Market Integration Test for Pacific Egg Markets

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Abstract

This paper uses of Johansen's multivariate cointegration test to test for egg market integration of six Pacific states, Washington, Idaho, Oregon, California, Nevada, and Arizona. We conclude that eggs from these states substitute for each other to some degree, and arbitrage possibilities through trade bind the egg prices. In addition, the Law of One Price (LOP), the case of perfect integration, is examined by testing the linear combination of cointegration vectors. Test results show that the LOP is not satisfied even though the egg markets in the six Pacific states are highly integrated. Arizona egg prices, California egg prices, and Washington egg prices play dominant roles on the Pacific egg market in the long run.

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Introduction

Market integration has become an increasingly interesting issue domestically and internationally (e.g., Gonzalez-Rivera and Helfand 2001; Goodwin 1992; Asche, Bremnes and Wessells 1999; Sanjuan and Gil 2001; Sexton, King and Carmen 1991; Ravallion 1986). In an integrated spatial market, prices are determined simultaneously in different locations. However, in the absence of spatial market integration, price information may be conveyed inaccurately, thus distorting producer marketing decisions and contributing to inefficient product movements (Goodwin and Schroeder 1991). Geographic markets are germane to agriculture because most agricultural products are bulky and/or perishable. Furthermore, areas of production and consumption are generally separated--hence there exist high transportation costs. Therefore, it is very useful to test whether the markets of a particular agricultural commodity in different locations are integrated.

Under conditions of spatially integrated markets, the analysis of price transmission can be used to assess the nature of the price relationship and the direction of the causal relationship between prices in trade surplus and deficit areas. Which markets, those in deficit or surplus areas, are most important in determining prices? What is the relationship of price responses in surplus areas to price changes in major deficit or consuming areas? Answers to these questions are important in the design of government market intervention policies such as price stabilization and environmental protection. For example, the effects of government intervention in a particular market can also be transmitted across markets that are spatially integrated. It is thereby not necessary for the government to intervene in all markets, but just in a few important ones and the influence will be extended to others.

Egg production and consumption in the U.S. exhibit very powerful regional characteristics (Figure 1). Most eggs are produced in the Midwestern and the Southern states in the U.S. However, since eggs are perishable and not easy to transport, few eggs are shipped between the east and the west. Among the western states, California accounts for most of the egg production. This study will focus on the movement of egg prices in six Pacific states: Washington (WA), Idaho (ID), Oregon (OR), California (CA), Nevada (NV), and Arizona (AZ).

Cointegration analysis has recently become more popular for investigating market integration through analysis of relationships among prices, because most price series tend to be nonstationary. Earlier empirical work was focused on the application of a bivariate cointegration test (Ardeni 1989; Baffes 1991; Schroeder and Goodwin 1990; Zanians 1993). The bivariate method is to make cointegration test of each two price series by assuming other prices have no effects on the market. This method was recently criticized for omitting prices because this omission neglects indirect linkages between two prices, so that it could lead to no conclusive results about the existence of a cointegrated market (Asche, Bremnes and Wessels 1999; Sanjuan and Gil 2001; Gonzalez-Rivera and Helfand 2001). Johansen's multivariate cointegration procedure is now most commonly applied to test for market integration.

Perfect integration is defined by the Law of One Price (LOP), which is used widely in the study of international trade and regional economics. The LOP holds for a group of prices when prices move in proportion to one another. In a set of n markets under the

LOP, two conditions must be satisfied: First, every pair of prices must be cointegrated; and second, every pair of prices must fulfill the parity condition, i.e., they move proportionally to each other over time. Both of these conditions can be tested by Johansen's multivariate tests.

The objectives of this paper are threefold: first, to use the multivariate approach to test for the integration of egg markets in the Pacific states of the U.S.; second, to test for the Law of One Price; and third, to ascertain whether the price in one particular state plays a dominant role in the integrated market. Arizona, California, and Washington are the focuses of this paper since they are the major egg production and consumption states in the Pacific area.

