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COINTEGRATION TECHNIQUE TO DETERMINE MARKET PRICE INTEGRATION: APPLICATIONS IN FISHERY SECTOR

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Introduction

Stationarity is an important pre-requisite for time-series variables to possess and to be used effectively for drawing standard statistical/economic inferences involving them. A time-series is considered to be stationary if it possesses constant unconditional mean and variance over time. Such series perpetually return to their long-run equilibrium mean and variance in spite of temporary fluctuations. In economic literature, the implications of drawing economic inferences based on analysis involving non-stationary variables were more or less ignored for a long time. The irrationality of running spurious regressions with non-stationary time series and drawing important conclusions based on such analysis came to light with the publication of seminal papers by Granger and Newbold (1972) and Nelson and Plosser (1982). Thereafter, diagnostic checks for stationarity have emerged as an important norm before proceeding to any econometric analysis involving time-series variables. In addition, transforming non-stationary variables to stationary ones by successive differencing was mooted as a solution to the problem of non-stationarity. However, several statisticians through their subsequent works questioned the logic of using only the differenced series in economic models as it can potentially cause misspecification errors. Granger (1981) based on empirical examples suggested that a vector of non-stationary variables could have linear combinations which are stationary at levels. Subsequently, Engle and Granger (1987) showed that integrated variables having long-run equilibrium relation with each other can be identified by testing whether the residuals from a regression involving the original variables are stationary or not. This property of time series variables was denoted by the term 'cointegration' and turned out to be a corner stone in subsequent deliberations on the subject. Cointegration analysis, since then is used widely in the economic literature for defining relationships between wide variety of economic variables under varying economic contexts.

Cointegration: Methodological Framework

Let $Y_t = (y_{1t},...,y_{nt})'$ denote an (n×1) vector of I (1) time series. Y_t is cointegrated if there exists an (n×1) vector $\beta = (\beta_1,...,\beta_n)'$ such that,

$$\beta_0 Y_t = \beta_1 Y_{1t} + \cdots + \beta_n Y_{nt} \sim I(0) \qquad \text{........ (1)}$$

In words, the non-stationary time series in Y_t are cointegrated if there is a linear combination of them that is stationary or I (0).

For the sake of simplicity, the above relationship is explained considering the cointegrating relationship of only two variables, i.e., Y_t and X_t hereafter. Two times-series variables are said to be integrated if there exists a long-term equilibrium relationship between them and the degree of their long-run association can be obtained by fitting a classical regression model given by equation (2):

$$Y_t = \beta_0 + \beta_1 X_t + e_t$$

where,

Y_t = Dependent variable
X_t = Independent variable
β_0=Constant
β_1=Long-run elasticity, and
e_t= Error-term.

However, assumptions of the classical regression model necessitate that both Y_t and X_t variables should be stationary and the errors should have a zero mean and finite variance. A stationery series is one whose parameters (mean, variance and autocorrelations) are independent of time. As mentioned above, regression between two non-stationary variables may result in spurious relationship with high R^2 and t-statistics that appear to be significant, but with the results of having no economic meaning. Under such circumstances, the series have to be first checked for stationarity. If a time series requires first order differencing to be stationary, then it is said to be I (1) which means integrated of order one. I (2) series requires differencing twice to become stationary and so on. If it is verified that both the series are stationary, then the classical regression model [equation (1)] would hold good and the β coefficient would represent the coefficient of price transmission. However, if the two series prove to be non-stationary but integrated of the same order, the validity of regression can be checked by testing the residuals of the regression for stationarity. As demonstrated by Engle and Granger (1987), if the residuals from such a regression turn out to be stationary, then the series are co-integrated and there existed a long-run relationship between the two series. Engle-Granger theorem states that if a set of variables are co-integrated of order (1, 1), then there exists a valid error-correction representation of the data. Converse of this theorem also holds good, that is, if an error correction model (ECM) provides an adequate representation of the variables, then they must be co-integrated. However, if the series are integrated of different orders, the regression equations using such variables would be meaningless and it can be concluded that there cannot exist any long-term relationship between the two.

