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Vertical Price Transmission in the China's Layer Industry Chain: an Application of FDL Approach

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Abstract

This paper examines the vertical price relationship between upstream and downstream products in China's layer industry chain by estimating elasticity coefficients of the price transmission. We use cointegration tests, error correction models and finite distributed lag models to analyze vertical price shifts between corn, layer feed, egg-laying chicken and egg prices. With monthly data from 1994 to 2010, our results show that various prices in China's layer industry chain are well integrated. In addition, our results indicate that both long-run and short-run price relationships between upstream and downstream products in layer industry chain exist and the long-run equilibrium, to a certain extent, may eliminate the short-run dynamics price deviation. We also found that the influence of corn and feed prices on egg prices is still more remarkable than egg-laying chicken prices. Our findings imply that governments should pay more attention to corn and layer feed prices in order to stabilize egg prices under the conditions of market integration.

Key words: finite distributed lag model, vertical price transmission, layer industry chain, China

INTRODUCTION

Since the reform and opening up in 1978, China's economic system has changed significantly, and agricultural circulation system has developed rapidly. Before 1980, China had a restrictive state-run food system; some foods were sold at a fixed price in cities. After 1980, a series of market policies were introduced and the state-run system was dismantled (Huang and Rozelle 1998). Since then, China's agri-food market has experienced a gradual liberalization, moving from a state-owned system to a more diversified system. Along with market openness continues to expand, agricultural circulation system realized by plans to free markets regulated the circulation system of comprehensive conversion in 1992, the price of vegetables, fruits, edible oil, meat, eggs and sugar released in nationwide and executed market regulation. The changes in agricultural circulation system have greatly promoted agricultural production and development of circulation system, especially a multi-channel circulation system, not only enriched the market supply of farm products but also improved the managerial efficiency of agricultural markets.

With continuing institutional changes, agriculture and rural development, however, are facing more uncertain factors and more serious market risks (Zhang 2010). In recent years, prices of fresh agri-food, such as vegetables, fruits, meat, and eggs, were experiencing high volatility. According to the monitoring by Ministry of Agriculture of China, the changes of China agricultural product wholesale prices index show "N" shape during January 2005 to April 2010, increasing from 123.2

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in January 2005 to 174.2 in February 2008, and then dropping to 147.5 in February 2008, and again jumping back to a high level in December 2008. The unstable price level has negatively affected the daily lives of the people and seriously challenged national macro-management. The high volatility of commodity prices has caught attention from all sectors of the society.

Over the past several decades, there is a large volume of empirical work conducted on evaluating the impacts of the market reform process in developing countries. These studies concern different aspects such as the supply response (Jayne and Jones 1997; Chilowa 1998), the level and welfare effects of prices (Barrett and Dorosh 1996; Alderman and Shively 1996), and the extent of market integration for agricultural and food products (Phlips 1962; Gardner and Brooks 1994; Abdulai 2000; Cudjoe *et al*. 2010; Ge *et al*. 2010). Market integration is commonly described as the situation where a commodity price from one market can enter the other market (Abdulai 2000; Sanjuán and Gill 2001; Sanjuán and Dawson 2003; Getnet *et al*. 2005; Ge *et al*. 2010). The analysis of vertical price linkages along the industry chain between upstream and downstream has become a popular tool of evaluating the efficiency in agri-food systems over recent decades (Miller and Hayenga 2001; Bakucs and Fertõ 2005; Bernhard Brümmera *et al*. 2009).

In the past 10 years, the literature on China's agricultural market price is part of a much larger and rapidly growing body of literature on price relationship that highlights both the development of new empirical methods and their application in various product and country settings. In the late 1990s, some Chinese scholars tried to use simple correlations, cointegration, and market contact index methods to analyse spatial price transmission relationship. Those studies mainly focused on the grain markets including rice, corn, and wheat (Wan *et al*. 1997; Yu and Huang 1998; Tian 1998; Wu 1999). Studies have shown that Chinese agricultural commodity between spatially separated markets exist cointegrating relationship, and the degree of market integration is continuously improved (Tian 1998; Yu and Huang 1998; Wu 1999). Sophisticated econometric techniques are applied to analyze vertical price relationship in recent years, mainly concerning with grain, vegetable, meat, and aquatic products markets (Fan *et al*. 2007; Wang *et al*. 2007; Wang and Chen 2009; Hu and Li 2010; Xu *et al*. 2010; Dong *et al*. 2011). With one exception (Li *et al*. 2010), none of them, however, focused on China's eggs market.