In the following section, we briefly discuss the test procedures, including the Augmented Dickey-Fuller test and Johansen's test. The next two sections provide details on the data set and the empirical test results. Conclusions are drawn at the end.

Test procedures

Based on Gonzalez-Rivera and Helfand's (2001) definition, a market with n distinct locations will be considered integrated when the following two conditions are satisfied: (1) physical flows of goods among the n locations exist; and (2) these n locations share the same long-run information. The second condition is equivalent to the existence of one common integrating factor for all sets of prices under a multivariate cointegration framework. Corresponding to these two conditions are two steps to test for market integration: first, identifying the set of locations that are directly or indirectly connected by the trade; and secondly, determining one common integrating factor, shared by prices of those locations.

In this multivariate cointegration framework, the second condition of market integration implies that prices in n distinct locations must be cointegrated and there must be n-1 cointegrating vectors. In general, in a system with n data series and r cointegration vectors, there will be n-r different stochastic trends (Stock and Watson 1988). However, if there is more than one common trend, for example two, some prices could be generated by the first common trend, some by the second, and some by a combination of the first and second trends. Such markets are not considered fully integrated since the long-run movements in their prices are governed by more than one trend (Gonzalez-Rivera and Helfand 2001).

Before conducting the cointegration analysis, the stationarity properties of the data series must be checked to ensure that all of the price series are nonstationary and integrated to the same order. The Augmented Dickey-Fuller (ADF) test is widely used to test for the unit root of the series. The ADF test is generated from the following regression:

$$\Delta X_t = \delta + \rho X_{t-1} + \sum_{j=1}^{k} \phi_j \Delta X_t + e_t \qquad (1)$$

where the vector X represents the egg price series in six states: Arizona, California, Idaho, Nevada, Oregon, and Washington; t is the time index; $\Delta X_t = X_t - X_{t-1}$, and k is the lag order chosen such that $k / t^{1/3} \rightarrow 0$ as k and t $\rightarrow \infty$ and regression residuals behave as a white-noise series. δ is the deterministic part, which can be 0 (case 1), a constant (case 2), or a constant plus a linear time trend (case 3). The null hypothesis of ADF test is that the process has a unit root (nonstationary).

A nonstationary time series is said to be integrated to order 1, often denoted by I(1), if the series is stationary after first differencing. An (n x 1) vector time series Y_t is said to be cointegrated if each of the series taken individually is I(1) while some linear combination of the series $A'Y_t$ is stationary, or I (0), for some nonzero (n x 1) vector A (Hamilton, 1994).

The presence of an integrated market suggests that a set of prices for a common good in n distinct locations should possess only one common stochastic trend, or equivalently, should possess n-1 cointegrating vectors. Johansen's cointegration test is ideally suited to investigate such price linkages within a multivariate framework.

Consider a vector of n time-ordered variables X_t, where X_t follows an unrestricted vector autoregression (VAR):

$$X_t = \pi_1 X_{t-1} + \pi_2 X_{t-2} + \ldots + \pi_p X_{t-p} + \mu + \varepsilon_t \tag{2}$$

where each of the π_i is an n×n matrix of parameters, μ is a constant term, and ε_t are identically and independently distributed with zero means and a contemporaneous covariance matrix Ω.

The above VAR system can be written in error correction form (ECM):

$$\Delta X_t = \mu + \Pi X_{t-p} + \sum_{i=1}^{p} \Gamma_i \Delta X_{t-i} + \varepsilon_t \tag{3}$$

where $\Pi = \boldsymbol{I} - \pi_1 - \pi_2 - \ldots - \pi_p$, and $\Gamma_i = (\mathbf{I} + \pi_1 + \pi_2 + \ldots \pi_i)$, and p is chosen such that ε_t is a multivariate normal white noise process with mean 0 and a finite covariance matrix. The rank of Π, r, can be used to investigate the cointegration relationship. If $r = n$, the variables in levels are stationary; if $r = 0$, none of the linear combinations are stationary. When $0 < r < n$, there exist r cointegration vectors or r stationary linear combinations of X_t. The matrix Π can be factored as $\Pi = \alpha\beta'$, where both α and β are n×r matrices. β may be interpreted as the matrix of cointegrating vectors representing the long-run relationship, and α is the matrix for adjustment parameters.

