Cointegration Tests of Spatial and Variety Price Linkages In Regional Dry Bean Markets

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Abstract

Two sets of cointegration tests were performed on regional dry bean prices. The results show (1) prices for the same variety were cointegrated across geographically separated production areas, and (2) prices for different varieties grown in the same production area were not cointegrated. Processors respond to the same export demand signals.

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The US dry edible bean industry has unique structural features that may impair the market's ability to allocate and signal. Edible beans are grown in geographically separated production regions; Southern Idaho, northeast Colorado, eastern North Dakota, Michigan, and western Nebraska-eastern Wyoming. While most edible bean varieties are generally production substitutes, due to specialization in processing and variety breeding programs, each production area is dominated by one or two varieties. In each production area there are a large number of farmers selling to a highly concentrated bean processor segment. Small processors or buyers and the even smaller grower cooperatives are confined to single production regions, while a few large processors have multi-region operations. Bean processors clean and package beans, and serve as the buyer to the farmer and serve as the seller to export market dealers.

The majority of edible beans are exported internationally into a volitile market. The major export markets in the Middle East, Mexico and Central America, and Africa are politically and economically unstable which translates into price uncertainty. Iraq is a major buyer of Great Northern beans. Mexico buys only Pinto beans. At the farm level, bean varieties are production substitutes. However, at the market level little variety substitution is evidence -- each export market is dominated by a specific variety. Neither price nor volume of beans destined to these export markets is publicly available information.

There is no futures market for edible beans. To substitute for clear and timely national prices established by a futures market, USDA reports the prices of transactions for the dominant varieties in each major production region. Price information gaps occur when even the major markets lack transactions. A significant proportion of beans are contracted prior to harvest to a specific processor and contract prices are not reported. Farmers thus have difficulty determining current and future prices for different bean varieties to make production and marketing decisions. Some of the uncertainty over the price of a particular variety in a specific market area could be reduced if there was information on how edible bean prices compare across production areas and among different varieties.

To narrow the focus, we investigate weekly grower prices for Pinto and Great Northern beans in Colorado, North Dakota, Idaho, and Western Nebraska - Eastern Wyoming. These prices were recorded by the United States Department of Agriculture, Livestock and Seed Division (USDA, 1983-1996). From September 7, 1983, to August 6, 1996, there are 665 weekly prices for each variety in each market. A few weekly prices were missing due to extremely low market transactions. In this case, we assume that prices stayed the same following the previously recorded week.

The objective of this paper is to analyze dry edible bean grower prices for selected varieties and production areas to determine the efficiency of the market. Tests for spatial market linkage will be conducted using cointegration analysis. Cointegration analysis will also be used to determine if the price for different varieties are cointegrated.

Two groups of cointegration tests are performed. The first group is to compare Pinto and Great Northern bean prices in the same market, i.e. in Idaho market and in Western Nebraska & Eastern Wyoming market. Since Pinto and Great Northern are almost perfect substitutes to producers, the cointegration test will show whether there is a vertical linkage between these two varieties.

The second group of cointegration tests is to decide spatial linkages for the same variety in different markets, such as Pinto in Colorado, Idaho, North Dakota, and Western Nebraska & Eastern Wyoming. Based on the definition of commodity arbitrage, the difference between each market's price for the same commodity should be equal to transportation costs and other fixed costs. If not, this may be the evidence of market power on the part of the processors some geographic markets.

Theoretical Framework of Cointegration

One of the basic assumptions made in econometric modeling is the concept of stationarity. A time series is stationary if the series mean, variance and autocovariances are independent of time. Suppose y_t is a time series (or stochastic process) defined for t = 1,2,… and for t = 0,-1,-2,… . Formally y_t is covariance (weakly) stationary if the following conditions are satisfied (Rao, 1994):

$$E(y_t) = \mu \qquad (1)$$

$$E\left[(y_t - \mu)^2\right] = \operatorname{var}(y_t) = x(0) \qquad (2)$$

$$E\left[(y_t\ -\ \mu)(y_{t-\tau}\ -\ \mu)\right]\ =\ \operatorname{cov}(y_t\ ,\ y_{t-\tau})\ =\ x(\tau),\ \ \tau = 1,2,... \qquad (3)$$

A non-stationary series mean, variance, and covariance are changing over time, so that standard *t* tests in regression are no longer valid (Karbuz and Jumah, 1995). Holden and Perman (Rao, 1994) derived a relationship between stationarity and the existence of a unit root. Dickey and Fuller (1979 and 1981) demonstrated that if under the null hypothesis that a series has a unit root (i.e., if the series is nonstationary), then the t statistics for parameter estimates in a regression is not distributed as a Student t any more.