China is the world's largest producer of eggs, and the biggest consumer in the world. In 2010, the total production volume of eggs reached 27 650 thousand tons (National Bureau of Statistics of China, NBSC), accounting for over 40% of the world's total output. Major producing provinces include Hebei, Henan, Shandong, Hubei, Jiangsu, Sichuan, Heilongjiang, Hunan, Liaoning, and Anhui (Cao *et al*. 2010). The layer industry has become emerging major industry in the China's national economy, and been playing an important role for increasing farmers' income and promoting agricultural and rural development. Nevertheless, since 2007, the layer industry has experienced roller-coaster volatility, reducing small farmers' incentives of breeding. Although some studies have analyzed unilaterally the markets integration of corn, feed, layer, and egg (Tian 1998; Wu 1999; Cao *et al*. 2010; Li *et al*. 2010), so far, no system study on the four prices as a whole. Given the importance of layer industry and recent changes in egg markets, it is necessary to investigate the functioning of the vertical price relationship and the efficiency of price transmission in internal price system of layer industry. With a deep understanding of vertical price transmission, governments will be better able to manage high volatile prices in layer industry.

The objective of this article is to investigate a long-run and short-run relationship between upstream and downstream product prices in China's layer industry chain. The rest of the paper is structured as follows. Section 2 introduces an overview of the methodology used, including testing for unit roots, cointegration tests, error correction models, granger causality tests, and finite distributed lag models approach. A detailed description of our data set is given in Section 3. Empirical results and discussions are presented in Section 4. Finally, conclusions and implications are drawn in Section 5.

METHODOLOGY

The rate of price response is measured through the lag relationship between various prices. Since most economic and financial time series are not stationary, i.e., their mean and variance are not constant over time, the standard classical estimation methods, such as ordinary least squares (OLS) would lead to biased estimates or spurious regressions.

In economic literature, cointegration analysis has been commonly used to study market price relationship (Baffes 1991; Alexander and Wyeth 1994; Warell 2006; Motamed *et al*. 2008). Although many individual time series may not be stationary at levels, many of them exhibit the same stochastic trends, and tend to move together over the long run (Bakucs and Fertõ 2005). Two or more non-stationary variables are cointegrated if there exists a linear combination of these variables that is stationary. Cointegration implies that the stochastic trends of these variables are linked over time, indicating the existence of a long-term equilibrium relationship.

Several time series approaches will be used to examine the long-run and short-run price relationship in China's layer industry. First, the augmented Dickey Fuller (ADF) test is applied to test stationarity of time series. Second, a cointegration model is employed to investigate the existence of long-run equilibrium. Third, an error correction model is applied to examine if there is a short-run equilibrium for price series. Fourth, a Granger causality test is used to analyze the effect direction of these relationships. Finally, a finite distributed lag model is estimated to estimate the degree of price transmission. The statistical software STATA11.0 is used for empirical analysis.

Unit roots test

Unit root tests can be used to determine if trending data should be first differenced or time-trend regressed. In general, first differencing is appropriate for I (1) time series and time-trend regression is appropriate for I (0) time series. Furthermore, economic and finance theory often suggests the existence of long-run equilibrium relationships among nonstationary time series variables. That is, cointegration techniques can be used to model these long-run relationships only if these variables are I (1). Therefore, pre-testing for unit roots is the first step required for cointegration analysis.

To understand econometric issues associated with unit root and stationarity tests, let us consider the following autoregressive unit root tests process, AR (1):

$$y_t=\phi y_{t-1}+\mu_t \quad (1)$$

Where t=1, 2, 3···, ϕ is parameter to be estimated, and the μ_t is assumed to be white noise. If $|\phi|\geqslant 1$, y is a nonstationary series. In that case, the variance of increases over time and approaches to infinity.

Although there are several approaches to test for unit roots, we use the ADF test (Dickey and Fuller 1979, 1981). The test estimates the following equation (2) using OLS.

$$\Delta y_t=\alpha+\beta t+\varphi Y_{t-1}+\sum_{i=1}^{k}\delta_i\Delta Y_{t-k}+\nu_t \quad (2)$$

Where α is the drift term, β the intercept, t is the time trend variable, $\sum_{i=1}^{k}\delta_i\Delta y_{t-k}$ are lagged values of the independent variable to account for the autocorrelations in the residuals, and k is the number of lags which are added to the model to ensure that the residuals are white noise. Akaike information criterion (AIC) is then used to determine the optimal lag length k. Failure to reject the null hypothesis implies that the series is nonstationary.