Johansen suggests two test statistics to test the null hypothesis that there are at most r cointegration vectors in the system:

$$\lambda_{Trace} = -T \sum_{i=r+1}^{n} \ln(1-\hat{\lambda}_i) \tag{4}$$

$$\lambda_{Max} = -T \ln(1-\hat{\lambda}_{r+1}) \tag{5}$$

The first statistic is the trace test statistic and the second is for the maximum eigenvalue test. The alternative hypothesis is that there exist more than *r* cointegration vectors for the former while there are exactly *r* + 1 cointegration vectors for the latter. Each of the statistics of the two tests follows a non-standard distribution. Critical values are provided by Osterwald-Lenum (1992).

Johansen's multivariate test procedure also permits the hypothesis tests on the matrix of cointegrating vectors β, and the matrix of the adjustment parameters α. Based on Asche, Bremnes and Wessells (1999), testing the existence of perfect integration (LOP) among n markets is equivalent to testing whether the following equation is satisfied:

$$\beta = \begin{bmatrix} 1 & 1 & \dots & 1 \\ -1 & 0 & \dots & 0 \\ 0 & -1 & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \dots & -1 \end{bmatrix} \tag{6}$$

where β is an n × r matrix, n is the number of markets, and r is the number of cointegrating vectors. A test statistic is provided by Johansen which is Chi-square distributed under the null hypothesis.

The factor loading matrix α contains information about the dynamic adjustment of long-run relationships; we may also investigate whether a single price of a particular market drives all prices in the integrated market. A weak exogeneity test on the α matrix can accomplish this. The null hypothesis of weak exogeneity of the ith price is formulated as:

$$H_0\text{: } \alpha_{i1} = \alpha_{i2} = \ldots \alpha_{in} = 0 \tag{7}$$

where α_{ij} is the element in the ith row and jth column. In order to test whether the ith price series is weakly exogenous, we only need to test whether all of the parameters in the ith row of the α matrix are zeroes. A Chi-squre statistic can be used to test this hypothesis.

Data

The methods this paper adopted were applied to annual egg prices in six states of the Pacific area of the U.S. between 1960 and 1996. The states involved in egg production and consumption include Washington, Idaho, Oregon, Nevada, California, and Arizona. These data were published by the USDA National Agricultural Statistics Service in Agricultural Statistics. While production data are available on an annual basis, there are no direct consumption data. The state level consumption data were estimated on an annual basis from data on the state's population and per capita egg consumption (Agricultural Statistics). Eggs are perishable agricultural products and are not easy to transport over long distances, so it is more meaningful to study market integration within the specified geographical region than throughout the nation. California and Washington are large producers of eggs, whereas the other four states have relatively low productions of eggs.

The estimates of interstate trade among the six states are reported in Table 1. Annual price data over thirty-seven years are divided into two sub-periods, the period 1960-1977 and the period 1978-1996. Interstate trade in the first two columns was estimated by calculating the difference between a state's share of Pacific production and its share of Pacific consumption. Positive values indicate exports and negative values indicate imports. The last two columns show an index of self-sufficiency, which is defined as the ratio of a state's production share to its consumption share. A ratio close to one implies that a state is close to self-sufficiency. Table 1 shows that there exists trade among the states' egg markets within the Pacific area; California and Washington are the two major exporters while most of the deficit consumption is from Arizona and Nevada. The first condition for market integration—the existence of physical flows of goods among n locations--is satisfied.

Empirical Results

Before we can draw a conclusion of market integration, the second condition--the existence of one and only one common integrating factor of all series of prices--needs to be tested.