If a series follows the first order autoregressive process (AR(1)), for example:

$$y_t\ =\ \rho\, y_{t-1}\ +\ e_t\ ,\ \ t = ...,-1,0,1,.... \qquad (4)$$

where e_t is assumed to define a sequence of independently and identically distributed (*IID*) random variables with expected value zero and variance σ^2. The process in equation 4 is stationary when ρ is less than one in absolute value; i.e., -1 < ρ < 1. The AR(1) process has a unit root if and only if ρ is one, then the AR(1) process is non-stationary (Rao, 1994).

Most price series exhibit variation that increases in both the mean and the dispersion in proportion to the absolute level of the series. Much as the application of the difference operator frequently removes a time-dependent mean, but has little effect on stabilizing the variance of empirical time series. Cryer (1986) argues that, if the standard deviation of a series is proportional to its level, then the data expressed in terms if logarithms will exhibit approximately constant variance. Given that most empirical time series are integrated of order one, that is, require first differencing to remove time dependence in the mean, a useful result emerges when the difference and the logarithmic transformations are combined. This transformation also leads to the loss of long-run properties and the inability to obtain a long-run solution.

Granger (1981, 1991), Granger and Weiss (1983), and Engle and Granger (1987) have shown that, even though a given set of series may be non-stationary, there may exist various linear combinations of the individual series that are stationary. The desire to estimate models that combine both short-run and long-run properties and that at the same time maintain stationarity in all of the variables, has prompted a reconsideration of the problem of regression using variables measured in their levels. Cointegration is a statistical framework to test for long-run or steady-state equilibrium relationships among several non-stationary series.

The formal definition of cointegration of two variables developed by Engle and Granger (1987) is as follows:

Define: Time series x_{1t} and x_{2t} are said to be cointegrated of order d, b, where d ≥ b ≥ 0 written as

$$x_{1t}\ ,\ x_{2t} \ \sim\ CI(d\ ,\ b) \quad \text{if}$$

1. both series are integrated of order *d*,

2. there exists a linear combination of these variables, say $\alpha_1 \times x_{1t} + \alpha_2 \times x_{2t}$, which is integrated of order (d-b).

The vector [$\alpha 1$, $\alpha 2$] is called a cointegrating vector. If there is a long-run relationship between two (or more) nonstationary variables (all integrated of the same order), the idea is that deviations from this long-run path are stationary if the variables are to be cointegrated.

Cointegration Tests of Spatial Price Relationship

Spatial market integration necessarily imply a unique long-run equilibrium relationship in which deviations from regional price parity are forced to zero (Goodman and Schroeder, 1991). Pinto and Great Northern beans are perfect substitutes for the former in regional production. The two varieties can be planted with identical management practices and schedule. There is little costs to farmers when shifting between Pinto and Great Northern beans. Differences in Pinto or Great Northern prices in different markets should be exactly equal to transportation costs plus other constant costs. As for the two varieties in the same market, producers might expect two price series to follow each other closely since they act like substitutes.

Consider two price series in the following regression:

$$p_t^1 - \alpha - \beta p_t^2 = u_t \tag{5}$$

where p_t^1 and p_t^2 represent Pinto prices in two markets. Existence of perfectly spatially integrated markets (where price changes in one market are fully reflected by equilibrating changes in alternative market) necessarily requires that the estimated parameter of the cointegrating regression, $\hat{\beta}$, have a value of one. However, because the price series p_t^1

and p_t^2 are nonstationary in a cointegrated system, conventional t-test cannot be used to provide reliable hypothesis tests regarding the value of $\hat{\beta}$.

