A Necessary Condition for Market Integration Tests: The Case of the U.S. Broiler Industry

by

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Abstract:

Most studies on price relationships in spatial markets assume that perfect information is a public good. However, during the last two decades, the food industry in the U.S. has experienced a dramatic structural change, as have the structures of commodity markets; this is especially the case in the broiler industry. Tests for the presence of market integration are conducted within the framework of Neo-classical theory of the firm. Grower costs and transportation in five southern U.S. broiler states (AL, AR, GA, MS, NC) are considered in deriving necessary conditions before any conclusion on market integration is reached. Using both parametric and nonparametric tests, this study found that all price pairs have a long-run price relationship and markets are therefore integrated.
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Background:

Price relationships of agricultural commodities in different markets have been an important area of research among agricultural economists (Spiller and Huang; John Baffes; Sexton et al; Goodwin; Baulch; McNew and Fackler). Some have argued that the uniform price hypothesis holds for competing products under the assumption of perfect competition, no trade barriers and no transportation cost in spatial markets even if products are produced at different locations. Goodwin (1992) found that the law of one price (LOP) fails as a long-run equilibrium relationship in the U.S. wheat market when transportation costs are ignored. Baulch (1997) examined the validity of four well-known procedures such as the LOP, Ravallion tests, reintegration and Granger causality procedures to test the uniform price hypothesis. He conducted a series of Monte Carlo experiments and found that all tests are statistically flawed.

Several other studies measured market integration with the presence of arbitrage. These studies suggest that two different markets fail to perfectly integrate if one player in the market is able to construct two portfolios from each market which yield identical payoffs but with different prices. Secondly, it was argued that the price series in spatial markets can not be integrated in a stronger sense with the existence of cross-market arbitrage opportunities.

In general, past studies found the presence of market integration in different markets. However, conflicting results are also found. The probable source of such differences could come from failures to fully understand distinct characteristics such as production and marketing practices found in a specific market for a specific commodity, the presence of transaction as well as transportation costs (Goodwin; Baffes), the possibilities of arbitrage, the nature of information found in the market, or perhaps due to the dynamic nature of the data.

Most studies on price relationships at different markets assume that perfect information is a public good. However, during the last two decades, not only has the structure of the U.S. food industry experienced a dramatic structural change, but also the structure of commodity markets.
This is especially the case in the broiler industry. Recent industry studies showed that in 1997 the top four broiler integrators accounted for about 44 percent of U.S. broiler production (Murray, 1999). Davis et al (1999) argued that the U.S. broiler industry is characterized by a small number of large and vertically integrated firms that coordinate about ninety five percent of broiler production in the U.S. He further argued that the vast majority of broiler in the U.S. are raised under contracts. Under such production practices, broiler growers provide housing, equipment and labor to raise integrator-owned broilers to a pre-specified weight. Broiler integrators provide feed, veterinary services and other supplies. In most cases, the integrators also own feed mills, hatcheries, slaughter and processing plants. Given developments that have occurred in the industry (more integrated in both production and marketing practices), market integration studies are important and may provide useful information to market players.

U.S. broiler production is concentrated in the southern region, Arkansas and Georgia being the two largest producers. The modern broiler industry is recognized by its vertical integration and product differentiation (Murray, 1999; Martinez, 1999). The presence of vertical integration in the industry is well-documented, but specific issues relating to this integration, such as firm concentration and market dominance, have become more prominent in recent years (Davis, et al, 1999). The concentration ratio for the four largest firms went from 28 percent in 1980 to 51 percent in 1997. This recent increase is due to both efficiency and company buy-outs, merger and acquisition and strategic alliances. In recent studies, Martinez argued that positive effects out weighted negative effects of market contracts and vertical integration. Among others, are increased broiler supplies, reduced prices for chicken products, and improved product quality and consistency.

Total value of broiler sales in the U.S. has increased tremendously, from $1,014 million in 1960 to $19,394 million in 1997 (Broiler Industry, 1997). The increase in dollar value of broiler sales reflects increasing concerns for human health, convenience and real and perceived product value. For example, during the period 1965 -1996, annual per capita consumption of chicken has increased from just over 30 pounds to 75 pounds; during the same period red meat consumption,
particularly beef, decreased from 85 pounds to near 60 pounds (USDA/ERS report). Given the large increase in the value of broiler sales as shown in Figure 1, identifying and analyzing market integration in different broiler markets in the U.S. will give important contribution to the industry.

The broiler industry in top five producing states brought a total of US$8.6 billion into the respective state's economy, worth US $14.15 billion for the U.S. economy in 1997. Despite increasing broiler production, wholesale prices have been fluctuated from year to year as shown in Figure 1. Nominal wholesale price volatility among other factors are the biggest risk facing all players in the industry. Price volatility also directly affects grower income and state revenues as well as the U.S. economy. Therefore, appropriate study and analysis of wholesale prices in different markets should be examined. In particular, how is price volatility accommodated by both integrators and growers in the production processes. What strategies, if any should be pursued in dealing with volatility in price so that the industry might formulate a better product and market development policy both for primary processed and further processed broiler products.