First of all, time-series properties of the price series in the six states were examined. Box-Cox transformations were applied to the six series of prices to determine whether price levels or natural log prices should be used. The results are ambiguous. Further investigation of the data showed that the problem of increasing variances for each price series could not be improved by the log transformation, so price levels were chosen for the Augmented Dickey Fuller and Johansen's cointegration tests.

The ADF unit-root test results are reported in table 2. All three cases (zero mean, non-zero mean, and linear trend) of equation (1) were considered since each price may or may not have a constant or a trend. The top portion of the table shows the unit root test on price levels. Test statistics and P-values of egg prices in each state indicate that the null hypothesis of unit root cannot be rejected at the 10% significance level, i.e., all the price series are nonstationary. The bottom portion of the table shows the unit root test on the first difference of prices. The unit root hypothesis in first differences is rejected for all of the prices. This means that all of the data series for each state are nonstationary in the levels but stationary in first differences at 10% significance level, i.e., the series are integrated to order one, I (1).

Knowing that the variables are integrated to the same order, we can proceed with Johansen's cointegration tests to find cointegrating vectors that posit non-spurious long-run relationships among the variables. The results of Johansen's cointegration rank tests with four lags are presented in Table 3. Lag order for the test was chosen by using the minimum value of Akaike's Final Prediction Error (FPE). All prices were normalized to the price in California. Trace tests and Max eigenvalue tests gave consistent results. The multivariate cointegration test results indicate that there are five cointegration vectors among six price series, and hence there exists one common stochastic trend in the system. We can conclude that there is one integrated egg market for the six states in the Pacific area. An economic interpretation would indicate some factor (e.g., arbitrage) that makes the prices in different locations move together over time. In other words, the eggs from the six states in the Pacific area are within the same market boundaries.

Given that the eggs throughout the Pacific area are found to be in the same market, the LOP can be tested. As discussed earlier, when equation (6) holds, the LOP is satisfied for the system. The test is distributed as Chi-square with 5 degrees of freedom and the p-value of the test is less than 0.0001. As a result, the null hypothesis of perfect integration is at any reasonable significance levels. Johansen's multivariate test indicates that although the development of egg prices in the six states within the Pacific area seem to be highly integrated in the long run during the period 1960-1996, they are not perfectly integrated in the sense that changes in prices are not proportionally transmitted.

Weak exogeneity test results are presented in Table 4. The tests are Chi-square distributed with 5 degrees of freedom. The null hypothesis of weak exogeneity cannot be rejected for the egg prices in Arizona, California, and Washington. This result indicates that Arizona egg prices, California egg prices, and Washington egg prices could play dominant roles in the Pacific egg market in the long run. This is reasonable because California and Washington are two major egg exporters and Arizona is major egg importer. Hence, they reasonably seem to have more autonomy in the price determination process.

Conclusion

In this article, Johansen's multivariate cointegration test was used to test market integration of the egg market in six Pacific states (Washington, Idaho, Oregon, California, Nevada, and Arizona). Johansen's multivariate testing procedure can provide valuable information about long-run linkages among agricultural markets. Bringing to bear Gonzalez-Rivera and Helfand's definition of market integration--an integrated market requires that the set of locations share a trade commodity and long-run information--we tested the second condition by the cointegration test applied within a multivariate framework.

Evidence is found that there are physical flows among the six Pacific states, which makes market integration possible. Results from Johansen's cointegration test indicate that there is one common stochastic trend in the six-market price series. However, the LOP is rejected. Transportation and other transaction costs may prevent the markets in the six states from being perfectly integrated in the short-run. Weak-exogeneity test results indicate that three individual egg markets, Arizona, California, and Washington, play dominant roles in price formation on the Pacific egg market, a conclusion supported by the fact that each of these states is either a major importer or exporter. No evidence is found that the egg market price formation is dominated by either supply or demand side.