We adapt four testing procedures suggested by Engle and Granger (1987) for cointegration. They also provided critical values for a sample of 100 observations based on the results of Monte Carlo simulations for each proposed test statistics. Null hypothesis for each test is "no cointegration". Rejection of null hypothesis affirms integrated prices in regional markets with this case study.

1. The Co-integrating Regression Durbin Watson: $y_t = \hat{\alpha} x_t + \mathrm{c} + \hat{\mathrm{e}}_\mathrm{t}$ (6)

$$\text{Test Statistic } = DW = \left(\sum_{t=2}^{T} (\hat{e}_t - \hat{e}_{t-1})^2 \right) \Big/ \left(\sum_{t=1}^{T} \hat{e}_t^2 \right)$$

y_t and x_t are two price series. The null hypothesis of no cointegration is rejected for values of DW significantly different from zero.

2. Dickey Fuller Regression: $\Delta \hat{e}_t = -\phi \hat{e}_{t-1} + \hat{\varepsilon}_\mathrm{t}$

where $\hat{e}_t$ is defined in equation 6 and Δ is the first difference.

Test Statistic : τ_ϕ (the t statistic for ϕ)

This testing procedure considers whether the autoregressive parameter for the estimated residuals from the cointegrating regression (ϕ) is significantly different from one. If there is a unit root, then the two series are not cointegrated. The null hypothesis of no cointegration is rejected for values of ϕ which are significantly different from zero. Critical values are provided by Engle and Granger (1987).

3. Restricted VAR: $\Delta y_t = \hat{\beta}_1 \hat{e}_{t-1} + \varepsilon_{1t}$, $\Delta x_t = \hat{\beta}_2 \hat{e}_{t-1} + \hat{\gamma}\, \Delta y_t + \varepsilon_{2t}$ (7)

Test Statistic: $\tau^2_{\hat{\beta}_1} + \tau^2_{\hat{\beta}_2}$ (the sum of two t-statistics for $\hat{\beta}_1$ and $\hat{\beta}_2$)

This test involves the estimation of a vector error correction mechanism for the cointegrating regression. It bases on the joint significance of the error correction coefficients ($\hat{\beta}_1$ and $\hat{\beta}_2$). This test explains that a cointegrated set of variables can be equivalently expressed as an error correction model in (7). If $\hat{\beta}_1$ and $\hat{\beta}_2$ are jointly different from zero, the null hypothesis of no cointegration is rejected. Critical values are provided by Engle and Granger (1987).

4. Unrestricted VAR:

$$\Delta y_t = \hat{\beta}_1 y_{t-1} + \hat{\beta}_2 x_{t-1} + \hat{c}_1 + \hat{\varepsilon}_{1t} \quad (8)$$

$$\Delta x_t = \hat{\beta}_3 y_{t-1} + \hat{\beta}_4 x_{t-1} + \gamma \Delta y_t + \hat{c}_2 + \hat{\varepsilon}_{2t} \quad (9)$$

Test Statistics: $2[F_1 + F_2]$ where F_1 is the F statistic for testing $\hat{\beta}_1$ and $\hat{\beta}_2$ both equal to zero in (8), and F_2 is the F statistic for testing $\hat{\beta}_3$ and $\hat{\beta}_4$ both equal to zero in (9).

The last test procedure utilize a vector autoregression which is not constrained on satisfying the cointegration constraints. The null hypothesis of no cointegration is rejected if parameters $\hat{\beta}_1$ and $\hat{\beta}_2$ from (8) and $\hat{\beta}_3$ and $\hat{\beta}_4$ from (9) are jointly, significantly different from zero. A failure to reject the null hypothesis indicates the lack of a statistically significant relationship between current changes and past values of the economic variables. It implies a general failure of cointegration between variables (Goodwin and Schroeder, 1991; Engle and Granger, 1987).