This study assesses recent developments that have occurred in the broiler industry in the five largest broiler producing states in the U.S. Increasing vertical integration in both production and marketing practices as well as concentration ratio in the industry are expected to have impacts on price within various markets. Therefore, examining the price discovery processes is important. The objective of this study is to determine market integration given recent developments in the industry by taking into account the necessary conditions that need to be fulfilled. This study will analyze such issues and statistically show whether market integration hypothesis holds under imperfect information settings. Most past market integration research has hypothesized that two different markets have a long-run price relationship if they meets the spatial arbitrage conditions (Sexton, et al, 1991; Baulch, 1997) and has assumed that the probability of price differences in two different markets is conditional on transaction costs. This study takes into consideration the integrator’s cost in studying a long-run price relationship in two different markets. By doing so, not only a long-run price relationship can be studied, but the model can also provide information on various cost differentials between two different markets, which might
be an important source of market integration.

**Data and Methods:**

Necessary condition tests for the presence of market integration are conducted before any tests within spatial arbitrage or trade frameworks are pursued. Prior to any econometric estimation, ARCH (autoregressive conditional heteroskedasticity) in the error structure will also be tested, in addition to unit root tests on various broiler price series. A spatial arbitrage model to test for market integration will be applied to analyze the existence of a long-run price relationships among the different markets. Annual wholesale broiler price data used in this study cover the period of 1970 to 1997 and are from both USDA National Agricultural Statistics Services (NASS), USDA statistical bulletins and broiler reports as well as from industry sources.

Wholesale broiler prices at the farm level are for the five leading broiler producing states. The trends in nominal wholesale broiler price over years from Arkansas, Georgia, Alabama, Mississippi and North Carolina are presented in Figure - II (USDA report, 1999). It is interesting to see that prior to the early 1980's, wholesale prices in those five producing states had common movement. However, during 1980 to 1990 many changes occurred. Wholesale prices in Mississippi and Arkansas tended to move closely while prices in the three other states seemed to move as a different group. However, beginning in early 1990's wholesale prices in Mississippi moved away from Arkansas’ price and was more closely related to prices from the other group. Examining these price trends, one can see that there are two different groups of markets. The first group consists of four markets included Georgia, Mississippi, North Carolina and Alabama. The second group consists only Arkansas’ market. However, beginning in 1996 the Arkansas price also moved closer toward the other group. The graph of wholesale prices showed that in more recent years, markets are more integrated in the leading broiler producing states. Identifying the driving factors behind the integration are important and should be statistically examined.

Following Spiller and Huang (1986), prices in two regions for a homogenous product are said in the same economic market if the prices for that good or product differ by exactly the interregional transportation cost. Baulch (1997) argued that two different markets are said to be
integrated if, when trade takes place between them, price in the importing market equals price in
the exporting market plus the transportation and other transfer costs involved in moving food
between them.

Under a such definition, the equilibrium arbitrage condition for two markets at a given
time period \( t \) can be modeled as shown in equation (1):

\[
WP_t^B - WP_t^A = TC_t
\]

The above equation expresses the relationship between the wholesale price (\( WP \)) in market A and
market B at the same period \( t \) for the same commodity such and that the different between the
two prices are explained by the transaction cost (\( TC_t \)). When such a condition exists then it is said
that the two markets are integrated. The expression as stated in equation (1) is only valid if both
sellers and buyers in the two markets are in different or disperse locations. Included in the
transaction costs are transportation cost, loading and unloading costs and trader’s normal profit.

As explained above, the wholesale broiler prices used herein from the leading producing
states. Therefore, the above model as shown in equation (1) should be adjusted accordingly, and
the price in each respective state can be considered as a market equilibrium price. Contrary to the
definition of price in the Spiller and Huang, Sexton’s et al., and Baulch studies, in this study, the
broiler price in each respective state portrays a market clearing price jointly determined by both
market demand and supply located at a single point.

Suppose further that the price in either market is determined by factors that will directly
affect the marginal cost function of the producers or integrators. That is, the wholesale broiler
price in market B will be determined conditioned on the integrators’ cost of production at the
same location to bring the products to the market. The USDA survey reported in 1995 for the
Southern Plains that the production cost in terms of per pound saleable broiler for a typical broiler
operation consists of three main expenses: growers’ cost (1.64 cents), integrators’ cost (22.46
cents) and administration cost (0.47 cents). As one can see, the integrators’ cost is the largest
portion among those three components. Therefore, if the wholesale price can be thought of as a
random variable, then its distribution will depend or be conditioned on both the integrator and grower costs. Modeling the price relationship in different broiler market without taking into account the cost of production both for growers and integrators will result in a misleading conclusion. Therefore, the relationship between broiler wholesale price can best be explained by the following equation.

\[
WP_t^B \mid GC_t (\tilde{X}_t), IC_t (X_t) \] - \[WP_t^A \mid GC_t (\tilde{X}_t), IC_t (X_t) \] = TC_t
\]

