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Some Tests for Market Determination and the Law of One Price

: the Market for Whitefish in France

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Abstract

This paper examines the relationship between causality models and co integration models in testing for market integration and the Law of One Price. In our review, we show that co integration models, which allow for nonstationarity in prices, are a natural extension of the traditional causality methods and not an alternative approach. However, the choice of modelling method depends on the probability characteristics of the data. The Johansen test for co integration is a valid procedure for testing both causality and the Law of One Price for nonstationary data. An empirical analysis is provided using prices for the whitefish market in France.

Keywords:

Causality, Law of One Price, Co integration, Fish Prices

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 overtime to test for correlation and causality, and to test for the Law of One Price (LOP). More recently, for nonstationary price series, tests for co integration have been used to empirically define a market and to test for market integration.

The LOP has a long history in economics. 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. Moreover, if markets are not perfectly integrated the relationship between prices need not be proportional and the LOP is again violated. In the latter case, causality tests using stationary price series have proven useful in defining market boundaries (Horowitz, 1981; Ravallion, 1986; Slade, 1986; 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 (Ravallion 1986; Goodwin, Grennes and Wohlgenant, 1990).

Where price series show nonstationary probability characteristics, tests for co integration can be used in investigating market relationships.[1] 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).[2] Consequently, in this research, market definition and integration focused on observing a long-run co integrated relationship among the prices rather than a direct statistical test of the LOP. Statistical developments in co integration testing by Johansen (1988) provide a method for generating test statistics (i.e., likelihood ratios) with exact limiting distributions and will allow for direct testing of the LOP hypothesis (Johansen and Juselius, 1990). These techniques will be exploited here to test the LOP.

The purpose of the paper is to review some causality and co integration 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 depend on the probability characteristics of the underlying data series. 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, co integration procedures are required for tests of market integration and the LOP.

The empirical analysis is based 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.[3] 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.[4] 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 is 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.

The paper is organized as follows. In Section II, some causality and co integration models are reviewed and tests for the LOP are presented. The data used in estimation and the empirical results are reported in Section III. Section IV concludes.

1. Time Series Modeling of Market Integration

Economists have a long history of defining a market based on how prices of similar commodities vary in relationship to each other (see, Cournot, 1971; Marshall, 1947; Cassel, 1918). Stigler (1969, p. 85) argues that a market is defined as "the area within which the price of a commodity tends to uniformity, allowance being made for transportation costs". Based on a price definition of a market, there exists a large empirical literature investigating market definition and integration. Certainly, price models provide less information than partial equilibrium models of markets where demand and supply equations are specified and estimated. However, since accurate market price data are available more readily and to a larger extent than quantity data, price analysis will be possible where demand and supply estimates are not available.

It is common in studies of market integration to perform the analysis on the logarithms of prices, and we will proceed using this transformation. With stationary price series, the test for market integration with the least restrictive assumptions is the causality test for market boundaries used by Slade (1986).[5] Given a time series on two prices, say, p_t^1 and p_t^2, a causality test is performed by first running the regression[6]

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

The length of the lag on the two different prices is chosen so that e_t is a white noise error term. The data support a null hypothesis that p_t^2 causes p_t^1 if a joint test that all c_i parameters are zero is rejected. Economic theory gives little guidance as to the choice of dependent variable, and the test is repeated by interchanging price variables in Equation (1). This will allow a test of the null hypothesis that p_t^1 causes p_t^2. If causality is not observed in any of the equations, this is evidence that the goods are not in the same market. It is possible to observe that one price causes the other while the opposite causality does not hold. This is an interesting result and may occur for example, when there is one central market that affects regional markets, but where regional markets are not large enough to impact price in the central market.

In a dynamic sense, Equation (1) nests a test for a long-run LOP relationship if the restriction $\sum b_j + \sum c_i = 1$ holds true.[7] 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.[8] Hence, testing for the LOP is a more restrictive test than the general test of causality. It is of interest to note that the most restrictive version of the LOP model i.e., a simple static equation, is also the most commonly reported in the literature. In this case, the estimating equation is $p_t^1 = a + c_o p_t^2 + e_t$ and the static test for the LOP is test of the hypothesis that $c_o = 1$.

