Nonlinear Dynamics with Transaction Costs and Arbitrage: Evidence in the Broiler Product Market of Taiwan

Chin-Chia Liang*, Jeng-Bau Lin**

Abstract

In this study, we attempt to incorporate transaction costs presented by Dumas (1992), Michael et al. (1997), and Monoyios and Sarno (2002) into the exponential smooth transition autoregressive (ESTAR) model proposed by Granger and Teräsvita (1993) to capture the nonlinear properties between monthly wholesale and retail price and of the spread of the broiler products. The dynamic relationship between the wholesale and retail broiler prices by the conventional linear models is indeed inappropriate in the presence of transaction costs. Transaction costs would result in the existence of the inner band for arbitrages in the Taiwanese broiler product market within which excessively profitable trading opportunities are impossible. The finding that the existence of excessively positive spreads produced persistent arguments between the wholesale and retail processing and thus destroyed the market mechanism suggests that policy makers may consider granting more licenses to potential wholesalers in allowing for high competition, and hence monitor the environment for market trading to guarantee the achievement of efficiency under the fair schemes.

Keywords: Nonlinear mean reversion; Transaction cost; Broiler spread; Exponential smooth transition autoregressive model

JEL classification: C22, Q13, Q18

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I. Introduction

Many empirical researches have focused on the linear dynamic behavior of the basis in financial derivatives for almost one and half decades. However, no presence of transaction costs was assumed in most of the previous studies. A consideration of transaction costs into the dynamic model as suggested by Dumas (1992), Michael et al. (1997), and Monoyios and Sarno (2002) might capture the nonlinear adjustment process for the futures basis series. Recently, Abdulai (2002) carried out a nonlinearly asymmetric analysis on the relationship between producer and retail pork prices in Switzerland. Holt and Craig (2006) observed a hog-corn cycle arising from technical changes in the family of smooth transition autoregressive (hereafter STAR) models. Nevertheless, these two works did not consider transaction costs into the nonlinear STAR framework in primary commodity markets.

A few of previous researches had actually concentrated on modeling similar attributes for primary commodity prices. Much earlier, Harlow (1960), Jelavich (1973), Larson (1964), Shonkwiler and Spreen (1986), and Hayes and Schmitz (1987) employed the linear dynamic models for capturing essential features of primary commodity price behaviors. Chavas and Holt (1991) used linear models to examine that the U.S. hog-corn cycle might be associated with deterministic chaos. However, Labys et al. (2000), Davidson et al. (1998) found the result that many primary commodity prices exhibit identifiable cyclical behavior which might be...

On the other hand, an application of threshold-type models originally proposed by Tong (1990) characterized the behavior of the futures basis, which allowed transaction costs for forming bands within which no adjustments take place. However, Dumas (1992) suggested that under certain restrictive conditions such as identical transaction costs and homogeneity of agents, the mean-reverting behavior would tend to smooth the transition between regimes. In examining nonlinear adjustments in real exchange rates, Michael et al. (1997) further considered transaction costs in the STAR models and find strong evidence of mean-reverting behavior for purchasing power parity (hereafter PPP) deviations. In addition, in investigating the dynamic behavior of the stock index futures basis, Monoyios and Sarno (2002) implemented a study on the persistence of deviations of the futures basis in the cost-of-carry model, and found that nonzero transaction costs might lead to the basis displaying nonlinear mean reversion behavior.

