel 1918). While the concept of a market is unproblematic in theory it is often difficult to define empirically. The importance in empirically defining a market can be seen in antitrust and antidumping cases, and in price support schemes, for example. Empirical measures of market definition and integration have focused on the relationship among prices over time to test for correlation and causality, and to test for the Law of One Price LOP. More recently, for nonstationary price series, tests for cointegration have been used to empirically define a market and to test for market integration.

The LOP has a long history in economics as market integration is complete when it holds. However, market restrictions necessary for the condition to hold empirically are severe and attempts at measurement can be easily violated, e.g., by non-perfect substitutability of products or where transportation costs impede market adjustment. In the latter case, causality tests using stationary price series have proven useful in defining market boundaries (Horowitz, 1981; Ravallion,

1986; Slade, 1986; Squires, Herrick and Hastie, 1989; Gordon, Hobbs and Kerr, 1993). In the former case, allowances can be made for price adjustments occurring overtime and for testing a long-run LOP relationship (Goodwin, Grennes and Wohlgenant, 1990).

Where price series show nonstationary probability characteristics traditional econometric approaches are no longer valid. However, tests for cointegration can be used in investigating market relationships.<sup>1</sup> Early research using this technique was motivated by the LOP and estimation was carried out using a two-step Engle-Granger (1987) procedure. The two-step procedure, however, does not have well defined limiting distributions and direct tests of the LOP hypothesis are not possible (Hall, 1986).<sup>2</sup> Consequently for this early research market definition and integration focused on measuring a long-run cointegrated relationship among the prices rather than a direct statistical test of the LOP. Statistical developments in cointegration testing by Johansen (1988) provide a method for generating test statistics (i.e., likelihood ratios. with exact limiting distributions and allow for direct testing of the LOP hypothesis (Johansen and Juselius, 1990). These techniques will be exploited here to test the LOP.

Aggregation theory has also made use of the relationships among prices in defining aggregate units. The first criterion for aggregation in economics is the

composite commodity theorem of Hicks (1936) and Leontief (1936). For a bundle of goods, if individual prices move proportionally over time, the bundle can be represented by a composite price index. Lewbel (1996) provides an important generalization of this theorem for empirical purposes and Asche, Bremnes and Wessells (1999) show that if the LOP holds, the generalized composite commodity theorem by Lewbel (1996) also will hold. Hence, market integration tests based on LOP can also provide useful information with respect to commodity aggregation.

The main purpose of the paper is to review some causality and cointegration models that can be used to investigate market integration and to test for the LOP. We emphasize the similarities and differences between the models and that the choice of methods in applied research depends on the time series characteristics of the underlying data series. It is important to note that for either the causality or cointegration approach, the underlying economics and the hypotheses that are being tested are the same. The difference is in the empirical approach to measurement and testing. If the price series are nonstationary, the use of causality methods may lead to an over rejection of the LOP, as critical values for hypothesis testing are increased (Granger and Newbold, 1986; Banerjee, Dolado, Galbraith and Hendry, 1993). In this case, cointegration procedures are required for tests of market integration and the LOP.

An empirical analysis is carried out on prices of whitefish products in France. Whitefish products are of interest because fishermen in France derive a large portion of their income from these fish species.<sup>3</sup> Fishermen have organized regional associations to represent producer interests with the purpose of stabilizing or increasing the price of fish and, thereby, fishermen's income.<sup>4</sup> To what extent regional price stabilization is possible will depend on the extent of market integration across product types. There is evidence that prices of frozen cod fillets in the different country markets of France, Germany, UK and USA are part of a well-defined and integrated international market (Gordon and Hannesson, 1996). In addition, if it were observed that prices of frozen cod fillets are also integrated with prices of other whitefish products in France, this would be evidence of an integrated international market for the different whitefish products. Finally, we investigate whether there is a link between the whitefish species and the salmon market.

The paper is organized as follows. In the next section, some causality and cointegration models are reviewed and tests for the LOP are presented. Following this, the data used in estimation and the empirical results are reported. The final section concludes.



## 2. Time Series Modeling of Market Integration

In general micro economic theory assumes that there exists a market place defined over a group of commodities. The commodities compete in the same market because consumers or producers consider the goods substitutable to some extent. Whether commodities are substitutes can be measured by estimating demand and/or supply equations and by testing whether there are cross-price effects. If the commodities are substitutes, they compete in the same market. The most common measure of cross-price effects is cross-price elasticities, which can be derived empirically from demand relationships. However, in many cases, it is difficult to obtain the necessary data to generate good estimates of demand equations. Often market price is available but good quantity measures are more difficult to obtain and estimates of cross-price effects based on demand and supply equations may be seriously biased.<sup>5</sup>

While measuring the degree of substitution is the preferred way of determining to what extent commodities compete, the development or changes in prices overtime provides valuable information on the relationship among commodities. The importance of prices in defining markets was recognized early on by economists. In 1838 Cournot defined a market in the following way:

*“It is evident that an article capable of transportation must flow from the market where its value is less to the market where its value is greater, until difference in value, from one market to the other, represents no more than the cost of transportation” (Cournot, 1971).*

Similar definitions have been provided by a number of prominent economists like Marshall (1947), Cassell (1918) and Stigler (1969). Stigler maintains the spirit of Cournot in defining a market as "the area within which the price of a commodity tends to uniformity, allowance being made for transportation costs". While Cournot and Stigler focus on geographical space the concept also applies to product space, where quality differences take the place of transportation costs (Stigler and Sherwin, 1985).