Following Tsoulouhas and Vukina (1999), the growers cost in equation (2) is assumed to be a function of the number of flock to be raised (\(\tilde{X}\)). Under a single point assumption, the transaction cost (\(TC_t\)) will reduce and only contain producers’ normal profit (\(D_t\)), because under this paradigm, the transportation cost becomes insignificant. The integrator serves the same market where the production was taken place. (\(D_t\) in this study is the average producer’s normal profit for a particular market.) Therefore, \(TC_t\) terms in equation (2) can be substituted by \(D_t\) and one can rewrite equation (2) as:

\[
WP_t^B \mid GC_t (\tilde{X}_t), IC_t (X_t^i) \] - \[WP_t^A \mid GC_t (\tilde{X}_t), IC_t (X_t^i) \] = \(D_t (X_t^o)\)
\]

The \(\tilde{X}\) and \((X_t^o)\) are the number of birds raised by growers and sold to the market.

Martinez (1999) argued that since the first broiler contract was signed in 1933, the broiler industry has been characterized by vertical integration. Integration in the broilers industry through production contracts and integrated operations facilitated the adoption of new technology and gains in production and marketing efficiency. Knoeber and Thurman (1995) found that production contracts in the industry have been successful in shifting the risks associated with both price and production from growers to integrators [who are considered to have more resources compared to those of growers].

Under such production practices, broiler growers provide housing, equipment and labor to raised broilers which is owned by the integrators to a pre-specified weight. From the grower
stand point, the cost incurred is due to fixed cost such as depreciation of fixed assets, interest, insurance, repair and maintenance. The fixed cost comprises about sixty percent of growers’ cost; the largest components out of the fixed cost are from depreciation of fixed assets. Since the rate of fixed assets depreciation is known and remains fixed during the production processes, the growers’ cost is then very much determined and no longer stochastic.

The integrators provide feed, chicks, veterinary services and other supplies. Large broiler integrators also own feed mills, hatcheries, slaughter and processing plants. Based on the survey that was conducted in 1995 by USDA/ERS in the southern broiler producing states, the cost associated with feed is the most single important component in the integrators’ cost. Feed cost per pound basis and calculated for saleable live weight comprises about 74 percent of integrators’ expenses.

Given this important fact, broiler wholesale prices will be affected by \((X^I_t)\). Therefore, equation (3) can be rewritten as follows:

\[
(4) \quad [WP^B_t | \bar{GC}_t, IC_t (X^I_t)] = [WP^A_t | \bar{GC}_t, IC_t (X^I_t)] + D_t (X^O_t)
\]

Rearrange the terms by placing broiler wholesale price in region A to the right hand side of the equation, one can rewrite equation (4) as follows:

\[
(5) \quad [WP^B_t | \bar{GC}_t, IC_t (X^I_t)] = [WP^A_t | \bar{GC}_t, IC_t (X^I_t)] + D_t (X^O_t)
\]

However, through the production contract, integrators are responsible to provide broiler feed. In addition to the broiler feed, the volume of production (rotation of flocks) at a given farm and the size of the chicken house is also determined by integrators (Vukina, 1998).

Assuming that integrators have previous experience for each individual farmer, then feed utilization \((X^I_t)\) for each farmer becomes predetermined and no longer stochastic. In addition, through the marketing contract between integrators and the fast food industry or large grocery
chains, broiler wholesale price (WP) is much more predetermined in more recent years. However, in this study WP is treated as a random variable and its value is conditional on integrator’s cost (IC) in each respective market and not by feed costs. In the long-run $D_i$ will equal zero because the assumption of long-run equilibrium in a competitive market (Kreps, 1990).

Taking the first derivative on both sides of equation (5) with respect to $(IC_t)$, the following expression results:

\[
\frac{\partial WP_t^B(IC_t^B)}{\partial IC_t^B} \Delta IC_t^B = \frac{\partial WP_t^A(IC_t^A)}{\partial IC_t^A} \Delta IC_t^A
\]

Superscripts A and B denote markets A and B, respectively. The necessary condition for market integration as shown in equation (6) takes into account not only the integrator’s cost differentials in two different markets, but it also has several desirable properties. First, the model ensures that the price series are stationary, a requirement for eliminating the problem of spurious regression (Granger and Newbold, 1974). Secondly, both the first and second terms in equation (6) express market equilibrium conditions in the output market and at the same time take into account any infinitesimal changes ($\partial$) that will effect the integrator’s cost component in the respective market, other than the previously mentioned cost component$^2$.

Market integration in a spatial context should meet the necessary conditions before markets can be claimed to have integrated. As shown in equation (6), integration in the markets will not exist if the price series in two different markets are not an equilibrium price. Secondly, not only are the price series at equilibrium level as results of demand and supply forces in the output markets, but the price series also causes firms and consumers to attain allocation efficiency. This is an equilibrium condition based on Neo-classical theory of the firm. These additional conditions are imposed in studying market integration, thereby minimizing the risk of

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$^2$Readers who are interested in the topic might be able to read more about the derivation and the mathematical proof from Eugene Silberberg (1990) or Hal R. Varian (1999).
making false inferences.