Taiwan entering into the World Trade Organization (WTO) in 2002 initialized the opening of broiler products imports from abroad. Deregulation of chicken meat imports may result in structural changes in broiler farm prices and in a more competitive environment in Taiwan. Nevertheless, some institutional factors such as an inefficient quotation system, information asymmetry and marketing rigidity have long distorted the market mechanism for broiler trading. Particularly, the seven largest wholesalers with an 80% market power in the broiler product markets have enjoyed high bargaining power and excessively economic profits or spreads. The existence of positive spreads has led to frequent complaints from the retailers against the wholesalers in the market, and thus has motivated authors in Taiwan to examine
whether the broiler spread exhibits linear or nonlinear process, and the implications for agricultural economics and the suggestion for policy making in relevant industries under investigation. Lee et al. (2006) examined the behavior of Taiwanese hog wholesale prices in the STAR models, and found evidence that the nonlinearity in hog wholesaler prices existed and that there were structural changes in most local hog wholesale markets surveyed. In addition, Huang et al. (2007) investigated the structural change and asymmetry of the price in the Taiwanese broiler product market.¹

It seems plausible to presume the spread of broilers in the Taiwanese market exhibits smooth movements by observing the data pattern on the spread of broilers during the sample period of 1999:M1 through 2007:M12 shown below. Along the line of reasoning above, this study hence attempts to incorporate transaction costs presented by Dumas (1992), Michael et al. (1997), and Monoyios and Sarno (2002) into the STAR models proposed by Granger and Teräsvirta (1993), and Teräsvirta (1994) to examine the nonlinear dynamic behavior of the spread in the Taiwanese broiler products market. The crucial contribution of this study is, for the first time, to investigate the nonlinear features in the broiler spread process and to provide plausible interpretations and suggestions for policy making in the Taiwanese broiler product market. Therefore, the rest of the study is set out as follows. Section II establishes a model describing the nonlinear adjustment of the spread of broilers. Section III presents testing procedures for model adequacy for nonlinearity in the spread. Section IV provides plausible methodologies for conducting unit root, cointegration, nonlinearity as well as restricted ESTAR tests and analyzes the empirical results. Section V ends with concluding remarks.

¹ Those who are interested in understanding recent development of the Taiwanese broiler product market may refer to the draft paper by Huang et al. (2007).
II. Nonlinear Adjustment of the Broiler Spread

The no-arbitrage condition between the wholesale price and the retail price of broilers implied by the cost-of-carry model with zero transaction cost in a form of continuously compounded interest is:

\[ R_{t,T} = W_t \exp[(c + q)(T - t)] \]  (1)

where \( R_{t,T} \) is the retail price of the broiler products bought at time \( t \) that are sold at time \( T \), \( W_t \) is the wholesale price at time \( t \) in the broiler product market, \( c \) is the constant ratio of cost of carry to wholesale price, and \( q \) is the constant normal profit rate. When proportional transaction costs (hereafter \( c_f \)) containing transportation expense, commission fees and time for trading are considered into trading in broiler products, the inequality expression for the cost-of-carry model with transaction cost can be rewritten by:\(^2\)

\[ R_{t,T} \geq W_t \exp[(c + q)(T - t)] + cf \] (2)

Eq.(2) takes equality when zero economic profit occurs; otherwise, non-zero profit indeed exists, which means that an arbitrage activity may proceed before the incentive to make economic profits disappears. Alternatively, inequality in Eq.(2) holds if the retail price exceeds

\(^2\) A discrete version of the cost-of-carry model of this kind is \( R_{t,T} = W_t[(1 + c + q)] + cf \).

\(^3\) The inequality expression of Eq. (2) used in this study is different from the equality expression in Monoyios and Sarno (2002) due to the special feature in the broiler product market.
the wholesale price plus the addition terms consisting of carrying cost, transaction cost and normal profit, which implies that the spread for trading broiler products is sufficiently large to induce wholesalers to enter the market. Therefore, a positive incentive for arbitrage on the products represents the spread of broilers falls into the outer band. There is no incentive, on the other hand, for such an arbitrage if the spread falls into the inner band.

Based on the cost of carry model with transaction costs defined above, the conventional version of Eq. (2) can be written in logarithm form as:

$$ r_t = v + zw_t + s_t $$  

(3)

where $r_t$ is the log retail price, $w_t$ is the log wholesale price, $v$ is the log (carrying cost and normal profit and transaction cost), and $s_t$ is the spread of broilers under the restriction that $z$ is equal to unity. The modified view represents the cost-of-carry model with transaction costs to hold true as long as $s_t$ is stationary, thus assuming a linear process for $s_t$ implies that the adjustment process is continuous with a constant speed of adjustment. However, Michael et al. (1997) indicated that the presence of transaction costs implies that a nonlinear adjustment process of $s_t$ has implications for the conventional linear cointegration test of the cost-of-carry model.