Cointegration test

Each individual price time series must be tested for stationarity before using cointegration test. If two price time series are nonstationary and both follow an I (1) process, a cointegration test can be employed to determine the long-run relationship between two price time series. Unlike a regular regression method, a cointegration analysis is used due to its capacity of dealing with nonstationary variables.

One of the most popular cointegration test method, initially developed by Johansen (1988) and extended by Johansen and Juselius (1990), is based on maximum likelihood estimates of the cointegrating regression system as in the following equation:

$$\Delta y_t=\alpha+\psi x_t+\Pi y_{t-1}+\Gamma_i\sum_{i=1}^{p}\Delta y_{t-i}+\varepsilon_t \quad (3)$$

Where y_t is the vector to be tested for cointegration;

x_t is the vector of exogenous stationary variables; ψ, II, and Γ are coefficient matrices; p is the order of the lagged differenced dependent variables, also determined by AIC.

In this study, the Johansen maximum likelihood method is used to test for the presence of cointegrating longrun relationship among the four prices. If the four prices are cointegrated, the Johansen procedure permits hypothesis testing of a zero restriction on the coefficients in the cointegrating vector, using the likelihood ratio (LR) test which follows a chi-squared distribution. The Johansen likelihood ratio test is based on the rank of the coefficient matrix, and hypotheses with respect to different number of cointegrating vectors are tested by using the trace statistic. Seo (1998) demonstrates that the distribution of the cointegration rank test with stationary covariates is a mixture of a chi-squared distribution and a nonstandard distribution specified by Johansen (1988, 1991). Therefore, we obtain the asymptotic critical values from Seo (1998) for the cointegration rank test, in which several stationary exogenous variables are included.

Error correction model

The cointegration test considers only the long-run relationship between the time series, but it does not deal with the short-run dynamics explicitly. A good time series model should describe both long-run equilibrium and the short-run dynamics simultaneously. For this purpose, we use an error correction model (ECM), also called Engle-Granger two-step procedure for cointegration, to analyze the short-run dynamics of time series. To start, we run a cointegration regression of y on x in (4):

$$y_t=\beta_0+\beta_1 x_i+\mu_t \quad (4)$$

Then we defined the error correction term by

$$\hat{\mu}_t=y_t-\hat{\beta}_0-\hat{\beta}_1 x_t \quad (5)$$

Where $\hat{\mu}_t$ is the error from a regression of y_t on x_t, $\hat{\beta}_1$ is a co-integrating coefficient. Furthermore, we run an ECM regression of on and $\hat{\mu}_t$ in (6):

$$\Delta y_t=\alpha+\gamma\Delta x_t+\zeta\hat{\mu}_{t-1}+\varepsilon_t \quad (6)$$

Where $\hat{\mu}_{t-1}$ can be thought of as an equilibrium error (or disequilibrium term) occurred in the previous period. If the coefficient of $\hat{\mu}_{t-1}$ is non-zero, the model is out of equilibrium and vice versa.

Granger causality test

When a cointegration relationship is present for two time series, a Granger causality test can be used to analyze the direction of the co-movement relationship (Granger 1969). In principle, a time series x is said to Granger cause another time series y if changes in x happened first then and followed by changes in y. More specifically, if series x causes series y, two conditions must be satisfied: (1) x has predictive power when forecasting y, in other words, the regression of y on x has a large R^2; (2) y has no predictive power in x. In this study, the number of lags is consist with the determination of the lag length for vector autoregression model (VAR), it is determined according to AIC.

In order to determine the Granger causality relationship between two price series x and y (assuming two time series are stationary), we run the following two regressions, including the regression of y on x in equation (7) and the regression of x on y in equation (8):

$$y_t=\alpha+\sum_{i=1}^{m}\theta_i y_{t-i}+\sum_{j=1}^{n}\beta_j x_{t-j}+\varepsilon_t \quad (7)$$

$$x_t=\alpha+\sum_{i=1}^{m}\delta_i x_{t-i}+\sum_{j=1}^{n}\eta_j y_{t-j}+\varepsilon_t \quad (8)$$

Based on the estimated OLS coefficients for the equations (7) and (8), the following two hypotheses are tested:

Test 1: $\sum_{j=1}^{n}\beta_j=0$

Test 2: $\sum_{i=1}^{n}\eta_{i=0}$

A failure to reject hypothesis 1 means there is no Granger causality from x to y, and a failure to reject hypothesis 2 indicates that there is no Granger causality from y to x. Failure to reject both implies that x and y are independent.

