Dynamics of Price-Cost Margins in the U.S. Meat Industry

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Abstract

This study analyses the stochastic behavior of price-cost margins (PCMs) in the U.S. meat industry. It, first, develops and estimates a vertical relationship economic model to derive PCMs in the U.S. meat industry (Beef, Pork, and Poultry). Second it analyzes the behavior of PCMs by decomposing them into their seasonal, cyclical, and trend components using the state-space and the Kalman filtering methods. Price-cost margins in the U.S. meat industry are governed by two common trends and two common cycles. The study also found cyclical variability of PCMs is the highest with chicken, secular variability of PCMs is the highest with pork, while seasonal variability of PCMs is the highest with beef.

Key words: Vertical relationship, price-cost margins, market channel, meat industry, state-space Kalman filter.

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Introduction

The spread between retail prices and farm prices in the U.S. meat market has widened over the years. For instance, farm-retail price spreads for beef increased by 75% between 1990 and 2003 from $0.916/lb to $1.610/lb in absolute terms. Similarly, farm-retail price spread for pork increased by more than 81% between 1990 and 2003 and chicken price spread increased by only 13% during the same period (USDA, 2007). However, the U.S. per capita meat consumption did not change drastically between 1990 and 2003 (USDA, 2007), which raises concerns about the competitiveness of the U.S. meat industry[2].

Understanding the dynamics of the meat farm-price spreads and their implications is a key issue for policymakers, producers, meatpackers and retailers, and consumers. Policymakers use price spreads to measure efficiency and equity of a marketing system. Producers use these spreads, through the retail prices, as an information tool to better meet consumer's expectations and thus, to better market their products (Hahn, 2004). From a meat packer and retailer's point of view, the goal is to increase the value-added to the farm products in order to get the highest margins possible. In contrast, consumers seek lower retail prices, thus preferring lower price spreads.

Widening farm-retail price spreads for foods received a significant attention from researchers that attempt to explain the decline of consumers' dollar share allocated to producers. As researchers seek a better understanding of these dynamics, one explanation that emerged was the increased concentration level of the meatpackers and retailers, which implies the existence of market power at either or both levels of the marketing channel. As Morrison (2001) reported the share of the top four meatpackers reached 82% in 1994, raising questions about the effects of this

[2] Gardner (1975) argues that the markup pricing by marketing firms is related to the supply and demand shifts.

consolidation on retail prices and the prices received by livestock producers. Schroeter and Azzam (2000) addressed the issue of market power in a bilateral oligopoly where a concentrated manufacturing industry produces a product and sells it to a concentrated retailing industry. The study focused on the U.S. wholesale market for beef and revealed wholesalers are price-taker when they deal with retailers.

Another explanation to the widening farm-retail spreads suggested by the literature is the cost structure approach. These studies explore questions regarding the effect of cost efficiency gains on cattle producers and meat consumers. Morrison (2001), for example, focuses on the measurement of cattle input market power and cost economies while allowing for market power at the output level. The results indicate little market power exploitation in either the cattle input or beef output markets, and that any apparent evidence of market power is counteracted by cost efficiencies.

The objectives of this study are twofold. First we develop a model that computes retailers' implied price-cost margins (PCMs) in the U.S. meat industry and analyzes the behavior of these PCMs by decomposing them into their seasonal, cyclical, and secular components using the state-space and the Kalman filtering technique. We define retailers' PCMs as the difference between the retail price and the retail marginal cost, including the wholesale and the farm prices. Second, given the wholesale-retail and the farm-wholesale spreads, the non-meat marginal cost (excluding farm and wholesale prices) is derived. Implied PCMs and marginal cost are keys in terms of understanding to what extent market power versus cost efficiency offers a consistent explanation to the widening farm-retail meat spreads.