The stationarity of a series can be tested using a unit root test, the most widely used being Augmented Dickey-Fuller(ADF) unit root test. It would test the null hypothesis that the series has a unit root, i.e. non-stationary.

The test is applied by running the regression of the form given in Equation (3):

$$Y_t = \beta_1 + \delta Y_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta Y_{t-i} + \varepsilon_t$$

where, e_t is a pure white noise error-term and $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$.

Once it is established that the order of integration is the same for the variables of interest, the second stage of testing co-integration can be undertaken. The co-integrating equation is the same as Equation (1). The error-term arising from this regression is then subjected to testing of stationarity. The ADF test in this context is known as Augmented Engle-Granger test whose critical values were provided by Engle and Granger (1987). Davidson and Mackinnon (1993) have revised these values and in the present study, these values have been used. The stationarity in the error-term confirms co-integration between the series and the existence of long-term equilibrium. However, there can be short term disequilibrium which means that a change in series is not immediately passed on to the other. Using the Error Correction Model (ECM), the speed of adjustment towards the long-run path can be ascertained and the model is represented by Equation (4):

$$\Delta Y_t = \alpha_0 + \alpha_1 \Delta X_t + \alpha_2 e_{t-1} + \varepsilon_t$$

where, e_{t-1} is the lagged error-term of the co-integrating regression and ε_t is the disturbance- term. The magnitude of α_2 explains the speed at which the series approaches equilibrium and it is expected to be negative, so that the equilibrium is restored in the long-run.

Application in Fishery Sector: An Example

In the fish marketing system, price movements in different markets depend to a large extent on the cross market movement of available catch, which in turn, is governed by the demand and supply factors. The extent of price transmission from one market to the other and its direction are the important aspects to be looked into, as these would provide valuable information on the degree of integration, and in turn, the efficiency of these markets (Shinoj *et al*, 2008). In this paper, the degree of spatial market integration between two coastal fish markets in India, i.e., Visakhapatnam and Chennai has been studied by applying cointegration analysis based on monthly retail price data[1] on important fish species. The data used pertains to the period 1998 to 2012.

As a first step to determine the price transmission mechanism between the markets for the fish species considered, an augmented Dickey-Fuller (ADF) unit root test was applied to ascertain the stationarity of the monthly price series. The results of this exercise are presented in Table 1.

Table 1. Augmented Dickey-Fuller unit root test on domestic retail market prices of sardine

Market	Commodity price series (in log)	Level	First difference	Level of integration
Vishakhapatnam	Sardine	-3.641**	-9.220***	I (1)
Vishakhapatnam	Mackeral	-3.820**	-8.903***	I (1)
Vishakhapatnam	Seerfish	-4.104***	-9.150***	I (1)
Vishakhapatnam	Pomfret	-2.815ns	-9.217***	I (1)
Vishakhapatnam	Tuna	-4.487***	-9.588***	I (1)
Vishakhapatnam	Shrimp	-2.231ns	-6.848***	I (0)
Chennai	Sardine	-3.165 ns	-8.718***	I (0)
Chennai	Mackeral	-4.914***	-8.520***	I (0)
Chennai	Seerfish	-3.760**	-8.570***	I (0)
Chennai	Pomfret	-3.314ns	-8.049***	I (1)
Chennai	Tuna	-6.214***	-9.882***	I (1)
Chennai	Shrimp	-3.324 ns	-7.766***	I (0)

Notes: *** and ** denote significance at 1per cent and 5 per cent levels respectively;

McKinnon critical values of ADF statistic under the assumption of both constant and time trends in the series are -4.015 (1 per cent) and -3.440 (5 per cent); Unit root test assumes both constant and time trends.