Finite distributed lag model

Although Granger causality test demonstrates the direction of co-movement relationship for two price series, it does not analyze the specific quantitative relationship and time effect between two series explicitly. A finite distributed lag (FDL) model might be appropriate if we believe that one or more variables to affect y with a lag (Wooldridge 2006). So, when there exists Granger causality between two time series, we use a FDL model to further study the specific quantitative relationship and time effect between time series. Assuming that the effect of a change in a variable x affects y only for a fixed period of time, we define a FDL model by the following equation:

$$y_t=\alpha_0+\beta_0 x_t+\sum_{i=1}^{q}\beta_i x_{t-i}+\varepsilon_t \quad (9)$$

Where q is the (finite) number of lags to be considered. Here we assume that the errors are independent and identically distributed. The parameter β_0 captures the immediate change in y due to a unit in x at time t which is called as the impact propensity or impact multiplier. The long-term change in y given a permanent increase in x is called the long-run propensity (LRP) or long-run multiplier, LRP=$\beta_0+\sum_{i=1}^{q}\beta_i$.

Throughout the literature on FDL (or PDL) model, we find numerous assertions that the Almon method is the preferred method (Almon 1965; Cooper 1972; Fomby *et al*. 1988). So, in order to avoid the effect of multicollinearity, this study applies the Almon method to estimate of the FDL model.

DATA DESCRIPTION

The data used in this analysis is monthly observations of national average wholesale prices obtained from the Ministry of Agriculture of China. Key variables include four prices series in layer industry chain, that is, corn price (cp), layer feed price (fp), egg-laying chicken price (lp), and egg price (ep). The data cover the period from June 1994 to June 2010. Table 1 presents the descriptive statistics for key variables of the data.

Fig. presents the historical trends for prices of corn, layer feed, egg-laying chicken, and egg. All four price series show strong nonstationarity and similar patterns of changes over time. All prices are spot, expressed in RMB yuan kg^{-1} and converted to natural logarithms.

EMPIRICAL RESULTS AND DISCUSSION

Unit root tests

As a prerequisite for the cointegration analysis, we first checked the time series properties of the price series using the ADF test mentioned above. In 2002, the Chinese inland SARS happened, which caused heavy losses on layers industrial chain, and inner prices system of layer fluctuated fiercely. In order to compare the change of prices transmission mechanism, we divided the sample into two periods: June 1994 to December 2001 and January 2002 to June 2010. The unit root tests are carried out for each subsample.

Table 2 shows the results of the ADF tests for both the 1994-2001 period and the 2002-2010 period. All tests are specified with an intercept and a deterministic time trend. The results provide strong evidence of rejecting the null hypothesis of a unit root in all four price series in first differences, indicating that the four price time series display significant I (1) patterns. In addition, a time series plot in Fig. 1 seems to show a long-run co-movement relationship for the four series.

Table 1 Descriptive statistics of key variables (RMB yuan kg^{-1})

Variable	Number of observations	Mean	Standard deviation	Minimum	Maximun
Corn price	194	1.37	0.27	0.89	2.09
Layer feed price	194	1.97	0.28	1.49	2.62
Egg-laying chicken price	194	2.41	0.37	1.64	3.39
Egg price	194	6.75	1.07	4.80	9.24