To motivate the LOP and price-founded definitions of a market, Figure 1 sketches the equilibrium for two markets. For expository purposes prices in both markets are initially normalized at  $p$ . Assume then that there is a supply shock in Market 1 that shifts the supply schedule to  $S1'$ , giving  $p'$  and  $q1'$  as new price and quantity. This causes the price to decrease while the quantity increases. What happens in Market 2 depends on the degree of substitution between the two commodities.<sup>6</sup> If there is no substitution possibilities between

the two markets/commodities there will be no change in price and quantity in Market 2. If the goods are perfect substitutes, the demand schedule in Market 2 is shifted down to  $D2'$  as consumers substitute commodity 1 for commodity 2, and the fall in price is just enough to equilibrate prices in both markets at  $P'$ . (This is the Law of One Price). If the goods are imperfect substitutes, the demand schedule in Market 2 is shifted down somewhat, say to  $D2''$  but not enough to equate prices in the two markets.

As mentioned above, the strength of the influence of the shock in Market 1 on Market 2 is normally measured by the cross price elasticities.<sup>7</sup> However, one can also look at the effect of the supply shock only from the price space. The price change in Market 1 can impact price in the other market in a number of ways. If there is no substitution effect, the demand schedule does not shift and there is no movement in price in Market 2. If there is a substitution effect the demand schedule in Market 2 shifts down, and the price in this market shifts in the same direction as the price in Market 1. At most the price in Market 2 can shift by the same percentage as the price in Market 1, (i.e., the Law of One Price holds) and relative prices are constant. Hence, with respect to structural information about a market, analysis of price relationships can provide information on

- 1) Whether the two markets (goods) do not compete

- 2) Whether they are imperfect substitutes
- 3) Whether they are perfect substitutes so that the relative price is constant.

This is then the basis for the hypotheses we want to test when investigating relationships between prices.

Several studies have pointed out that the adjustment towards a new equilibrium can be delayed by adjustment costs (Ravallion, 1986; Slade, 1986; Goodwin, Grennes and Wohlgenant, 1990). This can be modeled when investigating relationships between prices by specifying a dynamic model. With a dynamic model one can also investigate whether the adjustment process is bi- or unidirectional. If causality goes only in one direction, this can be interpreted as price leadership for the price that does not adjust. An example of this case is where there is one central market that affects price setting in smaller regional markets but not the reverse.<sup>8</sup>

#### *Empirical specifications with stationary data*

It is common in studies of market integration to perform the analysis on the logarithms of prices, and we will proceed using this transformation. Given time series on two prices, say,  $p_t^1$  and  $p_t^2$ , the simplest specification to test for market integration is

$$p_t^1 = a + bp_t^2 + e_t \quad (1)$$

A null hypothesis that  $b = 0$  is a test that no substitution possibilities exist. A null hypothesis that  $b=1$  is a test for constant relative prices and the LOP.<sup>9</sup> The constant term  $a$  is the logarithm of a proportionality coefficient, and is zero if the prices are identical with exception of the arbitrary deviations caused by the error term. A nonzero constant term is in most cases interpreted as transportation costs or quality differences, which then are assumed to be constant.<sup>10</sup> Economic theory gives little guidance as to the choice of dependent variable, and the test is therefore often repeated by interchanging price variables in Equation (1).<sup>11</sup>

In the early 1980s, several authors argued that adjustment could be costly and therefore take time. To account for this, models were introduced with variable specifications that could distinguish between short- and long run effects. Slade (1986) used a simple model to account for dynamic adjustment to market integration.<sup>12</sup> This test is performed by first running the regression<sup>13</sup>

$$p_t^1 = a + \sum_{j=1}^m b_j p_{t-j}^1 + \sum_{i=0}^n c_i p_{t-i}^2 + e_t \quad (2)$$

The lag structure on prices is chosen so that  $e_t$  is white noise. The data support a hypothesis that there is a relationship, or in statistical terms that  $p_t^2$  causes  $p_t^1$ , if a joint test that all  $c_i$  parameters are zero is rejected.<sup>14</sup> Interchanging price variables in Equation 2., allows a test of the null hypothesis that  $p_t^1$  causes  $p_t^2$ .

In this dynamic specification, test results based on different dependent variables have an economic interpretation. If one price causes the other while the opposite causality does not hold, this is evidence of price leadership. If causality is not observed, the markets are independent. A test for a long run LOP relationship corresponds to a test that the restriction  $\sum b_j + \sum c_i = 1$  holds.<sup>15</sup> What is more, if the restrictions  $c_o = 1$ ,  $c_i = 0$  and  $b_j = 0$ ,  $\forall ij > 0$  cannot be rejected, this is evidence that the LOP holds in a static sense, and hence Equation (2) nests Equation (1). An example of this approach related to seafood is Squires, Herrick and Hastie (1989).