Conceptual Analysis and Model Derivation

The procedural approach follows two steps. First, an industry related demand for beef, pork and poultry is estimated using the Almost Ideal Demand System (AIDS) model of Deaton and Muellbauer (1980) for meat (beef, pork and chicken). Second, the demand results are used to compute the PCMs following the approach used in Chidmi and Lopez (2007). The non-meat marginal cost is also computed in this step. The derived PCMs are then decomposed into their permanent, seasonal, and transitory components using a multivariate unobserved component model cast in state-space model.

Demand

The Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980) is used to estimate a demand system for beef, pork and chicken. AIDS model is consistent with the adding-up, homogeneity and symmetry restrictions of the demand theory. The AIDS model is a flexible model that allows consistent aggregation of micro-level demands up to a market demand function, and does not require additive preferences (Eales and Unnevehr, 1988). Following Deaton and Muellbauer (1980), the AIDS model is specified as follows:

(1) $$w_i = \alpha_i + \sum_{j=1}^{n} \lambda_{ij} \ln p_j + \theta_i \ln(\frac{X}{P}),$$

where w_i is the budget share of the ith meat product, p_j are prices of the meat products, X is the total expenditure on all the meat products in the system, and P is a price index given by

(2) $$\ln(P) = \alpha_0 + \sum_i \alpha_i \ln p_i + \frac{1}{2} \sum_i \sum_j \lambda_{ij} \ln p_i \ln p_j .$$

As mentioned above, consistency with demand theory implies the following restrictions: adding-up (i.e., $\sum_i \alpha_i = 1, \sum_i \lambda_{ij} = 0$ and $\sum_i \theta_i = 0$), homogeneity (i.e., $\sum_j \lambda_{ij} = 0$) and symmetry (i.e., $\lambda_{ij} = \lambda_{ji}$).

Since the budget shares sum up to 1, one share equation is dropped from the system to avoid singularity and its parameter estimates were recovered by applying the adding-up, homogeneity, and the symmetry restrictions. The Marshallian price elasticities implied by the nonlinear AIDS model are given by

(3)
$$\frac{\partial q_i}{\partial p_j}\frac{p_j}{q_i} = \begin{cases} \dfrac{\lambda_{ij} - \theta_i(w_j - \theta_j \ln(\frac{X}{P}))}{w_i} - 1 & if \quad i = j \\ \dfrac{\lambda_{ij} - \theta_i(w_j - \theta_j \ln(\frac{X}{P}))}{w_i} & otherwise, \end{cases}$$

and the income elasticities are given by

(4)
$$\frac{\partial q_i}{\partial X}\frac{X}{q_i} = \frac{\theta_i}{w_i} + 1.$$

The model is estimated using iterative seemingly unrelated regressions model of Zellner (1962, 1963) . The beef and chicken expenditure share equations are estimated simultaneously with the price index *P*.

<u>Supply</u>

Considering the case where a retailer chooses the retail price for each meat category it sells to maximize his own profits in a horizontal Nash–Bertrand model of competition. The r^{th} retailer's profit function, which he seeks to maximize, is as follows:

(5) $$\pi_r = \sum_j (p_j - c_j) q_j \qquad \text{where} \quad j = \text{beef, pork, chicken}$$

where p_j is the retail price of the meat product *j*, c_j is the retail constant marginal cost for product *j* and q_j is the quantity of meat *j* consumed. The first-order conditions are given by

(6) $$q_j + \sum_k (p_k - c_k) \frac{\partial q_k}{\partial p_j} = 0,$$

Repeating the procedure for each retailer and stacking the solutions together, the implied PCMs are given by

(7) $$p_j - c_j = -\Delta_p^{-1} q_j$$

where Δ_p is the price response matrix with the elements given by $\Delta_{ij} = \frac{\partial q_j}{\partial p_i}$. Using equation (7), the Lerner indices are then given by

(8) $$L_j = \frac{p_j - c_j}{p_j}.$$

The non-meat marginal cost for each product may also be obtained from equation (7). Since the farm-retail spreads and the retail prices are observable, we can easily compute the marginal cost from the implied price-cost margins.