Using the bi-variate equation, co integration is based on the time series properties of the residuals predicted from the estimation. The two price series are said to be These first attempts at testing the LOP although simple provide a direct link to early tests for co integration between two price series based on the Engle and Granger (1987) test procedure co integrated if the residuals are stationary. The test is general in the sense that no restrictions are imposed on the estimated coefficients. It is interesting to note that if the individual price series are nonstationary but together form a co integrated system, the error terms 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 the prices to maintain the equilibrium defined by the co integrated vector. Hence, a static representation of the LOP cannot be correct when prices are nonstationary.[9] Because the Engle and Granger test statistics do not have well defined limiting distributions, hypothesis testing on the estimated parameters (i.e., the co integration vector) is not valid. Consequently, a direct test for the LOP is not possible using this method.[10]

Developments in co integration testing by Johansen (1988) offers a solution to this problem by modelling the price relationships in a VAR format. Using a system of equations 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.[11]

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

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

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

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

with $\Gamma_i = -\mathrm{I} + \Pi_1 + \ldots + \Pi_i$ and i=1,…, k-1.

Here, ΓK is the long-run solution to Equation (2).12 If ΔPt 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 (3) are stationary and the error term, et is by assumption stationary. Hence, either Pt contains a number of co integrating vectors, or ΓK must be a matrix of zeros. The rank of ΓK, 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 which are stationary. When $0<r<N$, there

exists *r* co integrating vectors, or *r* stationary linear combinations of P_t.

The co integration test has a direct relationship to the causality test. Two data series will be co integrated 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 co integration implies causality. Accordingly, finding prices to be co integrated can be regarded as evidence of causality.

When data series are co integrated, one can factor Γ_K, such that, $\Gamma_K = \alpha\beta'$, where both α and β are ($N \times r$) matrices. The matrix β contains the co integrating vectors and α the adjustment parameters. Both matrices, or in our case vectors, are of interest. The adjustment parameters (or factor loadings) are closely 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.[13] The test for weak exogeneity does provide a test for the hypothesis of no long-run causality. Further, since the α matrix cannot have zero rank when a co integration relationship has been found, at least one of the parameters must be different from zero.

The matrix β contains the long-run parameters in the system. These are of interest for testing the LOP. Johansen and Juselius (1990) show that any linear restriction on the co integrating vector can be tested using a likelihood ratio test. For the LOP to hold for the case in hand, the restriction that the co integrating vector is (1,-1) must be valid. As this test is only valid in a long-run sense, whether the LOP holds in the short run must be tested on short-run parameters. This can be done within a normal error-correction model. Nevertheless, the interest here is in testing a long run hypothesis of the LOP based on co integration and causality models.

2. Empirical Analysis

Our empirical procedure is first, to examine the probability characteristics of each price series to determine the stationarity properties. Second, based on these results a co integration procedure is used to investigate market integration and to test for the LOP using price data for the French whitefish market. Finally, as an empirical exercise, we report test results for the LOP using causality models, and show that for the nonsationary price data used here causality results over reject the null hypothesis of LOP.

Monthly value and quantity figures for different whitefish species are collected from Eurostat's trade statistics for France. Monthly price series were obtained by a value quantity transformation and missing observations were interpolated following Gordon and Hannesson (1996). Prices are collected for frozen fillets of cod, haddock, redfish and saithe.

The price data used in empirical testing are summarized graphically in Figure 1. In the figure, the prices of frozen fillets from cod, haddock, redfish and saithe are shown for the period 1983-1995. 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 each price series for evidence of stationarity. This is important because if the data are stationary in level form, causality models are the appropriate framework for investigating market integration and testing the LOP. On the other hand, if the data are nonstationary, co integration procedures are required for the analysis. In this study, an Augmented Dickey-Fuller (ADF) test is used to measure for stationarity of each price series (Dickey and Fuller, 1979; 1981). For each individual price (p_{it}) the ADF statistic is measured from the following regression

$$(4) \qquad \Delta p_{it} = \beta_o + \beta T + \sigma p_{it-1} + \sum_{\gamma=1}^{k} \alpha_{\gamma} \Delta p_{it-\gamma} + \varepsilon_t ,$$

where Δ is the difference operator and T is a time trend. The lag length, k, is set to achieve white noise in the error term (Gordon, 1995). 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 σ 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.[14] 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) and, therefore, co integration procedures are the correct tool for determining market boundaries and testing for the LOP.