### *Empirical specifications with nonstationary data*

During the 1980s, economists recognized that most economic time series are nonstationary. This means that normal statistical inference is not valid for linear regressions on nonstationary data and casts doubt on the reliability of early results obtained using the approach described above. In general, for nonstationary data there will be no linear long-run relationship. However, if the data series in question have common stochastic trends, the linear combination of two nonstationary data series can be stationary and the data series are said to be cointegrated (Engle and Granger, 1987).

It is also of interest to note that if the individual price series are nonstationary but together form a cointegrated system, the error term in a static regression equation must be serially correlated (Engle and Granger, 1987). This implies that for nonstationary prices there must be some dynamic adjustment occurring in order for prices to maintain the equilibrium defined by the cointegrated vector. Hence, a static representation of the LOP cannot be correct when prices are nonstationary.<sup>16</sup>

There are two common approaches to testing for cointegration; the Engle and Granger (Engle and Granger, 1987) test and the Johansen test (Johansen, 1988; 1991). The Engle and Granger test for cointegration is a straightforward regression procedure. However, there are two problems with this test. First, it is subject to the same normalization problem in setting the dependent variable as with stationary data. Second, and more seriously, is that normal statistical inference and tests for the LOP are not valid, although cointegration test for a (substitution) relationship between two commodities is possible.<sup>17</sup>

Developments in cointegration testing by Johansen (1988) offers a solution to the problems with the Engle and Granger test by modeling the price relationships in a VAR format. Using a system of equations, one can avoid the simultaneous equation bias that may be introduced in Equation (1) if both price

series are endogenous. What is more, since estimation and testing is carried out within a system format, normalization on the prices is not necessary.<sup>18</sup> Likelihood-ratio tests can be used to investigate hypotheses on the parameters, and hence test for the LOP. Finally, since the VAR model is itself dynamic, one will also be able to test hypotheses with respect to the adjustment process and in particular, to test for price leadership.

Given a vector,  $P_t$ , containing the variables of interest, in our case the two prices, the Johansen test is carried out using the following VAR representation;

$$P_t = \sum_{i=1}^{k-1} \Pi_i P_{t-i} + \Pi_k P_{t-k} + \mu + e_t, \quad (3)$$

where each  $\Pi_i$  is a  $N \times N$ . matrix of parameters,  $\mu$  is a constant term and  $e_t \sim iid(0, W)$ . The system of equations can be written in error correction form as;

$$\Delta P_t = \sum_{i=1}^{k-1} \Gamma_i \Delta P_{t-i} + \Gamma_K P_{t-k} + \mu + e_t \quad (4)$$

with  $\Gamma_i = -I + \Pi_1 + \dots + \Pi_i$  and  $i=1, \dots, k-1$ . Here,  $\Gamma_K$  is the long-run solution to Equation (3).<sup>19</sup> If  $\Delta P_t$  is a vector of first difference stationary variables, then the left-hand side and the first  $k-1$ . variables on the right-hand side of Equation (4) are stationary and the error term,  $e_t$  is by assumption stationary. Hence, either  $P_t$  contains a number of cointegrating vectors, or  $\Gamma_K$  must be a matrix of zeros. The rank of  $\Gamma_K$ , defined by  $r$ , determines how many linear combinations of  $P_t$  are stationary. If  $r=N$ , the variables are stationary in levels; if  $r=0$ , there exist no



linear combinations that are stationary. There are two asymptotically equivalent tests for cointegration in the Johansen framework, a likelihood ratio test and a Trace test. When  $0 < r < N$ , there exists  $r$  cointegrating vectors, or  $r$  stationary linear combinations of  $P_t$ . When data series are cointegrated, one can factor  $\Gamma_K$ , such that,  $\Gamma_K = \alpha\beta'$ , where both  $\alpha$  and  $\beta$  are  $N \times r$  matrices. The matrix  $\beta$  contains the cointegrating vectors or the long-run relationships and  $\alpha$  the adjustment or factor loading parameters.

The cointegration test has a direct relationship to the causality test. Two data series will be cointegrated only if there exists a statistically significant linear relationship between them. If there is a linear relationship between two data series, there must also be a causal relationship. Indeed, Granger (1969) originally introduced the concept of causality and noted that cointegration implies causality. Accordingly, finding prices to be cointegrated can be regarded as evidence of causality, although it need not be bi-directional. Information with respect to whether there is causation in both directions or whether there is price leadership is contained in the adjustment parameters. Formally the adjustment parameters are related to the concept of weak exogeneity, since if all adjustment parameters are zero in one equation, this variable is weakly exogenous for the long-run parameters in the remaining equations (Johansen and Juselius, 1990). However, this implies that the

parameters on the levels of the variables in the system are zero in this equation, and hence, that the other variables cannot in the long run cause this variable. For there to be no causality, the short-run parameters on the other variables must be zero.<sup>20</sup> The test for weak exogeneity does provide a test for the hypothesis of no long run causality. Further, since the  $\alpha$  matrix cannot have zero rank when a cointegration relationship has been found, at least one of the parameters must be different from zero.