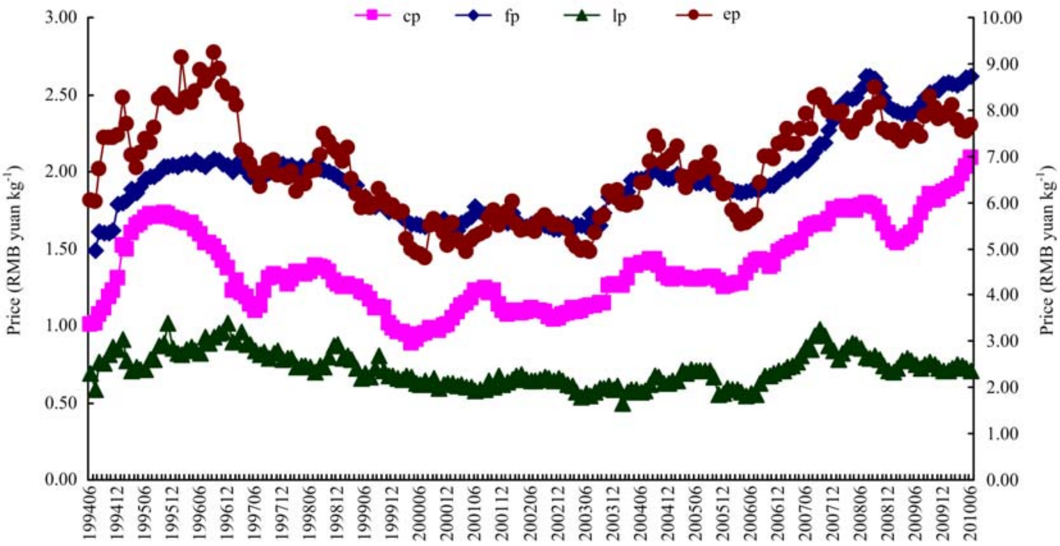

Fig. Time series plot of the price series in 1994-2010. The vertical axis on the left is for the price curves with cp and fp, the vertical axis on the right is for the price curves with lp and ep. Source: the Ministry of Agriculture of China.

Therefore, a cointegration analysis is conducted and a bivariate ECM is set up for the price system of layer industry chain in order to examine both long-run and short-run price equilibriums.

Cointegration test

To test for cointegration, a two-step approache, also known as the Johansen procedure, is used (Johansen 1988, 1991; Johansen and Juselius 1990). The method involves a system of likelihood ratio tests that can be implemented in two steps. Firstly, the optimal lag number of VAR model representation is determined using AIC. Secondly, the cointegration rank is then investigated through two different tests trace tests and maximum-eigenvalue tests, given the optimal lag length obtained at the first step.

Table 3 reports the cointegration test results. Based on the AIC criteria, two lags are chosen for the period of 1994-2001 and one lag is chosen for the period of 2002-2010. The trace test and maximum-eigenvalue test of the null hypothesis of the rank being two or more can't be rejected in either case at the 5% significance level in 1994-2001 period, and being one or more is accepted in either case at the 5% significance level in 2002-2010 period. Here, the data indicate the presence of two cointegrating vector among four price series in 1994-2001 period, and one cointegrating vector among four price series in 2002-2010 period, thus these four price series move jointly in the long term among two periods. In other words, although each of the series is nonstationary with level shift, they tend to move to-

Table 2 Test for unit root and stationary

Series[1)]	1994-2001 period			Series[1)]	2002-2010 period		
	ADF	Testing form[2)]	Testing result		ADF	Testing form[2)]	Testing result
lncp	-1.256	(c, t, 0)	Fail to reject	lncp	-1.947	(c, t, 0)	Fail to reject
lnfp	-1.826	(c, t, 0)	Fail to reject	lnfp	-1.583	(c, t, 0)	Fail to reject
lnlp	-1.734	(c, t, 0)	Fail to reject	lnlp	-1.929	(c, t, 0)	Fail to reject
lnep	-1.184	(c, t, 0)	Fail to reject	lnep	-2.064	(c, t, 0)	Fail to reject
Δlncp	-5.012***	(c, t, 0)	Reject	Δlncp	-5.467***	(c, t, 0)	Reject
Δlnfp	-7.891***	(c, t, 0)	Reject	Δlnfp	-7.530***	(c, t, 0)	Reject
Δlnlp	-11.666***	(c, t, 0)	Reject	Δlnlp	-9.229***	(c, t, 0)	Reject
Δlnep	-8.088***	(c, t, 0)	Reject	Δlnep	-7.774***	(c, t, 0)	Reject

[1)] The symbol Δ is a differencing operator.

[2)] c is a constant, t is the trend, k is lagging number (here k=0).

***, the reject of the null at 1% significance level.

Table 3 Cointegration test[1)]

Hypothesized no. of CE(s)[2)]	1994-2001 period			
	Trace test	5% critical value	Max-eigen test	5% critical value
None	83.13	47.21	48.49	27.07
At most 1	34.64	29.68	23.74	20.97
At most 2	10.89*	15.41	7.04*	14.07
At most 3	3.85	3.76	3.85	3.76
At most 4	-	-	48.49	27.07
Hypothesized no. of CE(s)[2)]	**2002-2010 period**			
	Trace test	5% critical value	Max-eigen test	5% critical value
None	51.63	47.21	28.02	27.07
At most 1	23.61*	29.68	14.52*	20.97
At most 2	9.08	15.41	9.00	14.07
At most 3	0.08	3.76	0.08	3.76
At most 4	-	-	28.02	27.07

[1)] Lags interval=2 in 1994-2001 period, lags interval=1 in 2002-2010 period for the four series (selected by AIC criteria).

[2)] Hypothesized no. of CE(s) is the same as rank under null hypothesis, here None shows r=0, At most 1 shows $r\leqslant 1$, At most 2 shows $r\leqslant 2$, At most 3 shows $r\leqslant 3$, At most 4 shows $r\leqslant 4$.

gether in the same direction for the long run and maintain a stationary linear relationship.