McNew and Fackler (1997) argued that most market integration studies in the past have two weaknesses: the notion of market integration (spatial price behavior) is confused with market efficiency studies or the Law of One Price (LOP) and failure to interpret the economic meaning of arbitrage opportunities. They claimed that if opportunities exist, then they will be absorbed and eliminated instantly so that they are not even reflected in the observed variables, including market prices. This study gives new insights in response to their concerns in that it stresses economic meaning rather than application of statistical methods to data. Even though this paper starts with spatial arbitrage model, economic meaning and real world and industry reality are also incorporated into the analysis such that the final model has different economic interpretations than those in the original model, expressed in equation (1).

There are three variations of equation (6). The first possibility would be that the integrator’s marginal cost in the two markets are the same. Under such a condition, equation (6) becomes:

\[
\frac{\partial WP_t^B(\text{IC}_t)}{\partial \text{IC}_t} \cdot \Delta \text{IC}_t = \frac{\partial WP_t^A(\text{IC}_t)}{\partial \text{IC}_t} \cdot \Delta \text{IC}_t
\]

(7)

The second and the third variations of equation (6) occur when the integrator’s cost in the two markets are not the same. If the integrator’s cost in market A is greater than that of in market B, i.e, \((\Delta \text{IC}_t^B) < (\Delta \text{IC}_t^A)\), then equation (1) can be written as follows:

\[
WP_t^B(\text{IC}_t^B) + \bar{\epsilon} [(\text{IC}_t^A), (\text{IC}_t^B)] = WP_t^A(\text{IC}_t^A)
\]

(8)

However, when the reverse is true then equation (8) turns to be the following:

\[
WP_t^B(\text{IC}_t^B) - \bar{\epsilon} [(\text{IC}_t^A), (\text{IC}_t^B)] = WP_t^A(\text{IC}_t^A)
\]

(9)

\(\bar{\epsilon}\) in both equation (8) and (9) is a random variable and its value dependent on integrators’ cost in
both markets. It can also be interpreted as a measurement of the cost competitiveness or allocative efficiency between two integrators in two different regions. The magnitude of $\bar{\varepsilon}$ will depend on the variation of integrators’ cost. However, if both integrator’s cost in the two market are independent identically distributed, then one can find the necessary condition such that the wholesale price to cost ratio in each market are optimized at equilibrium levels as shown in equations (10) and (11), respectively:

\[
\frac{\partial \bar{\varepsilon}(IC_i^A, IC_i^B)}{\partial IC_i^A} \bar{IC}_i^A = \frac{\partial WP_i^A(IC_i^A)}{\partial IC_i^A} \bar{IC}_i^A
\]

\[
\frac{\partial \bar{\varepsilon}(IC_i^A, IC_i^B)}{\partial IC_i^B} \bar{IC}_i^A = \frac{\partial WP_i^B(IC_i^A, IC_i^B)}{\partial IC_i^B} \bar{IC}_i^B
\]

Equations (10) and (11) suggest that integrators’ cost differentials in two different markets should be taken into consideration when analyzing market integration for a homogenous commodity between two different markets, especially in a long-run context. This condition seems to be intuitive. If the integrators’ cost are significantly different due to location, then in the long-run they might be able to relocate their operation to areas that has competitive advantage, providing that the benefit is far beyond the cost associated with the relocation, which is the case for broiler industry. Alternatively, it may choose to expand in these same competitively advantaged areas.

The broiler industry is more labor intensive than many alternative manufacturing activities. Therefore, where wage differentials are significant between two regions, then the industry may tend to move out from higher wage areas to less expensive wage areas. Concentration of broiler production in the southern U.S. by agricultural economists (USDA/ERS, 1995) is often explained to result from labor cost being less expensive in the region; as well as lower feed costs. Since market integration in this study follows the extension of spatial arbitrage paradigm (Spiller and
Jarque-Berra normality tests on the residuals will be applied as an alternative to assure that the error terms are indeed normal. If the normality is fail to be rejected, then the final estimation of the model should be pursued using nonparametric statistical test. Readers who are interested on such issues might consult Mood, Graybill and Boes (1974)

In their study, Spiller and Huang assumed that price differences in two markets are distributed with a constant mean. Assume that both wholesale price (WP) and integrator’s cost (IC) in two different locations are random variables which are normally distributed, i.e:

\begin{align}
W_{increatenos} P_{i}^{A} & \sim N(\mu_{A}, \sigma_{A}^{2}) \\
W_{increatenos} P_{i}^{B} & \sim N(\mu_{B}, \sigma_{B}^{2}) \\
\text{and} \\
IC_{i}^{A} & \sim N(\tilde{\mu}_{A}, \tilde{\sigma}_{A}^{2}) \\
IC_{i}^{B} & \sim N(\tilde{\mu}_{B}, \tilde{\sigma}_{B}^{2})
\end{align}

When estimating the ratio of two random variables, i.e., wholesale price and integrators’ cost, one notices that the distribution of wholesale prices are not independent but depend on the integrators’ cost. However, as long as the integrators’ cost are normally distributed, then the ratio will also have normal distribution. The ratio of two normal distributions, will also follow normal distribution. However, the final estimation follows the model as explained in equation (6). There are several points that need to be addressed.