Granger and Terasvirta (1993) suggested that the nonlinear adjustment process can be characterized based on a smooth transition autoregressive (STAR) model as follows:

$$ s_t = \alpha_0 + \sum_{j=1}^{p} \alpha_j s_{t-j} + F(s_{t-j})(\beta_0 + \sum_{j=1}^{p} \beta_j s_{t-j}) + \epsilon_t $$  

(4)

where $\epsilon_t$ is an independently and normally distributed random variable with a zero mean and constant variance $\sigma^2$, and $F(s_{t-j})$ is a transition function which, by convention, is bounded by zero and one. In general, there are two types of the transition function in $F(s_{t-j})$. The first one is the exponential function:

$$ F(s_{t-j}) = \begin{cases} 
0 & \text{if } s_{t-j} < \theta \\
1 - \exp(-\frac{s_{t-j}}{\delta}) & \text{if } \theta \leq s_{t-j} \leq \delta \\
1 & \text{if } s_{t-j} > \delta 
\end{cases} $$

(6)
\[ F(s_{t-d}) = 1 - \exp(-\gamma(s_{t-d} - c)^2), \quad \gamma > 0 \]  \hspace{1cm} (5)

and the second is the logistic function:

\[ F(s_{t-d}) = \left(1 + \exp(-\gamma(s_{t-d} - c))\right)^{-1}, \quad \gamma > 0 \]  \hspace{1cm} (6)

Therefore, the STAR models can be distinguished in the exponential smooth transition autoregressive (ESTAR) model and the logistic smooth transition autoregressive (LSTAR) model:

\[ s_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i s_{t-i} + (1 - \exp(-\gamma(s_{t-d} - c)^2))(\beta_0 + \sum_{i=1}^{q} \beta_i s_{t-i}) + \varepsilon_t \]  \hspace{1cm} (7)

\[ s_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i s_{t-i} + (1 + \exp(-\gamma(s_{t-d} - c))^{-1}(\beta_0 + \sum_{i=1}^{q} \beta_i s_{t-i}) + \varepsilon_t \]  \hspace{1cm} (8)

According to Michael et al. (1997), reparameterizing the STAR models (Eqs. (7) - (8)) thus gives:

\[ \Delta s_t = \alpha_0 + \rho s_{t-1} + \sum_{i=1}^{p-1} \alpha_i \Delta s_{t-i} + F(s_{t-d})\{(\beta_0 + \rho^* s_{t-1} + \sum_{i=1}^{q-1} \beta_i \Delta s_{t-i})\} + \varepsilon_t \]  \hspace{1cm} (9)

where \( \Delta s_{t-j} = s_{t-j} - s_{t-j-1} \). In this form, the crucial parameters are \( \rho \) and \( \rho^* \). As indicated by Monoyios and Sarno (2002), an incorporation of transaction costs into the STAR framework means that the larger the deviations from the equilibrium value of the spread, the stronger will be the tendency to move back to equilibrium, thus implying that if \( \rho \geq 0 \) holds, both \( \rho^* < 0 \) and \( (\rho + \rho^*) < 0 \) must hold. In other words, for small deviations the adjustment process may be characterized by unit root or even explosive behavior, but for large deviations the process is mean-reverting.
III. Testing Procedures

Following Granger and Teräsvirta (1993) and Teräsvirta (1994), we detect the model adequacy for STAR based on the following testing procedures. First, we specify a linear AR(p) model, which forms the spread of the linearity test, and then determine the appropriate value of the delay parameter, d, by testing linearity for different values of the delay parameter and by carrying out the estimation of the auxiliary regression:

\[ s_t = \alpha + \sum_{j=1}^{p} (\beta_{0j} s_{t-j} + \beta_{1j} s_{t-j}^2 s_{t-d} + \beta_{2j} s_{t-j}^2 s_{t-d}^2 + \beta_{3j} s_{t-j}^2 s_{t-d}) + \varepsilon_t \]  

where \( s_t \) is the residual of the AR(p) model. The linearity test is \( H_0 : \beta_{1j} = \beta_{2j} = \beta_{3j} = 0 \). The rejection of null hypothesis implies the adequacy of a STAR specification in modeling \( s_t \).