<u>*Multivariate Factor Model of Price-Cost Margins*</u>

Following Koopman et al. (2000), we proposed a generalized multivariate unobserved component model to capture the dynamics of price cost margins in the U.S. meat industry. With this modeling framework, PCMs are decomposed in their trend, cycle, and seasonal components. The evolution of these components is driven by their underlying stochastic properties, which are also captured in the model. Thus, each trend was specified as a stochastic level with a stochastic slope. Stochastic seasonal and cyclical components are also used as baselines in our modeling strategy. The overall model is specified as follows:

(9) $$\mathbf{Y_t} = \boldsymbol{\Theta_\mu \tilde{\mu}_t} + \boldsymbol{\tilde{\mu}_0} + \boldsymbol{\Theta_\psi \tilde{\psi}_t} + \boldsymbol{\gamma_t} + \boldsymbol{\varepsilon_t}$$

(10) $$\boldsymbol{\tilde{\mu}_t} = \boldsymbol{\tilde{\mu}_{t-1}} + \boldsymbol{\Theta_\beta \tilde{\beta}_{t-1}} + \boldsymbol{\beta_0} + \boldsymbol{\eta_t}$$

(11) $$\boldsymbol{\tilde{\beta}_t} = \boldsymbol{\tilde{\beta}_{t-1}} + \boldsymbol{\xi_t}$$

(12) $$\begin{bmatrix} \boldsymbol{\tilde{\psi}_t} \\ \boldsymbol{\bar{\tilde{\psi}}_t} \end{bmatrix} = \rho \left[\begin{pmatrix} \cos\lambda & \sin\lambda \\ -\sin\lambda & \cos\lambda \end{pmatrix} \otimes I_n \right] \begin{bmatrix} \boldsymbol{\tilde{\psi}_{t-1}} \\ \boldsymbol{\bar{\tilde{\psi}}_{t-1}} \end{bmatrix} + \begin{bmatrix} \boldsymbol{\omega_t} \\ \boldsymbol{\bar{\omega}_t} \end{bmatrix}$$

(13) $$\boldsymbol{\gamma_t} = \left(-\sum_{i=1}^{s-1} \gamma_{t-i} \right) \otimes I_n + \boldsymbol{\kappa_t}$$

where $\mathbf{Y_t}$ is a $n \times 1$ vector of PCMs, the vectors of time-varying parameters $\boldsymbol{\tilde{\mu}_t}$, $\boldsymbol{\tilde{\psi}_t}$, and $\boldsymbol{\gamma_t}$ represent the trend, cycle, and seasonal components and $\boldsymbol{\varepsilon_t}$ is the vector of irregular component, which drive the overall stochastic property of price-cost margins. The trend component is further decomposed in its level ($\boldsymbol{\mu_{t-1}}$) and slope components ($\boldsymbol{\tilde{\beta}_{t-1}}$). The stochastic properties of the trends are governed by the elements of $\boldsymbol{\eta_t}$. The slope component has a stochastic representation governed by the elements of the vector $\boldsymbol{\xi_t}$. The specifications used in equations (10) and (11) provide flexibility to the trend and enable the level and the slope to grow slowly overtime (Harvey et al., 1986). At steady state point, the level represents the actual value of the trend, while the estimated parameter of the slope is interpreted as its rate of growth. The cyclical components in equation (12) are specified as a succession of sine and cosine waves with the parameters $\rho \in [0,1]$ and $\lambda \in [0,\pi]$, referred to as damping factor and frequency of the cycles, respectively. Equation (13) illustrates the seasonal components specified as a summation of $s-1$ dummy variables ($s = 4$ for quarterly data). The stochastic nature of the cycles is governed by $[\boldsymbol{\omega_t}, \boldsymbol{\bar{\omega}_t}]'$, while that of the seasonal component is due to $\boldsymbol{\kappa_t}$. The coefficient matrices $\boldsymbol{\Theta_\mu}$, $\boldsymbol{\Theta_\psi}$, and $\mathbf{\Theta_\beta}$ are $n \times n$ factor loading matrices of the trend, cycle, and slope components with their respective elements θ_{ij} constrained to zero for all $i > j$ to ensure that the system is identified.