The price series corresponding to shrimp in Visakhapatnam and sardine, mackerel, seerfish, and shrimp in Chennai markets are proved to be stationary at level as well as at first difference as a consequence of the rejection of the null hypothesis that a unit root is present. In contrast, the prices of sardine, mackerel, seerfish, pomfret and tuna in Visakhapatnam and pomfret and tuna in Chennai markets became stationary only after the first differencing. The estimated ADF test statistics and their levels of significance corresponding to all the price series are presented in Table 1 for better clarity. The stationarity tests were performed under the assumption of the presence of time trends for the all the series considered.

[1]The price data used here are only indicative based on the broad market trends for the period considered. Therefore, the results presented may be taken only as hypothetical, meant for demonstration of the analytical procedure.

Table 2. Price integration between Vishakhapatnam and Chennai fish markets for major marine fish species

Fish species	Integrated/Not integrated	Elasticity of price transmission	Type of equilibrium	Lead market	Speed of adjustment
Sardine	Not Integrated	-	NA	NA	NA
Mackeral	Integrated	0.474^{***}	Long-run	VSP	NA
Seerfish	Integrated	0.544^{***}	Long-run	VSP	NA
Pomfret	Integrated	0.561^{***}	Short-run	CHN	-0.37^{***} (-4.124)
Tuna	Integrated	0.632^{***}	Long-run	VSP	NA
Shrimp	Not Integrated	-	NA	NA	NA

Notes: * and ** denote significance at 1 and 5 per cent levels respectively;
Figure within the parenthesis is Engle-Granger tau statistics for co-integration.

McKinnon critical values of ADF tau statistic are -3.48 (1 per cent) and -2.88 (5 per cent). NA denotes 'not applicable'.

The elasticity of price transmission for each of the fish species between the two markets were obtained by fitting regression models, as explained in methodology. Double log models were fitted so that the elasticities could be obtained directly from the estimated regression. A single step was required for all the combinations of stationary (at level) price series, but for other series, which were not stationary at level, a further two-step procedure was followed to ascertain the presence of co-integration. Table 2 presents a matrix with the price transmission coefficients for each of the market pair combinations. Besides this, the lead market[1] determining the flow of price signals between the market pairs, the type of equilibrium existing, and the speed of adjustment in case of short-run equilibrium are also presented in Table 2. It is clear that, the Visakhapatnam and Chennai markets are in long-run equilibrium in case of mackerel, seerfish and tuna, whereas they are not integrated at all in cases of sardine and shrimp. The estimated elasticity of price transmission shows relatively high level of flow of price signals between the market pairs in case of the fish species for which the markets are integrated. It is only in case of pomfret, that the market pair is cointegrated with short-run equilibrium with an error correction coefficient of -0.37 (significant at 1 % level). This coefficient indicates the speed of adjustment of the short- term fluctuations in prices towards the long term equilibrium. The fitted error correction model (ECM) for pomfret is depicted in Equation (5) presented below;

Error Correction Model for Visakhapatnam-Chennai market pair for pomfret:

$$\Delta \ln VSP = 0.002 + 0.253^{***} \Delta \ln CHN - 0.37^{***} e_t\text{-}1$$
$$(0.001) \quad (-0.09) \qquad\qquad (0.05)$$

Conclusions

This chapter helps to develop a fair understanding on cointegration as an econometric tool to assess the level of price integration between fish market pairs. The empirical example depicted above demonstrates how econometric techniques are useful to model the behaviour of market prices over time and to unveil the complicated price transmission process taking place between markets. Such studies are important to identify the presence of supply-side constraints existing in markets, and in turn to devise appropriate strategies so as to bring about greater integration between them.

[2] The lead market was identified by comparing the Akaike information criteria (AIC) and Bayesian information criteria (BIC) of the alternative fitted models.

Suggested Readings:

- Davidson, R. and Mackinnon, J.G. (1993). Estimation and Inference in Econometrics, Oxford University Press, New York, U.S.A.
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