Lastly, we choose between the LSTAR and ESTAR models through a sequence of test of nested hypotheses. This can be achieved by applying a sequence of tests within Eqs. (11a) - (11c) as follows:

\[ H_{0j} : \beta_{3j} = 0 \quad \text{for all } j = 1, \ldots, p \]  

\( 1 \leq d \leq 12 \)

4 In the empirical analysis below, Michael et al. (1997) and Monoyios & Sarno (2002) suggested the use of PACF rather than AIC and SBC is the better way for determining the lag number. The selection method in this study follows that of these authors.

5 By Terasvirta & Anderson (1992), in order to specify \( d \), the test is implemented in this study for the range of values \( 1 \leq d \leq 12 \) considered appropriate. If linearity is rejected for more than one value of \( d \), then \( d \) is determined as \( \hat{d} = \arg \min d p(d) \) for \( 1 \leq d \leq 12 \) where \( p(d) \) is the p-value of the selected test. The test has maximum power if \( d \) is selected correctly, whereas an incorrect selection of \( d \) weakens the power of the test.
The procedure for selecting the STAR models is as follows. Rejecting Eq. (11a) $H_{01}$ implies selecting the LSTAR model. Accepting Eq. (11a) $H_{01}$ and rejecting Eq. (11b) $H_{02}$ means the choice of the ESTAR model. Accepting Eq. (11a) $H_{01}$ and Eq. (11b) $H_{02}$ and rejecting Eq. (11c) $H_{03}$ leads to the choice of the LSTAR model.

IV. Methodology and Empirical Result

A. Data

The monthly data on the broiler wholesale and retail prices are obtained from the Agricultural Statistics Yearbook published by the Council of Agriculture in Taiwan. The sample period spans 1999:M1 through 2007:M12 during which the data patterns on the broiler wholesale and retail prices appear to move smoothly, and hence the data pattern on the spread of broilers exhibits smooth movements as shown in Fig. 1. In this study, all variables including the wholesale price, the retail price and the spread are in logarithm form. Here, the log spread is calculated as the difference between the log retail price and the log wholesale price from Eq. (3)
B. Unit Root and Cointegration Tests

In this subsection, we first implement testing for the unit root behavior for the wholesale price and the retail price series in the broiler product market. The results of standard augmented Dickey-Fuller (ADF) test statistics are reported in Table 1. Clearly, we are unable to reject the null hypotheses of unit roots for these two series at the 5% level of significance based on the conventional econometric theory. Nevertheless, first differencing each of the two price series appears to show the stationarity, thus indicating that the two series exhibit stochastic processes being integrated of order one. This result suggests that the cointegrating relationship between the wholesale price and the retail price for the broiler products may exist.

Table 1. ADF unit root test for the broiler prices

<table>
<thead>
<tr>
<th></th>
<th>Level</th>
<th>First difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Constant</td>
</tr>
<tr>
<td>Retail Price</td>
<td>1.376 (0.591)</td>
<td>1.559 (0.802)</td>
</tr>
<tr>
<td>Wholesale Price</td>
<td>-3.098 (0.029)</td>
<td>-3.537 (0.041)</td>
</tr>
</tbody>
</table>

Note: * denotes the rejection of the null hypothesis at the 5% significance level.
Next, an incorporation of transaction costs into the spread series may yield the nonlinear process of the spread. In order to ascertain the nonlinear stationary process of the spread, the methodology by Kapetanios et al. (2003) (hereafter KSS) is thus employed to capture the nonlinear smooth transition autoregressive process of the spread. The empirical result in Table 2 shows the rejection of the existence of nonlinear unit root of the spread at the 5% level, thus revealing the spread exhibits the nonlinear stationary process.