The matrix  $\beta$  contains the long-run parameters in the system. These are of interest with respect to the structural information in the system, and particularly for testing the LOP. Johansen and Juselius (1990) show that any linear restriction on the cointegrating vector can be tested using a likelihood ratio test. For the LOP to hold for the case at hand, the restriction that the cointegrating vector is (1,-1) must be valid. This test is then equivalent to the test of the long run LOP based on Equation (2).

### *Multivariate specifications*

Froot and Rogoff (1993) indicate that relationships like Equation (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. For instance in a multivariate test for the LOP the cointegration

vector must sum to zero, or in a single equation specification the right hand side variables 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 is also true for nonstationary data series with this data structure. It then follows that no structural information is lost by modeling only bivariate relationships.<sup>21</sup>

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. A potential problem is therefore that one might obtain different conclusions depending on which pairs one chooses in applied work, although this is theoretically impossible.<sup>22</sup> This problem is avoided in a multivariate specification as one then cannot estimate more than  $n-1$  cointegration vectors. Moreover, while all structural information is contained in the cointegration vectors, one will in some cases need the full system to find out if there are any exogenous variables.<sup>23</sup>

While this may indicate that in all cases one should estimate multivariate systems, a practical problem is that the results are often sensitive 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. Our experience suggests that bivariate models are to be preferred at least initially, since they contain all the relevant structural information, and in most cases also the information with respect to exogeneity. One can then, if it is of interest, continue with multivariate models.

### *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, the bundle can be characterized using a 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 – 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.<sup>24</sup> There are several ways to test for the generalized composite commodity theorem. One simple way in a market delineation context when prices are nonstationary is to investigate whether the

LOP holds (Asche, Bremnes and Wessells, 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.

### 3. Data

Our data set contains monthly French import prices for frozen fillets of cod, haddock, redfish and saithe from Eurostat. Monthly price series were obtained by a value quantity transformation and missing observations were interpolated following Gordon and Hannesson (1996). The price data used in empirical testing are summarized graphically in Figure 2. In the figure, the prices of frozen fillets from cod, haddock, redfish and saithe are shown for the period 1983-1995.<sup>25</sup> There appears to be a common price trend for all whitefish species, although the price levels differ with the perceived quality of the different species.

When investigating market integration, the first priority is to examine the time series properties of the price series. We use the most common approach, an Augmented Dickey-Fuller (ADF) test for this purpose (Dickey and Fuller, 1979; 1981). For each individual price ( $p_{it}$ ) the ADF statistic is measured from the following regression

$$\Delta p_{it} = \beta_o + \beta T + \sigma p_{it-1} + \sum_{\gamma=1}^k \alpha_{\gamma} \Delta p_{it-\gamma} + \varepsilon_t, \quad (5)$$

where  $\Delta$  is the difference operator and  $T$  is a time trend.<sup>26</sup> The lag length,  $k$ , is set to achieve white noise in the error term.<sup>27</sup> Using the level forms of each

series, the null hypothesis is that each data series is nonstationary. The null hypothesis is tested based on the ratio of  $\sigma$  to its standard error. 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 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 the prices are integrated of order one (i.e., stationary in first differences).

## 4. Empirical Analysis

With nonstationary price series, cointegration procedures are the correct tool for determining market boundaries and testing for the LOP. The results from the pair wise cointegration tests for frozen fillets from different species of whitefish are reported in Table 2.<sup>28</sup> There is six separate pair wise tests reported in the table. The first column of the table shows the different pairs of whitefish species used in testing. Columns two and three show the value of the calculated statistics for the Maximum Eigenvalue and Trace Test for testing the null hypothesis that there exists no cointegrating vector. Columns four and five repeat the tests under the null hypothesis that there exists less than or equal to one cointegrating vector. Finally, column six reports the test results for the LOP.

In all pair wise tests, the null hypothesis of no cointegrating vector  $\text{Rank} = 0$ . is rejected at the 1% or 5% level and allows rejection of the hypothesis of zero cointegrating vectors. On the other hand, the null hypothesis of less than or equal to one cointegrating vector  $\text{Rank} \leq 1$ . cannot be rejected at the 1% level. In combination, the two sets of results indicates that one cointegrating vector exists for each pair of fish prices.



These results show evidence that the prices of different whitefish species on the French market do not represent separate or independent prices but rather form part of a system of whitefish prices. It is possible that fish prices may vary in the short run but in the long run, prices must maintain the equilibrium across the different fish prices. In other words, different whitefish species in France compete in a single market.