Error correction model

Tables 4 and 5 present the estimation results of error correction model under different specifications. In both 1994-2001 period and 2002-2010 period, egg price, layer feed price, and egg-laying chicken price adjustment parameters are significantly different from zero, while the corn price ECT is not statistically significant. So it can be hypothesized that the corn price, layer feed price, and egg-laying chicken price drove the egg price toward the equilibrium level, meanwhile, egg price also drove the layer feed and egg-laying chicken price toward the equilibrium, but it did not prompt the corn price. Moreover, the convergence to long-term equilibrium was not uniform throughout the analysed different periods, e.g., in 1994-2001 period, the magnitude of the egg-laying chicken price ECT coefficient (-0.5660 and -0.5021) indicates fast adjustment to long-term equilibrium, whereas in 2002-2010 period the correction coefficient (-0.1452 and -0.1489) indicates slower adjustment. The market adjustment trend of egg price and layer feed price is similar with egg-laying chicken price. Overall, we can gain insights that from upstream to downstream products among layer industry chain, the long equilibrium relationship can eliminate short-run dynamics deviation to a certain extent, but the speed of adjustment in 2002-2010 period is slower than in 1994-2001 period.

Granger causality test

The existence of cointegration relationships between these price series means that at least one of them Granger causes the other (Narayan and Smyth 2004). Hence, Granger causality test was carried out to find the direction of causality of these price relationships. Table 6 shows that test results of each price pair for

Table 4 Results of error correction model (1)[1)]

	1994-2001 period				2002-2010 period			
	Δep_1	Δep_2	Δlp_1	Δlp_2	Δep_1	Δep_2	Δlp_1	Δlp_2
Δep	-	-	0.3321**	0.1368	-	-	0.5851***	0.5856***
Δcp	0.4042***	-	-0.2795	-	0.3404**	-	0.1276	-
Δfp	-	0.7620***	-	0.5713*	-	0.5882***	-	0.1051
Δlp	0.2656***	0.1662*	-	-	0.3334***	0.3518***	-	-
ECT_{t-1}	-0.2709***	-0.3104*	-0.5660***	-0.5021***	-0.2299***	-0.1841***	-0.1452**	-0.1489**
Cons	-0.0027	-0.0038	0.0010	0.0010	-0.0009	-0.0008	-0.0005	-0.0002

[1)] ECT_{t-1} is the error correction term, and shows the long-term equilibrium relationship between response variables, the coefficience indicates variable equilibrium relationship of the deviation from the long-term equilibrium, the adjustment will be to a state of equilibrium adjustment speed; Δep_1 shows the regression results of egg price on corn price and egg-laying chicken price; Δep_2 shows the regression results of egg price on layer feed price and egg-laying chicken price; Δlp_1 indicates the regression results of egg-laying chicken price on corn price and egg price; Δlp_2 indicates the regression results of egg-laying chicken price on layer feed price and egg price. -, no data. ***, **, and * denote significance at the 1, 5 and 10% level, respectively. The same as below.

Table 5 Results of error correction model (2)

	1994-2001 period		2002-2010 period	
	Δcp	Δfp	Δcp	Δfp
Δep	0.1408*	0.0577	0.072	0.0483
Δcp	-	0.1809***	-	0.3974**
Δfp	0.7882***	-	0.6777***	-
Δlp	-0.0445	0.0675**	0.0308	-0.0253
ECT t-1	-0.0141	-0.1418***	0.0188	-0.1084***
Cons	-0.0001	0.0013	0.0032	0.0017

both periods. Most of the results tend to suggest a directional causation running between all price pairs for the period of 1994-2001. However, changes in layer feed price do not respond to changes in egg-laying chicken price and changes in egg price do not respond to changes in egg-laying chicken price. For the period of 2002-2010, the test results are different, only half of total price pairs suggesting granger causality.

Table 6 Granger causality test

Test[1)]	1994-2001 period			2002-2010 period		
	Chi-square	*df*	*P*	Chi-square	*df*	*P*
cp excluded fp	10.163	2	0.006	1.824	1	0.177
cp excluded lp	7.824	2	0.020	0.006	1	0.938
cp excluded ep	5.264	2	0.072	4.082	1	0.043
fp excluded cp	20.938	2	0.000	14.866	1	0.000
fp excluded lp	13.059	2	0.001	1.036	1	0.309
fp excluded ep	6.038	2	0.049	0.633	1	0.426
lp excluded cp	6.605	2	0.037	3.423	1	0.064
lp excluded fp	3.441	2	0.179	3.749	1	0.053
lp excluded ep	28.704	2	0.000	0.688	1	0.407
ep excluded cp	13.059	2	0.001	14.620	1	0.000
ep excluded fp	2.780	2	0.249	4.528	1	0.033
ep excluded lp	9.916	2	;0.007	0.388	1	0.533

[1)] The null hypothesis for this Granger causality test is no causality; *P* value shows that test are rejected at 10% significance level.