The error components in equations (9) through (13) are assumed to follow a normal distribution with mean zero and variance-covariance matrices $\mathbf{\Sigma_\varepsilon}$, $\mathbf{\Sigma_\eta}$, $\mathbf{\Sigma_\xi}$, $\mathbf{\Sigma_\omega}$, and $\mathbf{\Sigma_\kappa}$ for the irregular, level, slope, cyclical, and seasonal components, respectively. If the variance matrices of the level, slope, and/or cycle innovations are less than full ranks, this would be an indication of a presence of common factors in the model, which is accounted in the model through a rank reduction of the factor loading matrix and its corresponding components. Using the Choleski decomposition of the variance covariance matrix of these components, we can write

$$\mathbf{\Sigma_\eta = \Theta_\mu D_\eta \Theta'_\mu}, \mathbf{\Sigma_\omega = \Theta_\psi D_\omega \Theta'_\psi}, \ \mathbf{\Sigma_\xi = \Theta_\beta D_\xi \Theta'_\beta}, \ \mathbf{\Gamma_\eta = \Theta_\mu D_\eta^{1/2}}, \ \mathbf{\Gamma_\omega = \Theta_\psi D_\omega^{1/2}}, \text{ and } \mathbf{\Gamma_\xi = \Theta_\beta D_\xi^{1/2}}$$

with $\mathbf{D_\eta}$, $\mathbf{D_\omega}$, and $\mathbf{D_\xi}$ being the diagonal matrices with diagonal elements corresponding to the eigenvalues of the level, slope, and cyclical innovations' variance matrices. The rank reductions are also accounted through the coefficient matrices $\mathbf{\Theta_\mu}$, $\mathbf{\Theta_\psi}$, and $\mathbf{\Theta_\beta}$. The factor loading matrices measure the relationship between the derived PCMs and the k common trends and s common cycles. We applied the Harvey, Ruiz, and Shephard (1994) multivariate unobserved component approach to test for the presence of common factor in our model. In presence of common factors, the corresponding diagonal elements of the matrix $\mathbf{D}$ converge to zero. Thus, the number of non-zero columns in the variance matrices is the same as the number of non-zero elements in $\mathbf{D}$ and is the rank of the variance covariance matrix. This approach enables us to circumvent the difficulties pertaining to unit root tests because of the low power associated with methods based on autoregressive approximations such as the Dickey-Fuller test. Further information on this approach can be found in (Harvey, Ruiz, and Shephard, 1994; Luginbuhl and Koopman, 2004; and Koopman and Lucas, 2005).

The data used in this study were retrieved from the Economic Research Service (ERS) of the U. S. Department of Agriculture (USDA) website. The data are retail values and price spreads for beef, pork and chicken, which are converted into quarterly frequency to match the quarterly consumption data retrieved from the same website.

Empirical Results

Demand Analysis

The results for the demand system are reported in Table 1. For the most part, the coefficients of the demand system are significant. The results indicate that an increase in the expenditure of meat would increase the budget share for pork and chicken and reduce the budget share for the beef. The Marshallian price elasticities and the income elasticities are reported in Table 2. All own price elasticities are negative, as expected. These own-price elasticities indicate an inelastic demand for the three categories of meat. In terms of the pattern of substitution, the cross-price elasticities indicate that U.S. consumers substitute pork for chicken and *vice versa*, while beef is a complement to chicken and pork. As for the income elasticities, beef, pork, and chicken are normal goods.