(i). The numerator and denominator on either side of the equation may or may not be I(1). If, all variables in that expression are I(1), meaning that they are stationary after first difference, then a long-run price relationship may hold. The stationarity of all variables implies that the covariance is constant.

(ii). If a different order of integration exists, then no long-run relationship prevails in the series. Either term (ratio) is able to explain variations of the other variable.

Under condition (i), estimation of market integration is equivalent to test the intercept, slope term

\begin{footnote}
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\end{footnote}
and common factors (CF) which bring the price series in two different regions together in a long-run price relationship. Assume that the expressions in both the lefthand and the righthand sides of equation (7) are $\hat{a}$ and $\hat{a}$. One can rewrite equation (7) as follows:

\begin{equation}
\hat{a}_0 + \hat{a}_1 + \hat{E}_1t + \hat{\sigma}_t = \hat{a}_0 + \hat{a}_1 + \hat{E}_2t + \hat{\Omega}_t
\end{equation}

(16)

Where: $\hat{a}_0$ and $\hat{a}_0$ are both the intercept terms; $\hat{E}_1t$ and $\hat{E}_2t$ are common factors that make the price series move together in the long-run; and $\hat{\sigma}_t$ and $\hat{\Omega}_t$ respectively are the error terms from the respective equation. Given the above model, the relationships between the two price series can be studied by testing the null hypotheses as shown in equation (16), (17) and (18) below.

\begin{equation}
H_0 : \sum_{i=1}^{n} \hat{a}_i = \sum_{j=1}^{n} \hat{a}_j, \quad \text{for } i \neq j;
\end{equation}

(17)

\begin{equation}
H_0 : \hat{a}_0 = \hat{a}_0 = 0;
\end{equation}

(18)

and

\begin{equation}
H_0 : \hat{E}_1t = \hat{E}_2t .
\end{equation}

(19)

The USDA/ERS survey in cooperation with Georgia Experiment Stations which was published in 1995, did not provide the integrator’s cost data on individual states. Rather, it grouped the five leading states (Arkansas, Georgia, Alabama, Mississippi and North Carolina) into one group. Therefore, the data to study the cost competitiveness among those five states is not available. Therefore, the final estimation will be pursued based on equation (16) and growers’ costs are assumed to be the same across different states.

Given the null hypotheses as shown in equations (17), (18) and (19), one might test them
to analyze whether the intercept, slopes and common driving factors (CF) are different as they are hypothesized. The results of the test might reveal the several possibilities summarized in Table 2. Each combination of rejections and failures to reject will have different economic interpretations concerning equilibria in the two markets. In order for the markets to have a long-run equilibrium in a stronger sense, one might not be able to reject all the null hypotheses. An additional requirement for testing market equilibrium as shown in equation (19) is important to assure that the two price series are moving together in the long-run due to a common factor or factors (CF). Failure to show that the CF are related to the price series moving together only results a weak version of market equilibrium.

Results and Discussion

Tests on stationarity conditions of the price series are conducted both on the price levels and on first differences of prices for five states (Table 3). The results indicate that most of the price series are I(0), e.g., that they have the same order of integration; in most cases they are stationary without differencing. However, several cases are found where the Augmented Dickey-Fuller statistics show that the unit root hypothesis cannot be rejected, in particular when a trend variable is included in the estimation. To make sure that the estimation can be carried out on stationary data and satisfies the necessary condition, first differences on price series will be used in the final estimation of the model. Results showed that the price series are uniformly stationary after first difference.

Given that the data are I(1), the cointegration test was pursued using a common factor model to test the null hypothesis as presented in equations (17), (18) and (19). The relationships among various price series are solved simultaneously using equation (16) and Table 4. The error terms are significant for at least three broiler equations in Georgia, Mississippi and North Carolina. This suggests that a long run price relationship might hold in these states. In most cases, price variations in Georgia are explained significantly by price variations in other states, except in Arkansas.
Price variation in Arkansas have a negative relationship with price variations in Georgia and Alabama. That is, increase in Arkansas broiler price will negatively affect broiler prices in these two states. Price variations in Alabama have a positive relationship with those of Arkansas and Georgia, but showed a negative relationship with those of Mississippi’s. In addition, price volatility in North Carolina is explained significantly by Georgia prices.

The results of testing the long-run broiler price relationship in five leading producing states in the U.S. are presented in Table 4. In all but three cases, the null hypotheses in the intercept term are rejected at a one percent confidence level. The null hypotheses on the slopes are generally not rejected. In order to conclude that a strong long-run price relationship occurs between two price series, one cannot reject all null hypotheses on the intercept, slope and CF terms. However, a conclusion of a weak form of a long-run price relationship can be reached if the null hypotheses on both the intercept and slope terms fail to be rejected.

From Table 5, one can see evidence of a strong long-run price relationships between Mississippi and North Carolina as shown by a small F-statistic. Price pairs in Georgia and Mississippi and Georgia and North Carolina are found to be weakly cointegrated. A weak form of price equilibrium results in these two-pair is because there is no evidence of finding a common factor (CF) in the errors terms that would make them move together in the long-run.