<table>
<thead>
<tr>
<th>Table 2. KSS unit root test for the spread</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spread</td>
</tr>
<tr>
<td>KSS</td>
</tr>
<tr>
<td>Level</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Spread</td>
</tr>
<tr>
<td>-3.417 ( 0.009)*</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Note:* denotes the rejection of the null hypothesis at the 5% significance level.</td>
</tr>
</tbody>
</table>

To accomplish the analysis of the long-run properties of the data, we now proceed with testing for the cointegrating relationship between \( r_r \) and \( w_r \) by employing the well-known Johansen (1988, 1991) maximum likelihood procedure in a vector autoregression comprising \( r_r \) and \( w_r \). Both Johansen likelihood ratio (LR) test statistics based on the maximum eigenvalue and on the trace of the stochastic matrix, respectively, clearly indicate that a cointegration relationship exists for both price series under investigation. Besides, according to the cost of carry model, the hypothesis of the restriction on cointegrating parameter equal to unity in Johansen cointegration test can not be rejected at the 5% level. The results in Table 3 show that there exists a unique cointegrating vector such that the long-run equilibrium relationship between the retail price and the wholesale price for the broilers and that the estimated value of cointegrating parameters is 1.0002 for the retail price and the wholesale price, which implies the two price series for the broilers co-move in the long run and hence the cost of carry model holds.
C. Linearity Tests and Specification of Nonlinear Models

According to Michael et al. (1997) and Monoyios and Sarno (2002), when determining the optimal lag number of AR(p), the partial autocorrelation function (PACF) rather than other information criteria such as AIC and SBC is employed as a selection criterion since the latter penalizes high-order terms.

Table 4 summarizes the results of linearity tests, which shows that the null of linearity has been rejected, at the standard significance level, and thus is in favor of the ESTAR specification when employing the Granger and Teräsvirta (1993) and Teräsvirta (1994) procedure for examining the model adequacy. Also, it is worthwhile to mention that this study finds the same evidence that there is a 4-6 week duration of production in chickens implied by

<table>
<thead>
<tr>
<th>Spread of</th>
<th>Lag Delay</th>
<th>( H_0 ): ( \beta_{3j} = 0 )</th>
<th>( H_{02}: \beta_{2j} = 0 )</th>
<th>( H_{03}: \beta_{1j} = 0 )</th>
<th>F statistic</th>
<th>Type of model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broilers</td>
<td>1 6</td>
<td>0.839</td>
<td>0.003*</td>
<td>0.602</td>
<td>3.158/0.028* ESTAR</td>
<td></td>
</tr>
</tbody>
</table>

Note: The values in cells for the nested tests \( H_{01}, H_{02} \) and \( H_{03} \) are P-values. An asterisk indicates the lowest P-value for the three tests. The threshold value for the linearity and the specification of the STAR model is 0.05.
the appropriate lag equal to one, which matches the observed price responses of the product cycle. The implication for a shorter duration is that the broiler product prices become more volatile than those of pork found in Lee et al. (2006).

D. Restricted ESTAR Model

To investigate the spread behavior of broilers of the cost-of-carry model with transaction costs, we employ the restricted ESTAR model in the reparameterization form as suggested by Michael et al. (1997) as follows:

\[
\Delta s_t = \alpha_0 + \rho s_{t-1} + \sum_{i=1}^{p-1} \alpha_i \Delta s_{t-i} + \{1 - \exp(-\gamma (s_{t-d} - c)^2)\} \{(\beta_0 + \rho^* s_{t-1} + \sum_{i=1}^{p-1} \beta_i \Delta s_{t-i})\} + \varepsilon_t \quad (12)
\]

\[
H_0^a: \alpha_0 = \beta_0 = c = 0
\] (13a)

\[
H_0^b: 1 + \rho = -\rho^* \quad \text{(for all } i=1, \cdots, p-1) \text{ given } H_0^a
\] (13b)

\[
H_0^c: \rho = 0 \text{ given } H_0^a \text{ and } H_0^b
\] (13c)