Finite distributed lag model

In order to gain further insight into how the upstream and downstream prices are dynamically interrelated, a FDL model was developed based on the results from the error correction models. The results of the FDL model, shown in Tables 7 and 8, display a number of interesting characteristics, include the interrelation between upstream product and downstream product (e.g., corn price-egg price, layer feed price-egg price and egg-laying chicken price-egg price). Here only the significant coefficients of variable are reported. Especially important are the equilibrium relationships and elasticity coefficient estimated based on these FDL models. The results indicate that the prices of upstream and downstream products have a consistent trend over time.

The relationship between cp and ep

The column (8) in Table 7 shows results of the impact propensity and the long-term propensity from corn price to egg price in 1994-2001 period. The estimate coefficients in Table 7 show that the direct impact of 1% increase (decline) of corn price causes 0.32% increase (decline) of egg price in short-term, and 1% increase (decline) in the price of corn will result in 1.07% increase (decline) of the egg price in long-term. The column (18) in Table 8 presents the transmission elasticity of both impact propensity and the long-term propensity from corn price to egg price in 2002-2010 period. The estimate coefficients show that the direct impact of 1% increase (decline) of corn price leads to 0.62% increase (decline) of egg price, and 1% increase (decline) in the price of corn will result in 1.37% increase (decline) of the egg price in a long-term. Comparing to the 1994-2001 period, the impact of upstream corn price on downstream egg price increased significantly in 2002-2010 period. Also, the column (2) in Table 6 and the column (12) in Table 8 indicate that direct impact of downstream egg price on upstream corn price. This results in a 0.15% increase in 1994-2001 period, and a 0.19% increase in 2002-2010 period, respectively.

The relationship between fp and ep

The results in Table 7 indicate that the direct impact of

Table 7 Results of finite distributed lag model in 1994-2001 period[1)]

	lncp (1)	lncp (2)	lnfp (3)	lnfp (4)	lnfp (5)	lnlp (6)	lnlp (7)	lnep (8)	lnep (9)	lnep (10)
Cons	-0.0013 (-0.41)	0.0011 (0.29)	0.0012 (0.59)	0.0014 (0.61)	0.0015 (0.71)	-0.0004 (-0.06)	-0.0009 (-0.12)	-0.0013 (-0.27)	-0.0011 (-0.22)	-0.0006 (-0.11)
lncp	-	-	0.2786 (5.22***)	-	-	-	-	0.3194 (1.9*)	-	-
$lncp_{t-1}$	-	-	-	-	-	-	-	0.3033 (1.78*)	-	-
$lncp_{t-2}$	-	-	-	-	-	-	-	0.4448 (2.57***)	-	-
lnfp	0.9466 (5.9***)	-	-	-	-	0.7773 (2.33**)	-	-	1.0323 (3.3***)	-
$lnfp_{t-1}$	0.6847 (4.59***)	-	-	-	-	-	-	-	-	-
lnlp	-	-	-	0.0758 (2.33**)	-	-	-	-	-	0.1604 (2.16**)
lnep	-	0.2365 (3.15***)	-	-	0.1486 (3.49***)	-	0.3135 (2.16**)	-	-	-

1) Only the significant coefficients of variable are reported. The same as below.

Table 8 Results of finite distributed lag model in 2002-2010 period

	lncp (11)	lncp (12)	lncp (13)	lnfp(14)	lnfp (15)	lnlp (16)	lnlp (17)	lnep (18)	lnep (19)	lnep (20)
Cons	0.0022 (1.21)	0.0062 (2.85***)	0.0057 (2.73***)	0.0015 (1.04)	0.0034 (2.08*)	-0.0016 (-0.31)	-0.0006 (-0.13)	-0.001 (-0.27)	0.0002 (0.05)	0.0026 (0.75)
lncp	-	-	-	0.4447 (7.11***)	-	0.4552 (2.03**)	-	0.6199 (3.6***)	-	-
$lncp_{t-1}$	-	-	-	-	-	-	-	0.3244 (1.77*)	-	-
$lncp_{t-2}$	-	-	-	-	-	-	-	0.4207 (2.58***)	-	-
lnfp	0.7106 (6.72***)	-	-	-	-	-	-	-	0.6558 (3.03***)	-
$lnfp_{t-1}$	0.2451 (2.34**)	-	-	-	-	-	-	-	-	-
lnlp	-	0.0868 (2.03**)	-	-	-	-	-	-	-	0.3465 (5.14***)
lnep	-	-	0.185 (3.39***)	-	0.1355 (3.04***)	-	0.6029 (5.14***)	-	-	-
$lnep_{t-5}$	-	-	-	-	0.0719 (1.67*)	-	-	-	-	-