Based on the result, one might argue that price series other than those previously discussed do not have a long-run price relationship (therefore LOP does not hold). This means that there is no such a common price that governs the industry in Arkansas and Alabama. However, normality test on the residual of the error terms $\sigma^2_t$ and $\Omega_t$ (using Jarque-Berra) suggested that out of five price series, only price series from Alabama and Arkansas are normally distributed -- the three others are not normal. Therefore, non-parametric tests are carried out using a Wilcoxon rank-sum test. The results of the tests on each price pair can be found in Table 6. Results suggest that the null hypotheses that the mean across price pairs are the same are not
rejected as shown by low $\chi^2$ - statistics. Therefore, one might conclude that price pairs have the same mean and therefore they do have common factors (CFs) that made them move together in the long-run.

At the 10%, 5% and 1 % confidence levels, the critical values of the t ($\hat{\sigma}_p$ and $\hat{\sigma}_q$) and F-statistics ($\bar{\sigma}_1$ and $\bar{\sigma}_2$) for a sample size equal to 25 are, respectively, $\hat{\sigma}_p$: -2.62, -3.00 and -3.75; $\hat{\sigma}_q$: -3.24, -3.60 and -4.38; $\bar{\sigma}_1$: 4.12, 5.18 and 7.88; $\bar{\sigma}_2$: 4.67, 5.68 and 8.21. The null hypothesis is rejected if the calculated pseudo t or F-statistics are greater than the critical t or F-values as reported by Fuller (1976) and Dickey and Fuller (1981). $\bar{\sigma}_1$ is based on the above equation but without the time trend in the equation.
References


Table 1 - Broiler Production and Value in Top Five Producing States in the U.S.\textsuperscript{4}

<table>
<thead>
<tr>
<th>Producing States</th>
<th>Production in number (billion heads)</th>
<th>Value of Production (billion US $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Georgia</td>
<td>1.154</td>
<td>1.182</td>
</tr>
<tr>
<td>Arkansas</td>
<td>1.155</td>
<td>1.164</td>
</tr>
<tr>
<td>Alabama</td>
<td>0.873</td>
<td>0.906</td>
</tr>
<tr>
<td>North Carolina</td>
<td>0.68</td>
<td>0.665</td>
</tr>
<tr>
<td>Mississippi</td>
<td>0.68</td>
<td>0.720</td>
</tr>
<tr>
<td>Total</td>
<td>5.689</td>
<td>4.637</td>
</tr>
</tbody>
</table>

\textsuperscript{4}Source: Poultry Production and Value, 1997.
Figure II - Trend of Nominal Broiler Wholesales Price (1970-1997)
### Table 2 - Null Hypotheses and Economic Interpretations

<table>
<thead>
<tr>
<th>Possible Cases</th>
<th>Null Hypotheses</th>
<th>Interpretations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\hat{a}_0 = \hat{a}_0 = 0$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\sum_{j=1}^{n} \hat{a}<em>j = \sum</em>{j=1}^{n} \hat{a}_j$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\hat{E}<em>{1t} = \hat{E}</em>{2t}$</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Reject</td>
<td>Reject</td>
</tr>
<tr>
<td>II</td>
<td>Fail To Reject</td>
<td>Reject</td>
</tr>
<tr>
<td>III</td>
<td>Fail To Reject</td>
<td>Fail To Reject</td>
</tr>
<tr>
<td>IV</td>
<td>Fail To Reject</td>
<td>Fail To Reject</td>
</tr>
<tr>
<td>V</td>
<td>Reject</td>
<td>Fail To Reject</td>
</tr>
<tr>
<td>VI</td>
<td>Reject</td>
<td>Reject</td>
</tr>
<tr>
<td>VII</td>
<td>Fail To Reject</td>
<td>Reject</td>
</tr>
<tr>
<td>VIII</td>
<td>Reject</td>
<td>Fail To Reject</td>
</tr>
</tbody>
</table>
### Table 3 - Augmented Dickey-Fuller Test on Stationarity Condition of Various Data Series Used in the Study