Since the series \(\Delta s_t\) are the mean-corrected deviations from equilibrium spread, the ESTAR model may be such that the restrictions of \(\alpha_0 = \beta_0 = c = 0\), thus implying that \(H_0^c\) holds. Next, \(H_0^b\) means that in the outer (arbitrage) band, when \(F(s_{t-d}) = 1\), \(s_t\) is a white noise, while \(H_0^c\) implies that when \(F(s_{t-d}) = 0\), the process of \(s_t\) in the inner (no-arbitrage) band has a unit root.

The upper part in Table 5 only reports the most parsimonious form of the estimated equations as in Eq. (12). Obviously, most of the estimated coefficients except for that of
transition parameter are significant at the 5% level. First, the parameter estimates shown in Table 5 have several important implications as follows. For the estimate of $\rho$, the first difference in the spread is significantly affected by the previous-period spread, thus indicating that when 1% changes in $s_{t-1}$ induce inverse changes in $\Delta s$, by 0.226%; in other words, 1% changes in $s_{t-1}$ cause 0.774% changes in $s_t$ in the same direction. Next, the estimate of $\beta_1$ equal to $-0.297$ shows that 1% changes in $\Delta s_t$ combined with the transition function lead to changes in $\Delta s_t$ by 0.297% in the opposite direction. Concerning the insignificant estimate of $\gamma$ representing the speed of transition in the spread when judged by its t-statistic, large changes in $\gamma$ have only a minor effect on the transition function, as indicated in Van Dijk et al. (2002), high accuracy in estimating $\gamma$ is not necessary. Finally, the threshold estimate of $c$ equals 0.855, which means that it has the long-run equilibrium level of the spread falling within two regimes.

According to Michael et al. (1997), the likelihood ratio statistics, $LR^a$, $LR^b$ and $LR^c$ are used in this study to test the null hypotheses of $H_0^a$, $H_0^b$ and $H_0^c$, respectively. The results from these $LR$ statistics shown in the lower part of Table 5 unanimously indicate that the relevant restrictions are clearly supported by the data of broiler price, which implies that when the equilibrium relationship between the retail price and wholesale price of broiler product exists, the spreads fall within stochastic bands where the spread seems to be mispriced due to bargaining power in the oligopolistic broiler product market, information asymmetries and other market imperfections such as quotation system and trading customary. In this study, an incorporation of transaction costs, as suggested by Dumas (1992), Michael et al. (1997), Monoyios and Sarno (2002), would make the adjustment process of the spread to exhibit nonlinear features. Therefore, transaction costs considered may result in the existence of the outer band for the broiler product market, which produces arbitrage incentives for which profitable trading opportunities are possible. Specifically, when the spreads are outside the band, the existence of arbitrage opportunities induces wholesale traders to buy broiler products.
from original suppliers and then sell them to retailers until excess profits over normal levels in this industry disappear.

However, there has been a very hot issue between wholesalers and retailers in the Taiwanese broiler product market for a long time. The seven largest wholesalers with an 80% market share have high bargaining powers in the oligopoly market. Persistent arguments from the retailers who are the downstream firms to resell the broiler products to end users (consumers) are that the excessive spreads or economic profits the wholesalers have made seem to give the retailers much pressure to raise the retail prices or even lessen the already small profits, and that the conflicts of interest between them might have resulted in making a stand against the authorized institution. Based on the practical experience above, the results obtained in this study suggest that the fair scheme for trading the broiler products should be established as soon as possible so that the policy maker can monitor effectively the environment for market trading to ensure the achievement of market efficiency.