a 1% increase (decline) of layer feed price generates a 1.03% increase (decline) of egg price in 1994-2001 period (Table 7, the column (9)), and a 1% increase (decline) of layer feed price generates a 0.66% increase (decline) of egg price in 2002-2010 period (Table 8, the column (19)). That is, comparing to 1994-2001 period, influence degree of upstream layer feed price to egg price decline significantly in 2002-2010 period. But the transmission elasticity from egg price to layer feed price nearly unchanged in two periods, the direct impact a 1% price increase (decline) of egg price generates a 0.15% price increase (decline) of layer feed price in 1994-2001 period (Table 7, the column (5)), and this coefficient is 0.14% in 2002-2010 period. (Table 8, the column (15)). Addition, the results in Table 8 also indicate that price is lagging transmission from downstream egg price to upstream layer feed price, the lag five egg price still impact layer feed price.

The relationship between lp and ep

We have compared the price relationship of egg-laying chicken and egg between 1994-2001 period and 2002-2010 period. The results clearly show that the downstream egg price responds to changes of upstream egg-laying chicken price. For the period of 1994-2001, the direct impact of 1% increase (decline) in egg-laying chicken price causes 0.16% increase (decline) in egg price (Table 7, the column (10)), while 1% increase (decline) in egg-laying chicken price generates 0.35% increase (decline) in egg price in the period of 2002-2010 (Table 8, the column (20)). Meanwhile, downstream egg price also affects upstream egg-laying chicken price. The direct impact of 1% increase (decline) in egg price generates 0.60% increase (decline) in egg-laying chicken price (Table 8, the column (17)), but the coefficients are 0.15 and 0.31% for layer feed price and egg-laying chicken price in the period of 1994-2002 (Table 7, the columns (5) and (7)), respectively. In 2002-2010 period, the direct impact of downstream egg price on corn price drops significantly, but the impact on egg-laying chicken price increases, however.

CONCLUSIONS AND IMPLICATIONS

While many empirical studies examined vertical price transmission in livestock markets in developed countries, our study focuses on how price of downstream product is formed and how vertical price transmission works in China's livestock market. We empirically analyzed the long-run and short-run relationship between the upstream product prices and the downstream product prices for China's layer industry chain. Under the cointegration framework, vertical price transmission was analyzed using a set of time series methods including Johansen's maximum likelihood approach, error correction model, Granger causality test and finite distributed lag model. In order to study the changes of price transmission over the past 16 years, we split our dataset into two periods, and carried out all tests for each period separately. Results indicate that the upstream products (corn, layer feed, and egg-laying chicken) and downstream product (egg) price in the China's layer industry chain move together in the long run. That is, they are cointegrated for both 1994-2001 and 2002-2010 period. Also, results from ECM show a statistically significant short-run dynamic between upstream product and downstream product. The significant coefficients of the equilibrium error terms in the ECMs confirm the existence of a nonspurious long-run relationship, especially from upstream product to downstream product. This means the long-run relationship among egg industry chain can eliminate short-run dynamics deviation.

In principle, our findings of market integration could suggest that any government market intervention is unnecessary. The problem of unstable prices under the conditions of market integration, however, calls for the role that governments can play in order to stabilize market prices. Hence, some governmental intervention is required to complement the integrated markets. The significant and stable vertical price relationships found in our estimations imply that intervention should target the upstream products prices due to their transitivity to the downstream product price. In other words, for China's layer industry chain, one possible measure to stabilize egg price might be to control corn price, layer feed price or egg-laying chicken price. Furthermore, we also found that the influence of corn and layer feed prices on egg prices is more remarkable than egg-laying chicken prices. The findings show that governments should pay more attention to corn and layer feed prices in order to stabilize egg prices under the conditions of market integration. By doing so, governments can avoid the cost of directly interventing egg price, but still can stabilize egg price through the vertical price transmission mechanism.

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