If the LOP holds for each pair of prices, each cointegrating vector takes the values  $(1,-1)$ . This restriction is tested for each pair of prices and the results reported in column 6 of Table 2. The LOP can not be rejected for cod and haddock, cod and saithe, and haddock and saithe, but the hypothesis is rejected, at either the 1% or 5% significant levels, for any combination of prices that includes redfish. Consequently, although cointegration tests show that redfish are part of a larger whitefish market the prices of this fish species does not follow the LOP in relation to other whitefish prices. These results also provide evidence that the market segments for cod, haddock and saithe are so highly related that the three species can be aggregated into a single good due to the generalized composite commodity theorem. The results suggest that this is not true for redfish. Finally, exogeneity tests are reported in Table 3. From the table, cod is exogenous in all cases where it is one of the products, while no other

species is exogenous in any test. Hence, we can conclude that cod is a price leader in the French whitefish market.

Finally, as an empirical exercise we treat the data as if stationary in levels and repeat the test for the LOP using causality models rather than cointegration models. We test both the static and dynamic specifications of the causality model. Our purpose here is to empirically show that causality models applied to nonstationary data will over reject the hypothesis of the LOP. In this exercise, since over rejection is the issue at hand, we use only whitefish prices that satisfy the cointegration test for LOP reported in Table 4. Six causality models are estimated, one equation for cod/haddock, haddock/cod, cod/saithe, saithe/cod, haddock/saithe and saithe/haddock (the first price in each pair is defined as the dependent variable). The test for LOP is first run for the simple two-variable static equation i.e., Equation (1) and then repeated for the dynamic lagged model i.e., Equation (2). The results are reported in Table 4. In the table, the first column defines the fish prices used in testing and columns two and three report the LOP results for the static and dynamic tests, respectively. The results for the static equation show a rejection of the LOP in five of the six pair wise tests, at either the 5% or 10% significant level. The results for the dynamic model are somewhat better but still three of the six tests reject the LOP. These empirical results are not surprising and are consistent with analytical results

which show that causality models will tend to over reject the LOP for nonstationary data. Our point here is that the many past studies using causality models that reject the LOP may be explained at least partially by the fact that nonstationary prices were used in estimation and testing.

To determine whether salmon is an important factor in the EU whitefish market, the price of imported salmon is introduced into the equation and pair wise testing against the different prices of whitefish species are performed. The French fish prices included in the pair wise tests represent fresh salmon, frozen cod, fresh cod, dried cod, and frozen saithe, haddock and redfish. The results are reported in Table 5. In column one of the table the different fish species used in testing are listed. Columns two and three show the value of the calculated statistics for the Maximum Eigenvalue and Trace Test for testing the null hypothesis that there exists no cointegrating vector. Columns four and five repeat the tests under the null hypothesis that there is less than or equal to one cointegrating vector.

The value of the test statistics reported in column two and three do not allow us to reject the null hypothesis of no cointegrating vector for all pair wise tests using either the Maximum Eigenvalue or Trace Test statistics. In other words, salmon does not form a cointegrated system with any of the different whitefish

species and product forms. For completeness we repeat the test under the null hypothesis of less than or equal to one cointegrating vector. For the results to be consistent the calculated values of the statistic should not allow us to reject the null of less than or equal to one cointegrating vector. For all pair wise tests the results show that the null cannot be rejected. These results are consistent with a conclusion of no evidence of a cointegrated system that includes salmon and whitefish species. The increased supply of salmon on the French market is an interesting development in the fish industry but the data and model used in this study shows no evidence of declining salmon prices influencing the prices of whitefish in the EU market.

## 5. Concluding Remarks

The purpose of this paper is to review the relationships between traditional parametric tests and cointegration tests for market integration using prices, and to define market boundaries for whitefish species within France. We show that traditional approaches like causality tests and tests for LOP provide the same economic information as cointegration tests. The difference is only that the approaches are appropriate for data with different time series properties. If prices are stationary, causality models should be used while if prices are nonstationary, cointegration models should be used.

For nonstationary prices, the Johansen cointegration procedure has the advantage in providing estimates of the cointegrating vector, as well as, allowing a direct test of the LOP hypothesis as well as for price leadership. This is in contrast to the Engle and Granger procedure that does not allow for hypothesis testing on the cointegration parameters. This is also of importance since if the LOP holds with nonstationary data, also the generalized composite commodity theorem will hold. The goods in question can then be aggregated into a single good.

For testing market integration and the LOP, the importance of choosing the correct econometric method is important. In past research, the LOP hypothesis has been tested by econometric techniques appropriate for stationary prices and the hypothesis commonly rejected. However, since the correct critical values when prices series are nonstationary are increased, this may have lead to an over rejection of the LOP.

The empirical results reported here indicate that there is one frozen fillet whitefish market in France that includes cod, haddock, saithe and redfish. What is more, the relative prices of frozen fillets of cod, haddock and saithe are consistent with a hypothesis of the LOP. Hence, the market segments for these species are so highly related that one can represent them as a single species with a single price. Redfish are an exception and the prices do not satisfy the LOP. Finally, together with market integration results reported elsewhere, which show a world market for frozen cod fillets, the results suggest support for a hypothesis that there is one global market for frozen fillets of whitefish. Finally, we cannot find any evidence that salmon is a part of this market.