<table>
<thead>
<tr>
<th>Null hypothesis for unit roots(^a)</th>
<th>Arkansas</th>
<th>Georgia</th>
<th>Alabama</th>
<th>Mississippi</th>
<th>North Carolina</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level</td>
<td>(\bar{\alpha})</td>
<td>Level</td>
<td>(\bar{\alpha})</td>
<td>Level</td>
</tr>
<tr>
<td>(\hat{\delta}_{\mu}, H_0 : (\hat{\alpha}_1 = 0 \mid \hat{\alpha}_2 = 0))</td>
<td>-2.27</td>
<td>-3.80***</td>
<td>-1.88</td>
<td>-3.77***</td>
<td>-1.77</td>
</tr>
<tr>
<td></td>
<td>-3.08*</td>
<td>-3.88**</td>
<td>-3.43**</td>
<td>-3.21*</td>
<td>-3.59</td>
</tr>
<tr>
<td></td>
<td>5.29**</td>
<td>7.71**</td>
<td>4.49*</td>
<td>7.32**</td>
<td>4.49*</td>
</tr>
<tr>
<td></td>
<td>8.08***</td>
<td>4.19*</td>
<td>7.24**</td>
<td>4.74*</td>
<td>5.29*</td>
</tr>
<tr>
<td>(\hat{\delta}_{\rho}, H_0 : (\hat{\alpha}_1 = 0))</td>
<td>6.11**</td>
<td>5.96**</td>
<td>6.65**</td>
<td>4.86*</td>
<td>7.24**</td>
</tr>
<tr>
<td>(\hat{\delta}_1, H_0 : (\hat{\alpha}_1, \hat{\alpha}_2) = (0, 1, 0))</td>
<td>5.29**</td>
<td>7.71**</td>
<td>4.49*</td>
<td>7.32**</td>
<td>4.49*</td>
</tr>
<tr>
<td>(\hat{\delta}_2, H_0 : (\hat{\alpha}, \hat{\alpha}_1, \hat{\alpha}_2) = (0, 1, 0))</td>
<td>5.29**</td>
<td>7.71**</td>
<td>4.49*</td>
<td>7.32**</td>
<td>4.49*</td>
</tr>
</tbody>
</table>

\(^a\)A number of different tests have been suggested by Dickey and Fuller (p. 1062-63, 1981) and Fuller (p. 373, 1976), based on the following model:

\[
\bar{\Delta} Y_t = \bar{\alpha} + \bar{\alpha}_1 Y_{t-1} + \bar{\alpha}_2 t + \sum \bar{\alpha}_j \bar{\Delta} Y_{t-j} + U_t
\]
### Table 4 - Estimation Results on Broiler Price Equations

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Arkansas (AP&lt;sub&gt;AR&lt;/sub&gt;)</th>
<th>Georgia (AP&lt;sub&gt;GA&lt;/sub&gt;)</th>
<th>Alabama (AP&lt;sub&gt;AL&lt;/sub&gt;)</th>
<th>Mississippi (AP&lt;sub&gt;MS&lt;/sub&gt;)</th>
<th>North Carolina (AP&lt;sub&gt;NC&lt;/sub&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.01 (4.53)*****</td>
<td>0.0005 (-0.28)</td>
<td>-0.007 (-3.22)*****</td>
<td>0.003 (1.00)</td>
<td>0.003 (0.78)</td>
</tr>
<tr>
<td>(\hat{\theta}_{t-1})</td>
<td>-0.08 (-0.21)</td>
<td>0.60 (8.63)*****</td>
<td>-0.31 (-1.52)</td>
<td>-1.12 (-8.92)*****</td>
<td>-0.78 (-3.01)*****</td>
</tr>
<tr>
<td>(\Delta P_{AR})</td>
<td>-0.04 (-0.49)</td>
<td>0.50 (5.60)*****</td>
<td>0.11 (0.80)</td>
<td>-0.31 (-1.92)*</td>
<td>-0.31 (-1.92)*</td>
</tr>
<tr>
<td>(\Delta P_{GA})</td>
<td>-0.27 (-0.49)</td>
<td>0.79 (3.16)*****</td>
<td>1.58 (7.28)*****</td>
<td>1.49 (4.90)*****</td>
<td>1.49 (4.90)*****</td>
</tr>
<tr>
<td>(\Delta P_{AL})</td>
<td>1.42 (5.60)*****</td>
<td>0.29 (3.16)*****</td>
<td>-0.44 (-2.02)*</td>
<td>0.15 (0.57)</td>
<td>0.15 (0.57)</td>
</tr>
<tr>
<td>(\Delta P_{MS})</td>
<td>0.25 (0.80)</td>
<td>0.46 (7.28)*****</td>
<td>-0.35 (-2.02)*</td>
<td>-0.39 (-1.70)</td>
<td>-0.39 (-1.70)</td>
</tr>
<tr>
<td>(\Delta P_{NC})</td>
<td>-0.49 (-1.92)*</td>
<td>0.31 (4.90)*****</td>
<td>0.08 (0.57)</td>
<td>-0.27 (-1.70)</td>
<td>-0.27 (-1.70)</td>
</tr>
<tr>
<td>(\Delta C)</td>
<td>0.0005 (1.10)</td>
<td>-0.0002 (-0.87)</td>
<td>-0.0002 (-0.53)</td>
<td>-0.00001 (-0.04)</td>
<td>0.0007 (1.91)*</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.94</td>
<td>0.99</td>
<td>0.98</td>
<td>0.97</td>
<td>0.97</td>
</tr>
<tr>
<td>(\chi^2) for Jarque-Berra</td>
<td>15.28*****</td>
<td>0.006</td>
<td>17.59*****</td>
<td>2.21</td>
<td>1.25</td>
</tr>
</tbody>
</table>

*aNumbers in parenthesis are t-statistics. ***, ** and * respectively are significant at 1, 5 and 10% confidence level. For a sample of size 28, the critical t-value at 1, 5 and 10% respectively are 2.76, 2.04 and 1.70.*
Table 5 - Results on the Cointegration Tests

