An Analysis of Cointegration: Investigation of the Cost-Price Squeeze in Agriculture

Jody L. Campiche
Agricultural and Food Policy Center
Department of Agricultural Economics
2124 TAMUS
Texas A&M University
College Station, TX 77843-2124
jcampiche@afpc.tamu.edu

Henry L. Bryant
Agricultural and Food Policy Center
Department of Agricultural Economics
2124 TAMUS
Texas A&M University
College Station, TX 77843-2124
h-bryant@tamu.edu

James W. Richardson
Agricultural and Food Policy Center
Department of Agricultural Economics
2124 TAMUS
Texas A&M University
College Station, TX 77843-2124
jwrichardson@tamu.edu

Joe L. Outlaw
Agricultural and Food Policy Center
Department of Agricultural Economics
2124 TAMUS
Texas A&M University
College Station, TX 77843-2124
joutlaw@tamu.edu

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Abstract

The differences in prices paid and prices received by farmers are examined using cointegration analysis. A Johansen cointegration test between prices paid and prices received revealed that the series were cointegrated. After accounting for technological change, we do not reject a long-run one-for-one correspondence between prices paid and prices received.

***Keywords**: Cointegration, Inflation, Prices Paid, Prices Received, Cost-Price Squeeze*

***JEL Codes**: C3, E0, Q1*

Introduction:

Since the 1970's, the effect of macroeconomic variables on agriculture has been a concern for economists. The concern is that inflation is much more apparent in prices paid by farmers than prices received by farmers and has resulted in a declining ratio of prices received to prices paid (cost-price squeeze). The cost-price squeeze theory says that when inflation is present, prices paid by farmers increase more than prices received by farmers (Tweeten and Griffin, 1976). Farmers are hypothesized to face rising costs for farm inputs while experiencing a much slower increase in prices received for their output. Inflation, as defined as an increase in the general price level, may have a minimal effect on farm income when prices received and prices paid by farmers increase proportionately. However, it is unlikely that all prices will increase in the same proportion.

Previous research has examined the impact of inflation on prices received and prices paid by farmers. Tweeten (1980) found that general inflation changes the ratio of prices received to prices paid by farmers because it impacts unevenly on the supply and demand curves for farm output. Tweeten and Griffin (1976) define inflation pass through as the portion of the increase in prices paid by farmers that is actually "passed on" in the form of higher prices received by farmers due to reduced input-use and output. Farmers are price-takers and have no direct means to pass higher input costs on to consumers (as can many firms producing farm inputs) so they must adjust their input use and output as the ratio of prices received to prices paid declines (Tweeten, 1980).

Tweeten (1980) reported that at high inflation rates, a cost-price squeeze is imposed on the farm sector since prices paid by farmers increase considerably faster than the inflation rate and only half of the increased cost is "passed on." Input-price inflation lowers output and results in higher prices received by farmers. Gardner (1981) found the same results as Tweeten (1980) when he examined the effect of inflation on prices received and prices paid by farmers without including any macroeconomic variables. However, when Gardner (1981) added additional macroeconomic variables to the model, he found that inflation did not have a direct effect on the cost-price squeeze.

Moss (1992) used cointegration analysis to determine if prices received and prices paid move together in the long-run. Moss (1992) defined cointegration as “the tendency of time series to move together in the long-run and implies a long run relationship between variables.” He found that prices paid and prices received by farmers were not cointegrated, which implied that a cost-price squeeze could not be rejected in the long-run. According to Engle and Granger (1987), if prices received and prices paid are cointegrated, a cost-price squeeze would not be present in the long-run.

The purpose of this study is to examine the relationship between prices paid and prices received by farmers using more recent data and cointegration techniques than used previously. As an extension of previous work completed in the area of inflation pass through for agriculture, we also analyze the response of prices paid and prices received to deviations from their long-run equilibrium relationship.