Evolution of Price-Cost Margins

The parameters of the demand estimation were used to compute PCMs for each time period, using equation (7). Graphical representations (available upon request) show distinct paths in the evolution of PCMs for beef, pork, and chicken throughout the sample period. Price-cost margins for beef exhibit a relatively stable path from the first quarter of 1990 through the last quarter of 1993 after which it follows an upward trend through the second quarter of 1997. From the second quarter of 1997 onward, PCMs for beef have been on the decline. Price-cost margins for pork seem to follow the opposite path with an upward trend from the beginning of the sample period through the fourth quarter of 1995 then follow a downward path through the second quarter of 1997 and have been on the rise since then. For chicken, PCMs are relatively stable from the beginning of the sample period through the fourth quarter of 1995 followed by downward trend through the fourth quarter of 1998. Form the last quarter of 1998 onward, the evolution of PCMs for chicken has been relatively stable. Price-cost margins of the three meat categories were all positive. Descriptive statistics based on the parameters of central tendencies (Table 3) show no significant difference in the average PCMs for beef, pork, and chicken. While the ranges in PCMs are relatively similar for beef and chicken, that for pork is 8 cents/lb. higher. For the higher moments, PCMs are left-skewed for beef and pork and right-skewed for chicken while the excess of kurtosis is relatively the same for all three. Thus, downward spikes are more prevalent in beef and pork sectors than in the broiler sector. We attempted to gauge the instability in the beef, pork, and chicken PCMs though the instability index. The results show that PCMs in the beef sector are relatively more stable than PCMs in the pork and broiler sectors. We also derived descriptive statistics of marginal cost and the Lerner indices. On average, the broiler sector is more cost competitive with an average marginal cost amounting to 50.89 cents/lb. followed by the pork sector. This cost competitiveness may be attributed to higher efficiency gain compared to the other two sectors as a result of deeper integration of the production process through widespread use of contracts and greater coordination across pricing points (Bastian et al., 2002).

Co-Movements of Price-Cost Margins in the Meat Industry

Table 4 illustrates the results of a rank restriction test based on an unrestricted and a restricted multivariate unobserved component models. The eigenvalues of the trend disturbances converge to zero for pork, indicating the presence of common trends between the three price-cost margins. Similarly, the eigenvalues of the cyclical and slope disturbances converge to zero for chicken, indicating presence of common slope and common cycle as well. Because of common factors, the following rank restrictions were applied to our restricted multivariate unobserved component model: $Rank\left(\mathbf{\Sigma}_{\eta}\right)=2$, $Rank\left(\mathbf{\Sigma}_{\beta}\right)=2$, and $Rank\left(\mathbf{\Sigma}_{\omega}\right)=2$. The findings about the rank restrictions also suggest the three PCMs are integrated of order one and two stochastic trends drive their evolution. Thus, there is evidence of long run relationships between PCMs of beef, pork, and chicken.

The relationships between the trends and cycles of these PCMs are illustrated in Table 5. As evidenced by the magnitude of the factor loading of -4.45, PCMs of pork increases with a decline of PSMs for beef. The presence of common factor is indicative of cointegration between beef and pork sectors. This is corroborated by the correlation between their trend disturbances, which converge to -1.0 in both the unrestricted and the restricted models. Figure 1 displays the path of the trend, slope, cycle, and seasonal components of the three PCMs. Using the unstandardized factor loading, we derived the rotated factor loading by orthogonal transformation and computed the communality scores related to each component. Our results indicate that the two common trends account for 100% of the variability of beef PCMs and 97.9% of the variability of pork PCMs. As for chicken, PCMs follows an intrinsic dynamic as the low communality score indicates.

The results are somewhat similar with respect to the slope. As for the cycle, magnitude of the factor loading pertaining to chicken is evidence of co-cyclicality between PCMs for beef and that of chicken. The calculated communality scores pertaining to the cyclical component indicate that the two common cycles contribute up to 54.6% of beef PCMs short term variability, 78.3% of that of pork, and 67.1% that of chicken. Thus, unlike in the long run relationship where the poultry sector follows a dynamic of its own, in the short run, however, the three sector share common transitory features. The two common cycles explained at least 54.4% of variability of PCMs of the beef sector in the short run, 78.3% of the variability of PCMs in the pork sector , and 67.1% of the variability of PCMs in the broiler sector.