The search for co integration in prices is based on pair wise testing of the different species of white fish. Johansen shows that it is possible to test for significant co integrating vectors r, using two alternative tests, the Trace test and the Maximum Eigenvalue test. The Trace test (η_r) is a likelihood ratio test for at most r co integrating vectors;

$$\eta_r = -T \sum_{i=r+1}^{N} \ln(1-\hat{\lambda}_i)$$

where T is the number of observations, and the $\hat{\lambda}_i$ are the Eigenvalues that solve the eigenvector problem. The Maximum Eigenvalue test (ξ_r), is a test of the null hypothesis of r+1 co integrating vectors against the alternative hypothesis of r co integrating vectors;

$$\xi_r = -T \ln(1 - \hat{\lambda}_{r+1}).$$

The results from the pair wise co integration tests for frozen fillets from different species of whitefish are reported in Table 2.15 There are 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 co integrating vector. Columns four and five repeat the tests under the null hypothesis that there exists less than or equal to one co integrating vector. Finally, column six reports the test results for the LOP.

In all pair wise tests, the null hypothesis of no co integrating vector (Rank = 0) is rejected at the 1% or 5% level and allows rejection of the hypothesis of zero co integrating vectors. On the other hand, the null hypothesis of less than or equal to one co integrating vector (Rank $\leq$ 1) cannot be rejected at the 1% level. In combination, the two sets of results indicate that one co integrating 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, it must be true that each co integrating 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 co integration 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.

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 co integration 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 co integration test for LOP reported in Table 2. 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 and then repeated for the dynamic lagged model (i.e., Equation 1). The results are reported in Table 3. 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 prices that most likely were nonstationary were treated as stationary when used in estimation and testing.

3. Concluding Remarks

The purpose of this paper is to review the relationships between traditional parametric tests and co integration 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 information as co integration tests. The difference is only that the approaches are appropriate for data with different probability characteristics. If prices are stationary, causality models should be used while if prices are nonstationary, co integration models should be used.

For nonstationary prices, the Johansen co integration procedures has the advantage in providing estimates of the co integrating vector, as well as, allowing a direct test of the LOP hypothesis. This is in contrast to the Engle and Granger procedure that does not allow for hypothesis testing on the co integration parameters.

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 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. 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, are results suggest a hypothesis that there is one global market for frozen fillet of whitefish.

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Footnotes

[1] See, e.g. Ardeni (1989), Goodwin and Schroeder (1990), Baffes (1991), Gordon, Salvanes and Atkins (1993), Zanias (1993), Doane and Spulber (1995), Sauer (1995), Bose and McIlgrom (1996), Gordon and Hannesson (1996), Asche, Salvanes and Steen (1997).

[2] 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.

[3] Whitefish include the species cod, haddock, redfish and saithe.

[4] 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.

[5] Slade's (1986) analysis is an extension of Horowitz (1981), but Horowitz assumes more restrictive dynamics.

[6] In some cases, exogenous variables that represent common trends for the prices are also included.

[7] Ravallion (1986) discusses in more detail the interpretation of different restrictions on the dynamic process.

[8] See the analysis of Isard (1977) and Richardson (1978).

[9] However, a static regression of the prices may of course provide a (super) consistent estimate of the long-run parameters.

[10] 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.

[11] 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; Zanias, 1993; Doane and Spulber, 1995).

[12] Note, there is no trend term in Equation (3).

[13] If all the short-run parameters are zero, the variable will be strongly exogenous.

[14] Lag length in the Dickey-Fuller tests is chosen by the highest significant lag coefficient.

[15] Lag length in the Johansen test is set by minimizing Schwartz' information criterion. Specification checks confirm the errors are white noise.