Data

The indexes of prices paid (PP) and prices received (PR) by farmers used in this study are the USDA quarterly average prices between the first quarter of 1973 and the third quarter of 2005. The data for PP and PR for 1973-1988 was taken from the United States Department of Commerce’s *Business Statistics* 1961-1988 (which is compiled from United States Department of Agriculture (USDA) National Agricultural Statistics Service) and the 1989-2005 data was collected from various issues of USDA’s *Agricultural Prices*. The index of prices paid by farmers measures the changes that occur in the level of prices paid by farmers and their families for family living expenses, production expenses, taxes, interest, and wage rates. The index of prices received by farmers is based on estimates of prices received for all commodities sold by producers to first buyers (point of first sale). The gross domestic product (GDP) and personal consumption expenditures component (PCEPI) of the implicit gross domestic product deflator are seasonally adjusted annual levels for each quarter from the Bureau of Economic Analysis from 1973-2005. The GDP measures the total value of all goods and services produced in the economy and is used as a measure of the total domestic output. The GDP implicit price deflator is a quarterly price index calculated by dividing nominal GDP by real GDP. It accounts for the effects of inflation, by reflecting the change in the prices of the bundle of goods that make up the GDP as well as changes to the bundle itself. The personal consumption expenditures price index is a nation-wide indicator of the average increase in prices for all domestic personal consumption and is used in this study as a measure of the general price level. The money supply (MS) is measured by the adjusted monetary base from the Federal Reserve Bank of Saint Louis.

Cointegration Model

Several methods are available to test for cointegration between variables. Two commonly used techniques are the Johansen approach and the Engle Granger approach. The Engle Granger approach is widely used in testing for cointegration in single equations. However, according to Harris (1995), when more than 2 variables are included in the model, more than one cointegration vector may be present. Using the Engle Granger approach, we can only show that a cointegration vector is unique when 2 variables are included in the model. If we assume that only one cointegration vector is present and more than one exists, we would not be able to obtain a valid estimate of the long-run relationships between the variables in the model. The estimation of a single equation, even when only one cointegration relationship exists, is inefficient because it does not result in the minimum variance against alternative methods (Harris, 1995).

The Johansen approach involves a multivariate autoregressive model that provides a method of estimating multiple cointegration relationships (Johansen (1988), Johansen and Juselius (1990)). We used the following model in vector error-correction form:

(1) $\Delta \mathbf{z}_t = \boldsymbol{\Gamma}_1 \Delta \mathbf{z}_{t-1} + \ldots + \boldsymbol{\Gamma}_{k-1} \Delta \mathbf{z}_{t-k+1} + \boldsymbol{\Pi} \mathbf{z}_{t-k} + \mathbf{u}_t$

The vector $\mathbf{z}_t$ is defined as a vector of *n* possible endogenous variables and models $\mathbf{z}_t$ as an unrestricted vector autoregression model including k-lags of $\mathbf{z}_t$. The estimate of $\boldsymbol{\Gamma}_i$ measures the short-run adjustment to changes in $\mathbf{z}_t$, while $\boldsymbol{\Pi}$ contains information on the long-run adjustment to changes in $\mathbf{z}_t$. Testing for cointegration involves testing the rank of $\boldsymbol{\Pi}$. If $\boldsymbol{\Pi}$ has full rank, the variables are stationary. If the rank of $\boldsymbol{\Pi}$ is zero, no cointegration relationships are present. If $\boldsymbol{\Pi}$ has reduced rank, we can divide $\boldsymbol{\Pi}$ into $\boldsymbol{\Pi} = \boldsymbol{\alpha\beta}'$, where $\boldsymbol{\alpha}$ represents the speed of adjustment and $\boldsymbol{\beta}$ is a matrix of long-run coefficients. Since this study included the analysis of more than 2 variables, along with the possibility of multiple cointegration relationships, the Johansen approach was utilized. A multivariate model was estimated to determine if prices received or prices paid by farmers are cointegrated with each other or with the money supply, gross domestic product, or the general price level.

Cointegration methods are useful when time series data are non-stationary and conventional econometric methods would encounter the problem of spurious regression (Harris, 1995). Spurious regression may appear to indicate significant long-run relationships between variables, when it is actually not the case. Therefore, the first step in the Johansen approach is to determine which variables are stationary and non-stationary in levels. For this study, the

Augmented Dickey-Fuller Test (ADF) developed by Dickey and Fuller (1979, 1981) and Said and Dickey (1984) was used to test each variable for a unit root. The null hypothesis of a unit root is rejected if the variable is stationary.