Stochastic Component Analysis

The estimated standard deviations of the disturbances associated with the irregular, trend, and cycle components capture the stochastic properties of PCMs in the livestock and poultry sectors. The stochastic component analysis reveals some interesting patterns regarding the after shocks behavior of PCMs in each sector. As Table 6 indicates, secular disturbances' variability is the highest for PCMs in the pork industry followed by the beef industry. However, cyclical disturbance variability is the highest in the chicken industry followed by the pork industry. As for seasonal disturbances variability, the beef sector exhibits instability the most followed by the chicken sector. We calculated the q-ratios between all innovation's variances relative to the trend disturbances and found that cyclical and seasonal disturbances dominate trend disturbances in the beef industry. The stochastic component analysis confirms the diminishing effect of seasonal shocks on PCMs in the pork and chicken industries. While the increased numbers of storage facilities have reduced the effects of seasonality in animal production, seasonal patterns still persist because of the effect of seasonal demand as Chevalier, Kashyap, and Rossi (2000) stated.

Analysis of the Final State Vector

The estimated final state vector (i.e., level, slope, cycle, and season) is presented in Table 7. The results show the level and slope pertaining to beef PCMs are significant at the 1 percent level. The level pertaining to chicken PCMs is also significant. While beef PCMS exhibit a downward stochastic trend, PCMs for pork and chicken do not show any significant growth path.

As for the cyclical component, statistical test was not conducted because the expected value of the cycle is zero. With respect to the seasonal components, there are significant differences between the last quarter (reference) and the remaining three quarters for PCMs in the three industries. These parameters of the state vector were used to compute the statistics presented in Table 8. With respect to the trend, the results indicate the trend value at steady state period is 77.2 cents/lb. for beef, 83.1cents/lb. for chicken, and $1.05/lb. for pork. The values of the slope are expressed in percent and indicate at steady state level, beef PCMs declined by 11.18% per year. While chicken PCMs remain relatively stable, pork PCMs appreciate by 4.5% per year. With respect to the cycle, the results express the value of the amplitude relative to the trend. Thus, for beef, the amplitude of the cycle represent approximately 3.97% of the trend while for pork and chicken the amplitude of their cycles represent 2.5 and 2.47% of there respective trends. As for the seasonal component, we present the deviation of the observed seasonal value relative to the trend. Thus, at steady state, PCMs in the beef industry are 3.71 and 11.91% below their trend line in the first and fourth quarters, respectively, and 7.19 and 9.99% above their trend line in the second and third quarters. For the pork industry, however, PCMs are 5 and 7.99% below the trend line in the second and third quarters and 2.83 and 11.25% above trend in the first and fourth quarters. For the broiler sector, PCMs are below their trend line in the second and third quarters and above the trend line in the first and fourth quarters. It transpires PCMs in the pork and chicken industries have similar seasonal behaviors. The periods of seasonally low PCMs in the beef sector correspond to those of seasonally high PCMs in the pork and broiler sectors. The reason for the counter seasonal behavior of PCMs in the beef sector versus the broiler and pork sectors may be due to difference in the length of the biological lag (shorter for pork and chicken) or the degree of efficiency gains in each sector.

Conclusion

First, an industry demand-related for beef, pork and chicken is estimated using an AIDS. Second, we consider the case where a retailer chooses the retail price for each meat category it sells to maximize his own profits in a horizontal Nash–Bertrand model of competition. The demand results are used to compute the PCMs and the marginal cost in each sector derived. The computed PCMs are then decomposed into their permanent, seasonal, and transitory components using a multivariate unobserved component model cast in state space. There is strong evidence of co-movement of PCMs in the U.S. meat industry. The overall pattern that emerges is that the degree of efficiency gain in each sector may be the determining factor shaping the evolution of these components.