<table>
<thead>
<tr>
<th>Price Series</th>
<th>$\hat{\alpha}<em>0 = \hat{\alpha}</em>{0j} = 0$</th>
<th>$\sum_{i=1}^{n} \hat{\alpha}<em>i = \sum</em>{j=1}^{n} \hat{\alpha}_j$</th>
<th>$\hat{\beta}<em>{1t} = \hat{\beta}</em>{2t}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tilde{\text{AP}}<em>{\text{AL}}$ vs $\tilde{\text{AP}}</em>{\text{AR}}$</td>
<td>10.24***</td>
<td>2.27</td>
<td>2.95*</td>
</tr>
<tr>
<td>$\tilde{\text{AP}}<em>{\text{AL}}$ vs $\tilde{\text{AP}}</em>{\text{GA}}$</td>
<td>8.04***</td>
<td>0.01</td>
<td>14.05***</td>
</tr>
<tr>
<td>$\tilde{\text{AP}}<em>{\text{AL}}$ vs $\tilde{\text{AP}}</em>{\text{MS}}$</td>
<td>6.66***</td>
<td>1.60</td>
<td>10.72***</td>
</tr>
<tr>
<td>$\tilde{\text{AP}}<em>{\text{AL}}$ vs $\tilde{\text{AP}}</em>{\text{NC}}$</td>
<td>5.55**</td>
<td>2.45</td>
<td>1.56</td>
</tr>
<tr>
<td>$\tilde{\text{AP}}<em>{\text{AR}}$ vs $\tilde{\text{AP}}</em>{\text{GA}}$</td>
<td>10.24***</td>
<td>3.68*</td>
<td>2.95*</td>
</tr>
<tr>
<td>$\tilde{\text{AP}}<em>{\text{AR}}$ vs $\tilde{\text{AP}}</em>{\text{MS}}$</td>
<td>10.84***</td>
<td>0.78</td>
<td>6.21***</td>
</tr>
<tr>
<td>$\tilde{\text{AP}}<em>{\text{AR}}$ vs $\tilde{\text{AP}}</em>{\text{NC}}$</td>
<td>10.24***</td>
<td>0.20</td>
<td>2.76</td>
</tr>
<tr>
<td>$\tilde{\text{AP}}<em>{\text{GA}}$ vs $\tilde{\text{AP}}</em>{\text{MS}}$</td>
<td>0.72</td>
<td>0.86</td>
<td>114.36***</td>
</tr>
<tr>
<td>$\tilde{\text{AP}}<em>{\text{GA}}$ vs $\tilde{\text{AP}}</em>{\text{NC}}$</td>
<td>0.35</td>
<td>1.91</td>
<td>20.96***</td>
</tr>
<tr>
<td>$\tilde{\text{AP}}<em>{\text{MS}}$ vs $\tilde{\text{AP}}</em>{\text{NC}}$</td>
<td>0.67</td>
<td>0.36</td>
<td>1.24</td>
</tr>
</tbody>
</table>

** and *** refers to significant at a five and one percent confidence level.
Conducted using Wilcoxon rank-sum test to see if the second random variable in the pair has the same mean as the first (Conover, W. J, 1999).

Table 6 - Kruskal-Wallis Nonparametric Test Results on Price Pairs

<table>
<thead>
<tr>
<th>Price Series</th>
<th>$z^2$ - Statistics</th>
<th>Pr &gt; $z^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{AL} \text{ vs } P_{AR}$</td>
<td>26.95</td>
<td>0.31</td>
</tr>
<tr>
<td>$P_{AL} \text{ vs } P_{GA}$</td>
<td>26.91</td>
<td>0.31</td>
</tr>
<tr>
<td>$P_{AL} \text{ vs } P_{MS}$</td>
<td>26.80</td>
<td>0.31</td>
</tr>
<tr>
<td>$P_{AL} \text{ vs } P_{NC}$</td>
<td>26.66</td>
<td>0.32</td>
</tr>
<tr>
<td>$P_{AR} \text{ vs } P_{GA}$</td>
<td>26.73</td>
<td>0.18</td>
</tr>
<tr>
<td>$P_{AR} \text{ vs } P_{MS}$</td>
<td>26.31</td>
<td>0.19</td>
</tr>
<tr>
<td>$P_{AR} \text{ vs } P_{NC}$</td>
<td>26.78</td>
<td>0.18</td>
</tr>
<tr>
<td>$P_{GA} \text{ vs } P_{MS}$</td>
<td>26.63</td>
<td>0.23</td>
</tr>
<tr>
<td>$P_{GA} \text{ vs } P_{NC}$</td>
<td>26.70</td>
<td>0.22</td>
</tr>
<tr>
<td>$P_{MS} \text{ vs } P_{NC}$</td>
<td>26.42</td>
<td>0.15</td>
</tr>
</tbody>
</table>

$^5$Conducted using Wilcoxon rank-sum test to see if the second random variable in the pair has the same mean as the first (Conover, W. J, 1999).