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**Table 1**  
**Augmented Dickey-Fuller Tests**

Variable	Test Statistic	Test statistic with trend	No. of lags
<i>Levels:</i>			
Cod	-2.336	-1.784	5
Haddock	-1.446	-1.409	5
Redfish	-2.389	-2.323	4
Saithe	-1.800	-1.774	2
Salmon	-0.671	-2.784	3
<i>First differences:</i>			
Cod	-4.808*	-5.007*	4
Haddock	-9.490*	-9.512*	4
Redfish	-7.307*	-6.149*	3
Saithe	-11.400*	-11.402*	1
Salmon	-5.350*	-6.327*	2

\* indicates significant at a 5% level. Critical values at a 5% level is -2.879 with a constant and -3.439 with a constant and trend (MacKinnon, 1991).

**Table 2**  
**Bivariate Johansen Tests for Cointegration for Frozen Whitefish Fillets**

Prices	Null Hypotheses <sup>a)</sup>				Law of One Price
	Rank=0		Rank=1		
	Max <sup>b)</sup>	Trace <sup>c)</sup>	Max	Trace	
Cod/Haddock	33.94*	38.9*	4.96	4.96	0.822
Cod/Redfish	35.27*	41.3*	6.03	6.03	13.369*
Cod/Saithe	31.09*	35.44*	4.34	4.34	0.098
Haddock/Redfis	17.38**	25.47*	8.08	8.08	4.842**
h	21.11*	27.6*	6.48	6.48	12.614*
Haddock/Saithe	35.69*	43.42*	7.72	7.72	0.001
Saithe/Redfish					

<sup>a)</sup> The null hypothesis is that the number of cointegrating vectors is equal to zero or one.

<sup>b)</sup> Maximum Eigenvalue Test

<sup>c)</sup> Trace Test

\*indicates significant at a 1% level and \*\* indicates significant at a 5% level.

**Table 3**  
**Exogeneity tests**

System	Test statistic	<i>p</i> -value
Cod and	0.481	0.4877
Haddock	14.563*	0.0001
Cod and	0.681	0.4092
Redfish	11.816*	0.0006
Cod and	1.551	0.2130
Saithe	10.012*	0.0016
Haddock and	5.513*	0.0189
Redfish	5.436*	0.0197
Haddock and	9.779*	0.0015
Saithe	4.945*	0.0251
Redfish and	8.979*	0.0027
Saithe	4.576*	0.0324

\* indicates significant at a 5% level

**Table 4**  
**Tests for the Law of One Price, Assuming Prices are Stationary**

	Static <sup>a</sup>		Dynamic <sup>b</sup>	
	F-test	p-value	F-test	p-value
Cod/Haddock	118.74*	0.000	5.26*	0.023
Haddock/Cod	0.131	0.718	0.22	0.640
Cod/Saithe	40.79*	0.000	3.44**	0.064
Saithe/Cod	3.55**	0.062	0.22	0.639
Haddock/Saithe	46.79*	0.000	1.75	0.188
Saithe/Haddock	3.55**	0.061	3.83**	0.052

<sup>a</sup> Testing the LOP in a static model:  $p_t^1 = a + c_o p_t^2 + e_t$  and test  $c_o = 1$ .

<sup>b</sup> Testing the LOP in a dynamic model:

$$p_t^1 = a + \sum_{j=1}^m b_j p_{t-j}^1 + \sum_{i=0}^n c_i p_{t-i}^2 + e_t \text{ and test } \sum_{j=1}^m b_j + \sum_{i=0}^n c_i = 1$$

\*indicates significant at a 5% level and \*\* indicates significant at a 10% level

**Table 5**  
**Bivariate Johansen Tests for Cointegration for between Whitefish Fillets and Salmon**

Prices	Null Hypotheses <sup>a)</sup>			
	Rank=0		Rank=1	
	Max <sup>b)</sup>	Trace <sup>c)</sup>	Max	Trace
Salmon/frozen cod	8.48	11.16	2.67	2.67
Salmon/fresh cod	16.51**	18.52	2.01	2.01
Salmon/dried cod	12.53	14.80	2.26	2.26
Salmon/saithe	8.06	9.99	1.93	1.93
Salmon/Haddock	15.39	17.45	2.06	2.06
Salmon/redfish	10.79	13.48	2.69	2.69