We are also interested in the behavior of the estimated residuals. From the middle part in Table 5, it can be seen clearly that the residual diagnostic tests are in general satisfactory since the p-values for the Jarque-Bera test statistic (JB), the Ljung-Box autocorrelation test statistic (Q(12)), and the autoregressive conditional heteroscedasticity test statistic (ARCH(4)) are virtually larger than 0.05. Next, for checking the adequacy of the ESTAR model describing the nonlinearily symmetrical dynamics in the spread of broilers, it is necessary to graph the estimated transition function for the spread as plotted in Fig. 2. Almost the observations for the spreads are scattered above and below the equilibrium level (0.855). We therefore are reasonably convinced that the selection of the ESTAR model is appropriate in this study investigating the nonlinear behavior of the broiler spread.
Table 5. Restricted ESTAR model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coefficient</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho$</td>
<td>-0.226</td>
<td>0.012</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>-0.297</td>
<td>0.002</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>2.12</td>
<td>0.116</td>
</tr>
<tr>
<td>$c$</td>
<td>0.855</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Diagnostic tests:

<table>
<thead>
<tr>
<th>Test</th>
<th>Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>JB</td>
<td>0.171</td>
</tr>
<tr>
<td>Q(12)</td>
<td>0.133</td>
</tr>
<tr>
<td>ARCH(4)</td>
<td>0.416</td>
</tr>
<tr>
<td>$LR^a$</td>
<td>3.674</td>
</tr>
<tr>
<td>$LR^b$</td>
<td>2.735</td>
</tr>
<tr>
<td>$LR^c$</td>
<td>0.325</td>
</tr>
</tbody>
</table>

Notes:
1. The number in parentheses denotes p-value.
2. $LR^a$, $LR^b$, $LR^c$ are likelihood ratio test statistics corresponding to the tests of Eqs. (13a)-(13c) (with degrees of freedom three, p, and one), respectively.
3. JB, Q(n) and ARCH(n) are the Jarque-Bera normality test, the Ljung-Box autocorrelation test and the autoregressive conditional heteroscedasticity test of Engle (1982).

Spread transition

Figure 2. Estimated transition function
V. Concluding Remarks

Following the nonlinear ESTAR model developed by Granger and Teräsvirta (1993), Terasvirta (1994) along with Dumas (1992), Michael et al. (1997) and Monyios and Sarno (2002), we examine empirically the dynamic relationship between the retail price and wholesale price and nonlinear behavior of the spread of broiler products based on the cost-of-carry model. In this study, the existence of transaction costs makes it possible for the spread of broilers to adjust toward its equilibrium value nonlinearly rather than linearly.

This study also finds the cointegrating relationship between the retail price and wholesale price of broilers exists. Except for some institutional factors such as inefficient quotation system, information asymmetry and marketing rigidity, which might distort the market mechanism and result in structural changes as indicated in literatures, the existence of transaction costs may lead to the fact that the spreads are outside stochastic bands so that they are mispriced. In this case, the presence of positive spreads induces the wholesalers to enter the market to implement profitable arbitrage activities, which eventually forces the spreads to restore to their equilibrium levels. Previous authors have long questioned the efficiency of the agricultural product markets and thus have been motivated to analyze the possibility of arbitrage activities in these markets. As stated above, market imperfections such as the existence of transaction costs, bargaining power, information asymmetry and the restriction on minimum purchase make the spreads to display the nonlinearity process, thus providing some plausible explanations of the equilibrium relationship between wholesale and retail prices. Along the line of this argument, we suggest that the government may consider to grant more licenses to potential wholesalers in allowing for high competition in the broiler product market, and that the fair schemes for trading the broiler products should be established as soon as possible so that policy makers can monitor effectively the environment for market trading to guarantee the achievement of market efficiency.

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交易成本與套利的非線性動態探討：台灣肉雞市場的實證

梁晉嘉*、林正寶**

摘要


關鍵詞：非線性均值回復、交易成本、肉雞的價差、指數平滑轉換自我迴歸模型

JEL 分類代號：C22, Q13, Q18

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