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Table 1: Parameter Estimates of Meat demand System

		Beef		Pork		Chicken	
Variable	Parameter	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Intercept	α_i	0.787[a]	0.255	-0.296	0.229	0.509[a]	0.176
Price of Beef	λ_{ij}	0.169[a]	0.052	-0.023	0.056	-0.147[a]	0.018
Price of Pork	λ_{ij}	-0.023	0.056	0.103[a]	0.037	-0.0816[a]	0.0337
Price of Chicken	λ_{ij}	-0.147 [a]	0.018	-0.0816[a]	0.0337	0.228[a]	0.025
Expenditure	θ_i	-0.106 [c]	0.067	0.148[a]	0.060	0.957[a]	0.102
R^2		0.867		--		0.842	

The signs ([a]) and ([c]) illustrate significance at the 1% and 10% level. No R^2 was provided for pork because pork was dropped from the estimation and its parameters were recovered by applying the adding-up, homogeneity, and symmetry properties of the AIDS model.

Table 2: Marshallian Price Elasticities and Income Elasticities

	Expenditure Elasticities		Price Elasticities					
			Beef		Pork		Chicken	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Beef	0.774[a]	0.035	-0.443[a]	0.021	-0.112[a]	0.005	-1.078[a]	0.052
Pork	1.529[a]	0.098	-0.540[a]	0.037	-0.484[a]	0.036	1.497[a]	0.077
Chicken	4.874[a]	0.937	-0.001	0.354	0.770[a]	0.061	-0.193[a]	0.060

The sign ([a]) illustrates significance at the 1% level.

Table 3. Summary Statistics of Price Cost Margins in the U.S. Livestock and Poultry Sectors (U.S. Dollars/per Pound)

	Beef	Pork	Chicken
Mean	1.001	1.001	0.998
Maximum	1.241	1.302	1.310
Minimum	0.678	0.662	0.740
Standard Deviation	0.112	0.156	0.152
Skewness	-0.188	-0.255	0.150
Kurtosis	2.905	2.426	2.139
Instability index	11.154	15.543	15.284

Notes: Instability index refers to the coefficient of variation (in %).

Table 4. Eigenvalues of the Diagonal Matrices under the Unrestricted Model

Components	Price Cost Margins		
	Beef	Pork	Chicken
Irregular ($\mathbf{D}_{\varepsilon}$)	0.014	0.026	0.016
Percentage (%)	25.00	46.43	28.57
Trend ($\mathbf{D}_{\eta}$)	0.011	0.000	0.007
Percentage (%)	61.11	0.00	38.89
Slope ($\mathbf{D}_{\xi}$)	0.004	0.003	0.000
Percentage	57.14	42.86	0.000
Cycle ($\mathbf{D}_{\omega}$)	0.011	0.012	0.000
Percentage (%)	47.83	52.17	0.000

Notes: The estimates correspond to the eigenvalues of the variance matrices of the irregular, trend, and cycle components. The number of nonzero eigenvalues is the rank of the corresponding matrix. The unrestricted log-likelihood value (LogL) was evaluated at 455.046.

Table 5. Estimated Factor Loadings (Θ_μ, Θ_β, and Θ_ψ) and Communality Scores of the Trend and Cycle of Price Cost Margins

		Standardized		Unstandardized		Rotated		Communality
Component	Price Cost Margin							
	Beef	1.000	0.000	0.011	0.000	0.217	0.976	1.000
Level	Pork	-4.450	1.000	-0.048	0.000	-0.966	0.216	0.979
	Chicken	-0.661	0.146	-0.007	0.000	-0.143	0.021	0.021
	Beef	1.000	0.000	0.004	0.000	0.785	0.586	0.959
Slope	Pork	-0.747	1.000	-0.003	0.003	-0.586	0.807	0.996
	Chicken	-0.257	0.068	-0.001	0.000	-0.202	-0.066	0.045
	Beef	1.000	0.000	0.011	0.000	0.682	0.284	0.546
Cycle	Pork	0.138	1.000	0.002	0.012	0.094	0.880	0.783
	Chicken	-1.062	0.812	-0.012	0.010	-0.725	0.381	0.671

Notes: The matrices Θ_μ, Θ_β, and Θ_ψ measure the contribution of the each common level, slope, and cycle to the variance of each price cost margin. The communality score measure the contribution of the two common levels, slopes, and cycles to the variance of each price cost margin. The restricted log-likelihood value was evaluated at 457.844.