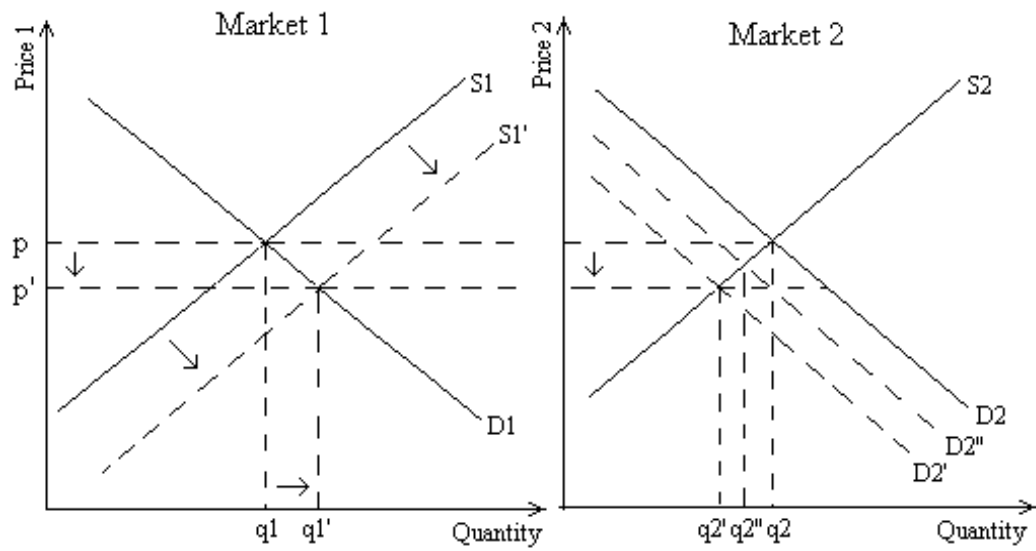
<sup>a)</sup> The null hypothesis is that the number of cointegrating vectors is equal to zero or one.

<sup>b)</sup> Maximum Eigenvalue Test

<sup>c)</sup> Trace Test

\*indicates significant at a 1% level and \*\* indicates significant at a 5% level.





**Figure 1. Potential Market Interaction Between Two Markets**

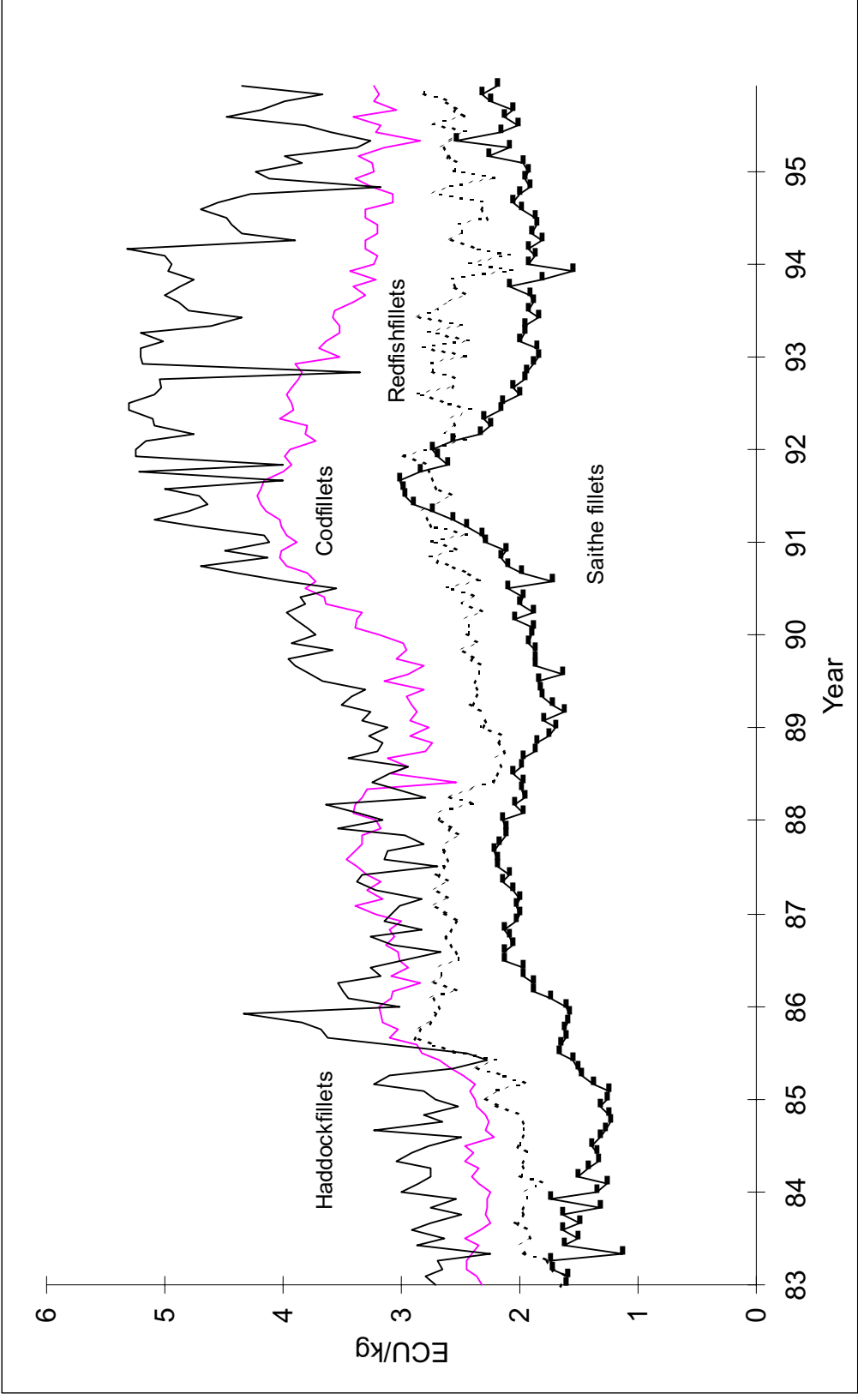


Figure 2. Import prices of frozen fillets from different whitefish species for France, 1983-1995