To determine if cointegration relationships exist between the variables, the cointegration rank (r) must be determined. The *Cats* programming package was used to determine the cointegration rank by examining the eigenvalue matrix. Johansen proposes two methods for determining the cointegration rank, the λ_{max} test and the trace test. For this study, to test the null hypothesis that there are r cointegration vectors, we use the λ_{max} statistic:

(2) $\lambda_{max} = -T \log (1 - \lambda_{r+1})$ $r = 0, 1, 2, \ldots, n\text{-}2, n\text{-}1$

where T is the sample size and λ_{r+1} is the eigenvalue corresponding to r + 1 cointegration vectors. We are testing the null hypothesis that r cointegration vectors are present against the alternative that r + 1 cointegration vectors exist. We fail to reject the null hypothesis, H_o: r when the λ_{max} statistic is less than the critical value. After finding the number of cointegrating vectors, the lag length must be determined. The Schwartz Information Criteria (SIC) was used to find the lag length based on 3 cointegration vectors.

Once the cointegration rank and number of lags was estimated, the next step in the cointegration analysis was to conduct hypotheses testing. In *Cats*, this involved testing linear restrictions on the cointegration space by inputting restrictions on each of the $\boldsymbol{\beta}$ vectors. In this research, we find a set of unique cointegrating vectors, corresponding to a set of restrictions on $\boldsymbol{\beta}$ that are not rejected using a likelihood ratio test.

After determining the appropriate cointegrating relationships, tests for weak exogeneity were conducted. To test for weak exogeneity, we tested the hypothesis that $\boldsymbol{\alpha}$ was equal to zero by placing row restrictions on $\boldsymbol{\alpha}$. The likelihood ratio test based on the χ^2 distribution was used to determine if the joint restrictions on $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ were valid. If a row of $\boldsymbol{\alpha}_{ij}$, $j = 1, \ldots, r$, contains all zeros, the cointegration vectors in $\boldsymbol{\beta}$ do not enter the equation determining $\mathbf{z}_t$ (Harris, 1995). The variable is weakly exogenous to the system and does not respond to changes in the long-run relationship. The non-zero columns of $\boldsymbol{\alpha}$ include information on the speed of the short-run adjustment to disequilibrium and which cointegration vectors enter each short-run equation (Harris, 1995). The amount of time required for the adjustment can be calculated by the following equation for the half life (Osbat, Ruffer, and Schnatz, 2003):

(3) $\text{half life} = \log (0.5) / \log (1- \boldsymbol{\alpha}_{ij})$

Results

The results of the ADF tests are shown in table 1. The tests do not reject the hypothesis of a unit root with non-differenced data. However, all series are stationary in first differences. Therefore, each variable is integrated of order one, I(1), and can be tested for cointegration. Based on the results of the cointegration rank test (as shown in table 2), there are 3 cointegration vectors. A single lag is used in the vector error-correction model, as this maximized the SIC.

A set of unique cointegrating vectors was identified that were not rejected by a likelihood ratio test (table 3). Results of the first cointegrating vector indicate that cointegration between prices received and prices paid cannot be rejected. Therefore, prices received and prices paid move together in the long run. These results are not completely consistent with previous findings. Moss (1992) found that prices received and prices paid were not cointegrated when interactions with other variables were omitted, so that a cost-price squeeze could not be rejected in the long-run. Moss (1992) did find cointegration between price paid and prices received when he included additional macroeconomic variables. However, results of this study indicate that prices received and prices paid move together in the long run in the absence of other macroeconomic variables. Tweeten (1980) found that inflation contributed to the cost-price squeeze in agriculture, or that an increase in the general price level causes an increase in prices paid by farmers.

However, results of this study show that prices paid do not adjust to changes in the general price level. Instead, the general price level adjusts to changes in prices paid, or the costs of production. In addition to the unique cointegrating relationships, the tested restrictions imply that PP is a weakly exogeneous variable. Therefore, PP does not adjust to changes in the other variables in the model. Tests for weak exogeneity were rejected for all other variables in the model. The first term in **α**, -.244, represents the short-run adjustment of prices received towards the first long-run cointegration relationship. Following a shock to the system, the half-life of deviations from prices received is 2.5 quarters, which means that prices received adjust rather quickly to changes in prices paid.