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Table 1. Estimated Interstate Trade of Eggs in the Pacific Area.

	Trade[a] (Percent of Pacific Production)[a]		Index of Self-Sufficiency (Production/Consumption)	
State	1960-1977	1978-1996	1960-1977	1978-1996
Arizona	-3.721	-7.526	0.341	0.117
Nevada	-1.450	-2.706	0.038	0.006
Idaho	-0.258	-0.301	0.888	0.882
Oregon	-1.168	-0.572	0.819	0.919
Washington	0.394	1.408	1.038	1.121
California	19.204	7.975	1.316	1.115

a: Positive values indicate exports and negative values indicate imports.

Table 2. Unit Root Tests for Price Series

Price Series	Case 1		Case 2		Case 3	
	Statistics	P-value	Statistics	P-value	Statistics	P-value
Price Levels						
Arizona	0.145	0.722	-1.892	0.332	-2.899	0.175
California	0.710	0.864	-1.445	0.549	-2.743	0.227
Nevada	0.562	0.832	-1.729	0.409	-2.842	0.195
Idaho	-0.007	0.674	-2.596	0.103	-2.021	0.570
Oregon	0.593	0.839	-1.430	0.556	-3.006	0.145
Washington	1.208	0.939	-0.817	0.802	-3.066	0.130
First Difference of Prices						
Arizona	-5.688	0.000	-5.629	0.000	-5.541	0.000
California	-5.095	0.000	-5.172	0.000	-5.074	0.001
Idaho	-5.794	0.000	-5.851	0.000	-5.756	0.000
Nevada	-6.895	0.000	-6.799	0.000	-6.727	0.000
Oregon	-6.092	0.000	-6.143	0.000	-6.045	0.000
Washington	-5.514	0.000	-5.759	0.000	-5.743	0.000