## NOTES

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<sup>1</sup> Applications to seafood data includes Gordon, Salvanes and Atkins (1993), Bose and McIlgrom (1996), Gordon and Hannesson (1996), Asche, Salvanes and Steen (1997) Asche and Sebulonsen (1998), Asche, Bremnes and Wessells (1999), Clayton and Gordon (1999), Asche (2001), Asche and Guttormsen (2001), Jaffry *et al* (2001) and Asche, Gordon and Hannesson (2002), Asche *et al* (2002).

<sup>2</sup> Papers referring to the LOP include Ardeni (1989), Baffes (1991) and Doane and Spulber (1995). Ardeni (1989) and Baffes (1991) impose price equality, which is a stronger restriction than price proportionality.

<sup>3</sup> Whitefish include the species cod, haddock, redfish and saithe.

<sup>4</sup> The Treaty of Rome allows collusion among producers to establish producer organizations in agriculture and fisheries. The purpose of the organization is to stabilize supply and producers' income. The organizations are meant to benefit both consumers and producers and not for the purpose of extracting excessive profits.

<sup>5</sup> See e.g. Winters (1984).

<sup>6</sup> For completeness one should also mention that if the demand schedule in Market 2 shifts upwards, the two goods are complements.

<sup>7</sup> Note, the same story can be told based on a demand shock but here it is producers that adjust to supply changes.

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<sup>8</sup> In product space, one good is set as the reference point and defines the quality for comparison with all other goods.

<sup>9</sup> See the analysis of Isard (1977) and Richardson (1978).

<sup>10</sup> Some authors argue that the assumption of constant transportation cost is too strict, and can at times cause tests to show less market integration than what actually exists. For instance, Goodwin, Grennes and Wohlgenant (1990) show closer market integration when transportation cost is explicitly modeled.

<sup>11</sup> This also gives rise to a simultaneity problem that often is acknowledged, but otherwise ignored. A good discussion can be found in Goodwin, Grennes and Wohlgenant (1990).

<sup>12</sup> Slade's (1986) analysis is an extension of Horowitz (1981), but Horowitz assumes more restrictive dynamics.

<sup>13</sup> In some cases, exogenous variables that represent common trends for the prices are also included.

<sup>14</sup> This in econometric terms is a test for Granger noncausality (Granger, 1969).

<sup>15</sup> Ravallion (1986) discusses in more detail the interpretation of alternative restrictions on the dynamic process.

<sup>16</sup> However, a static regression of the prices may of course provide a (super) consistent estimate of the long-run parameters.

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<sup>17</sup> One might, however, impose the restriction that  $a=0$  and  $b=1$ , and test the difference of the two prices for stationarity (Baffes, 1991). If the strict version of the LOP holds, this difference should be stationary.

<sup>18</sup> It is of interest to note that when using the Engle and Granger test, one might obtain conflicting results depending on the choice of dependent variable (Goodwin and Schroeder, 1990; Zanas, 1993; Doane and Spulber, 1995).

<sup>19</sup> Note there is no trend term in Equation (3).

<sup>20</sup> If all the short-run parameters are zero, the variable will be strongly exogenous.

<sup>21</sup> 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, Granger and Anderson, 1992).

<sup>22</sup> This conclusion is, of course, based on asymptotic theory.

<sup>23</sup> For instance, bivariate systems can indicate that data series  $a$  is exogenous for series  $b$ , but not that  $c$  is exogenous for  $a$  but not for  $b$ . A multivariate test would be able to resolve which variables are exogenous in the system, if any.

<sup>24</sup> As always, there is some cost involved. Aggregates constructed using the generalized composite commodity theorem cannot be used in welfare comparisons.

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<sup>25</sup> It would also be of interest to investigate the relationships for some species that are possible new entrants to the whitefish market, with Alaska pollock as the most interesting. However, fillets of Alaska pollock only became available in the late 1980s, and Alaska pollock appears as a separate species in European import statistics from 1989, and then only in very thin quantities. A reliable study of the impact of species like Alaska pollock must therefore wait until more data is available.

<sup>26</sup> We also conducted the tests with seasonal dummies. However, these did not lead to any changes in the results.

<sup>27</sup> The tests are often sensitive to the choice of lag length (Dods and Giles, 1995; Gordon, 1995). The lag length in the Dickey-Fuller test is set by the highest significant lag coefficient to ensure that all relevant information is included.

<sup>28</sup> Lag length in the Johansen test is set by minimizing Schwartz' information criterion. Specification checks confirm the errors are white noise.