The magnitude of the TREND variable in the first cointegrating vector indicates that prices received and prices paid move together in a one-to-one relationship after accounting for improvements in technology and efficiency gains. Therefore, all of the increase in prices paid by producers of average efficiency is "passed on" in the form of higher prices received due to restricted input use and output. Based on the speed of adjustment parameter, full inflation pass through is complete in seven and a half months. Tweeten and Griffin (1976) found that during periods of high inflation rates and a free market, only half of the increased cost is passed on. In a later study, Tweeten (1980) found that almost three fourths of the increased cost is passed on in the form of higher prices received by farmers.

Results of the second cointegrating vector indicate that MS, PCEPI, and GDP are cointegrated in the long-run. This result can be explained by examining the relationship between the MS, PCEPI, and GDP. The money supply is related to the overall price level by the equation of exchange in the quantity theory of money. The money supply times the constant velocity of money equals the average price level times real output (or nominal GDP). The equation of exchange can be used to show that the average price level increases with the quantity of money. An increase in the money supply shifts the aggregate demand curve to the right and results in a higher price level. Changes in the money supply result in equal percentage changes in nominal GDP. Therefore, as the money supply increases, nominal GDP will increase, resulting in an increase in the GDP deflator. If the money supply increases too quickly, inflation occurs since an increase in money relative to a fixed number of consumable goods and services results in rising prices.

As indicated by the third cointegrating vector, PP and PCEPI (general price level) move together in the long-run. This implies that the cost of producing agricultural goods (which should be closely related to the cost of producing other consumer goods) is a driving force for the general price level. Therefore, both the general price level and prices received are affected by the same underlying force, the price of productive inputs.

Conclusion:

The main objective of this study was to determine if a cost-price squeeze is present in agriculture and to determine the level of inflation pass through present in agricultural prices. It was hypothesized that prices received and prices paid by farmers were not cointegrated and that a cost-price squeeze could not be rejected in the long-run. However, based on the results of the cointegration analysis, the null hypothesis of cointegration between prices paid and prices received could not be rejected in the long run. After accounting for technology improvements and efficiency gains, prices paid and prices received move together in a one-to-one ratio in the long-run, and cost increases pass through in under eight months on average.

Additional research needs to be completed using individual commodity price indexes. For this study, highly aggregated data was used in the cointegration analysis. The prices paid index includes all commodities while the prices received index includes all production items. It may be possible to obtain more accurate estimates of the relationships between prices paid and prices received using price data for individual commodities. The extent and rate of inflation pass through may be more or less for individual agricultural commodities.

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Table 1. Unit Root Tests

Table 1: Unit root tests
Sample 1973:01 1995:03

Variable (X) (including trend)	Unit Root in Non-Differenced Data ADF	Unit Root with 1 Difference ADF
PR	-2.152	-22.418*
PP	-2.640	-8.338*
MS	-0.540	-15.712*
PCE	-2.146	-5.614*
GDP	-2.752	-3.818*

Significant at 5% level (*)
Critical values for rejection of hypothesis of unit root at 5% level
-3.423 for trended PR, PP, MS
-3.445 for trended PCE, GDP

Table 2. Cointegrating Rank

Eigenvalue Results		
λ_{max} Test Statistic	Ho: r	Critical Value
104.8	0	20.90
34.27	1	17.14
16.45	2	13.39
9.53	3	10.60
1.76	4	2.71

r is the maximum number of cointegrating vectors
Fail to reject Ho when test statistic < critical value

Table 3. Cointegration Results

The LR Test		ChISQ(7) = 4.85		p-value = .68		
Beta (transposed)						
PR	PP	MS	PCEPI	GDP	Trend	
1.000	-1.000	0.000	0.000	0.000	12.172	
0.000	0.000	1.000	103.066	-102.165	0.000	
1.000	0.000	0.000	-8.241	0.000	-10.053	
Standard Errors for Beta (transposed)						
PR	PP	MS	PCEPI	GDP	Trend	
0.000	0.000	0.000	0.000	0.000	0.516	
0.000	0.000	0.000	27.435	28.116	0.000	
0.000	0.000	0.000	1.656	0.000	1.159	
Alpha						
T-values						
PR	-0.244	0.002	-0.176	-3.876	0.070	-3.440
PP	0.000	0.000	0.000	0.000	0.000	0.000
MS	-0.003	-0.001	-0.016	-0.305	-0.144	-2.209
PCEPI	0.003	0.000	0.002	5.156	-1.147	4.705
GDP	0.002	0.000	0.003	4.365	1.703	6.365