Table 3. Multivariate Cointegration Test Results for Pacific Egg Prices

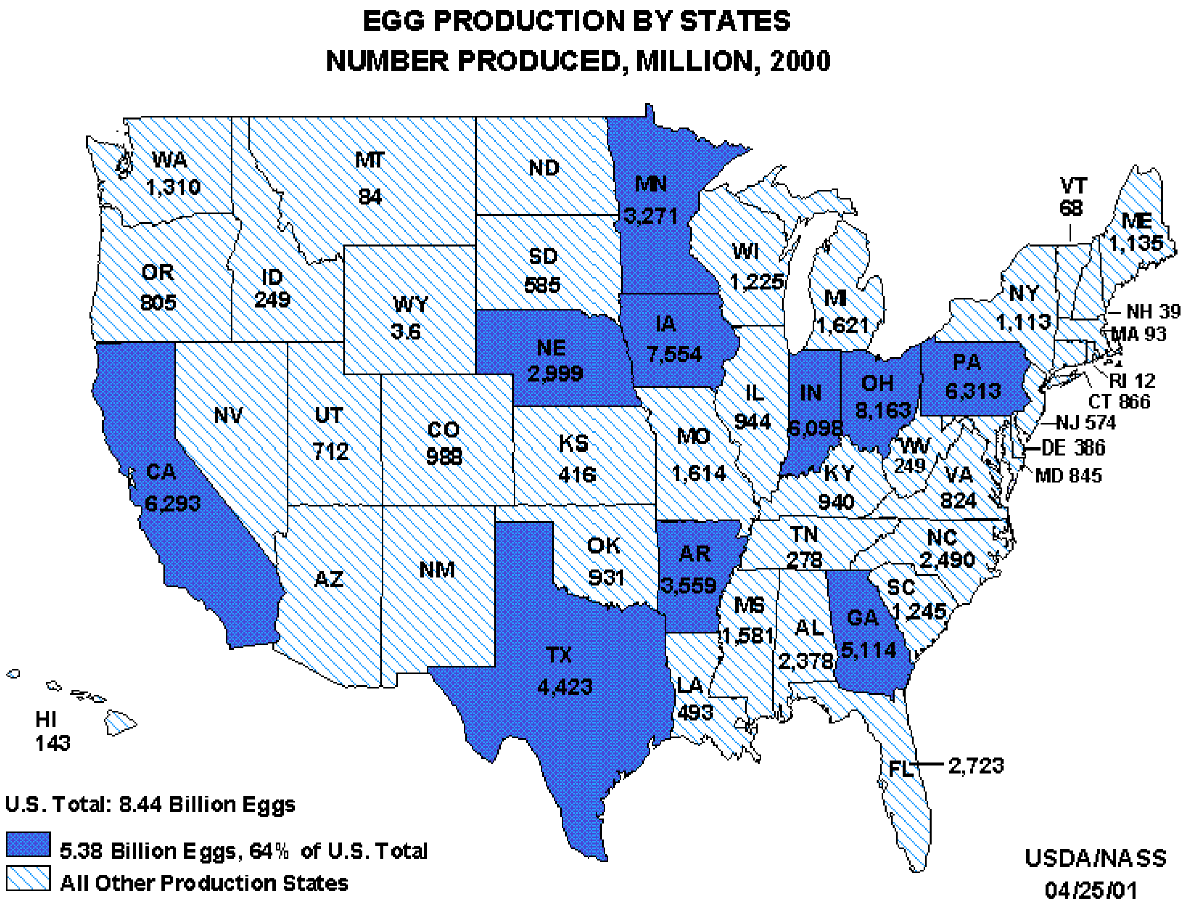
Null Hypothesis	Alternate Hypothesis	Cointegration Test Statistic	Critical Value
Trace Test			
H_0: r = 0	H_1: r > 0	256.64*[a]	93.92
H_0: r = 1	H_1: r > 1	162.66*	68.68
H_0: r = 2	H_1: r > 2	94.99*	47.21
H_0: r = 3	H_1: r > 3	53.59*	29.38
H_0: r = 4	H_1: r > 4	18.31*	15.34
H_0: r = 5	H_1: r > 5	2.98	3.84
Max Eigenvalue Test			
H_0: r = 0	H_1: r = 1	93.98*	39.37
H_0: r = 1	H_1: r = 2	67.67*	33.46
H_0: r = 2	H_1: r = 3	41.4*	27.07
H_0: r = 3	H_1: r = 4	35.28*	20.97
H_0: r = 4	H_1: r = 5	15.33*	14.07
H_0: r = 5	H_1: r = 6	2.98	3.76

a: An asterisk indicates rejection of the null hypothesis at the 0.05 significance level.

Table 4. Tests of Weak Exogeneity of Egg Price in Each State

State	Chi-square	DF	P-value
Arizona	6.86	5	0.231
California	6.62	5	0.250
Idaho	12.39*	5	0.030
Nevada	17.87*	5	0.003
Oregon	9.80*	5	0.081
Washington	6.35	5	0.274

Note: An asterisk indicates rejection of the null hypothesis at the 0.10 significance level.


EGG PRODUCTION BY STATES
NUMBER PRODUCED, MILLION, 2000
WA 1,310
MT 84
ND
MN 3,271
VT 68
ME 1,135
WI 1,225
OR 805
ID 249
SD 585
WY 3.6
MI 1,621
NY 1,113
NH 39
MA 93
IA 7,554
NE 2,999
PA 6,313
RI 12
CT 866
IL 944
IN 6,098
OH 8,163
NJ 574
NV
UT 712
CO 988
KS 416
MO 1,614
WV 249
DE 386
MD 845
CA 6,293
KY 940
VA 824
OK 931
AR 3,559
TN 278
NC 2,490
AZ
NM
MS 1,581
AL 2,378
GA 5,114
SC 1,245
TX 4,423
LA 493
HI 143
FL 2,723
U.S. Total: 8.44 Billion Eggs
5.38 Billion Eggs, 64% of U.S. Total
All Other Production States
USDA/NASS
04/25/01