Empirical Results

Table 1 provides the testing results for Pinto prices versus Great Northern prices in two markets: Western Nebraska & Eastern Wyoming, and Idaho. Pinto prices and Great Northern prices do not show any statistically significant cointegration in any market from all the tests. Since Pinto and Great Northern can be planted and managed in the similar way, farmers can shift easily between two varieties based upon price expectations. However, harvest prices and prices throughout the storage period are influenced by foreign demands from two independent markets. Therefore supply is basically set at planting, but demand for each variety can change throughout the year. Historical records show that Pinto prices have more seasonal variabilities comparing to Great Northern prices, and two price series act independently in the same market (Liang et.al. 1997). Our test results confirm that two price series are independent. Pinto and Great Northern prices are not cointegrated in Western Nebraska & Eastern Wyoming market, or in Idaho markets.

Table 2 lists the test results for Pinto prices in four markets, and Great Northern prices in two market. Pinto prices in four regional markets are significantly cointegrated, and the same conclusion applies to the Great Northern prices in two regional markets. When Pinto or Great Northern price goes up in one of the regional markets, farmers should expect to see prices increase in all of the markets. Each bean variety possesses a strong integrated relationship among different markets.

Summary and Implications

This research demonstrated that dry edible bean prices for the same variety were cointegrated across geographically separated production areas. Price for the same variety are cointegrated across markets as processors are responding to the same export demand signals. However, prices for different varieties grown in the same production area are not cointegrated. Supply potential for each variety is first determined at planting and finally decided in the yield at the end of the growing season. However, demand can and does change throughout the year and can vary substantially from year to year. Therefore, producers may rationally respond to prices at planting time by planting more of the higher priced variety, but due to fluctuations in demand this may or may not be the higher priced variety at harvest or into the storage period. It would appear that there are long periods of time when the prices of two varieties, that are production substitutes, may differ substantially. However, there long term average price level appears to be about equal (Liang, et.al., 1997).

Table 1. Cointegration Tests on Pinto Prices vs. Great Northern Prices in Different Markets

Market	Test	Test Statistics	Critical Value (Type I Error=1%)	Decision
W.Nebraska & E.Wyoming	DW	0.028	0.511	Accept Null
	DF	2.081	4.070	Accept Null
	VAR	4.341	18.300	Accept Null
	UVAR	20.378	23.400	Accept Null
Idaho	DW	0.022	0.511	Accept Null
	DF	1.919	4.070	Accept Null
	VAR	4.895	18.300	Accept Null
	UVAR	57.888	23.400	Reject Null

Table 2. Cointegration Test on Pinto and Great Northern Prices in Different Markets

Variety	Markets	Test	Test Statistic	Critical Value (Type I Error=1%)	Decision
Pinto	Idaho vs. Colorado	DW	1.182	0.511	Reject Null
		DF	16.728	4.070	Reject Null
		VAR	582.808	18.300	Reject Null
		UVAR	642.028	23.400	Reject Null
	Colorado vs. North Dakota	DW	0.589	0.511	Reject Null
		DF	10.647	4.070	Reject Null
		VAR	122.542	18.300	Reject Null
		UVAR	749.746	23.400	Reject Null
	Colorado vs. Nebraska*	DW	1.942	0.511	Reject Null
		DF	25.012	4.070	Reject Null
		VAR	739.077	18.300	Reject Null
		UVAR	835.618	23.400	Reject Null
	Idaho vs. North Dakota	DW	1.092	0.511	Reject Null
		DF	15.725	4.070	Reject Null
		VAR	352.419	18.300	Reject Null
		UVAR	338.746	23.400	Reject Null
	Idaho vs. Nebraska	DW	0.897	0.511	Reject Null
		DF	13.925	4.070	Reject Null
		VAR	237.809	18.300	Reject Null
		UVAR	647.142	23.400	Reject Null
	North Dakota vs. Nebraska	DW	1.233	0.511	Reject Null
		DF	17.184	4.070	Reject Null
		VAR	292.718	18.300	Reject Null
		UVAR	278.576	23.400	Reject Null
Great Northern	Nebraska vs. Idaho	DW	0.308	0.511	Accept Null
		DF	7.295	4.070	Reject Null
		VAR	56.583	18.300	Reject Null
		UVAR	144.856	23.400	Reject Null

*Note: Nebraska market covers Western Nebraska and Eastern Wyoming.

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