Table 6. Estimated Standard Deviations of Disturbances

Components	Beef		Pork		Chicken	
	Std. Deviation	q-Ratio	Std. Deviation	q-Ratio	Std. Deviation	q-Ratio
Irregular (σ_{ε})	1.099	1.021	3.149	0.650	2.018	2.839
Level (σ_{η})	1.076	1.000	4.384	1.000	0.711	1.000
Slope (σ_{ξ})	0.404	0.375	0.432	0.089	0.104	0.146
Cycle (σ_{ϖ})	1.091	1.014	1.239	0.256	1.541	2.167
Season (σ_{κ})	1.360	1.264	0.042	0.088	0.792	1.115

Notes: All standard deviation estimates are multiplied by 100. The q-Ratios measure the importance of each disturbance relative to the level disturbance. The parameters of the cycle are a damping factor ρ estimated at 0.941, a period $2\pi / \lambda$ evaluated at 3.81years, a frequency λ estimated at 0.412.

Table 7. Maximum Likelihood Estimates of the Final State Vector

		Beef		Pork		Chicken	
Variable	Parameter	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Level	μ_T	-0.256[a]	0.023	0.055	0.036	-0.184 [a]	0.014
Slope	β_T	-0.027 [a]	0.009	0.011	0.014	-0.001	0.002
Cycle	ψ_T	0.000	0.018	0.000	0.023	-0.000	0.019
	$\bar{\psi}_T$	-0.051	0.021	-0.031	0.026	0.031	0.009
First Quarter	γ_{T-1}	-0.126 [a]	0.013	0.106 [a]	0.011	0.137 [a]	0.028
Second Quarter	γ_{T-2}	0.095 [a]	0.009	-0.083 [a]	0.010	-0.053 [a]	0.007
Third Quarter	γ_{T-3}	0.069 [a]	0.008	-0.051 [a]	0.010	-0.085 [a]	0.007
Q(12)		11.675		12.037		5.008	
H(17)		0.791		0.364		0.543	
Rs^2		0.163		0.047		0.262	

The signs ([a]) illustrate significance at the 1% level. The statistic Q(12)is less than $\chi^2(12)$ at the 1% level, which indicates a failure to reject the null of no autocorrelation. The statistic H(17) is less than $F_{17.17}$ at the 1% level, which indicates a failure to reject the null of no heteroskedastic residuals. The goodness of fit Rs^2 refers to the coefficient of determination based on deviations around the seasonal means.

Table 8. Component Analysis at Steady State Period

	Beef		Pork		Chicken	
	Value	Percentage	Value	Percentage	Value	Percentage
Trend	0.773	---	1.056	---	0.831	---
Slope	---	-11.185	---	4.467	---	-0.687
Cycle	---	3.971	---	2.503	---	2.473
First	0.962	-3.713	1.028	2.835	1.001	0.147
Second	1.071	7.193	0.949	-5.001	0.917	-8.204
Third	1.099	9.991	0.920	-7.991	0.948	-5.169
Fourth	0.881	-11.914	1.112	11.253	1.147	11.472

Notes: The value of the trend (in U.S. Dollars per pound) is found by exponentiating the level coefficient on Table 5. For the slope, an annual percentage rate is provided, which represents the annual growth rate of the trend. As for the cycle, the results pertain to the amplitude relative to the corresponding trend value. As for seasonality, the values represent seasonal factors and the percentages represent the percentage of the observed seasonal value above or below the trend line.

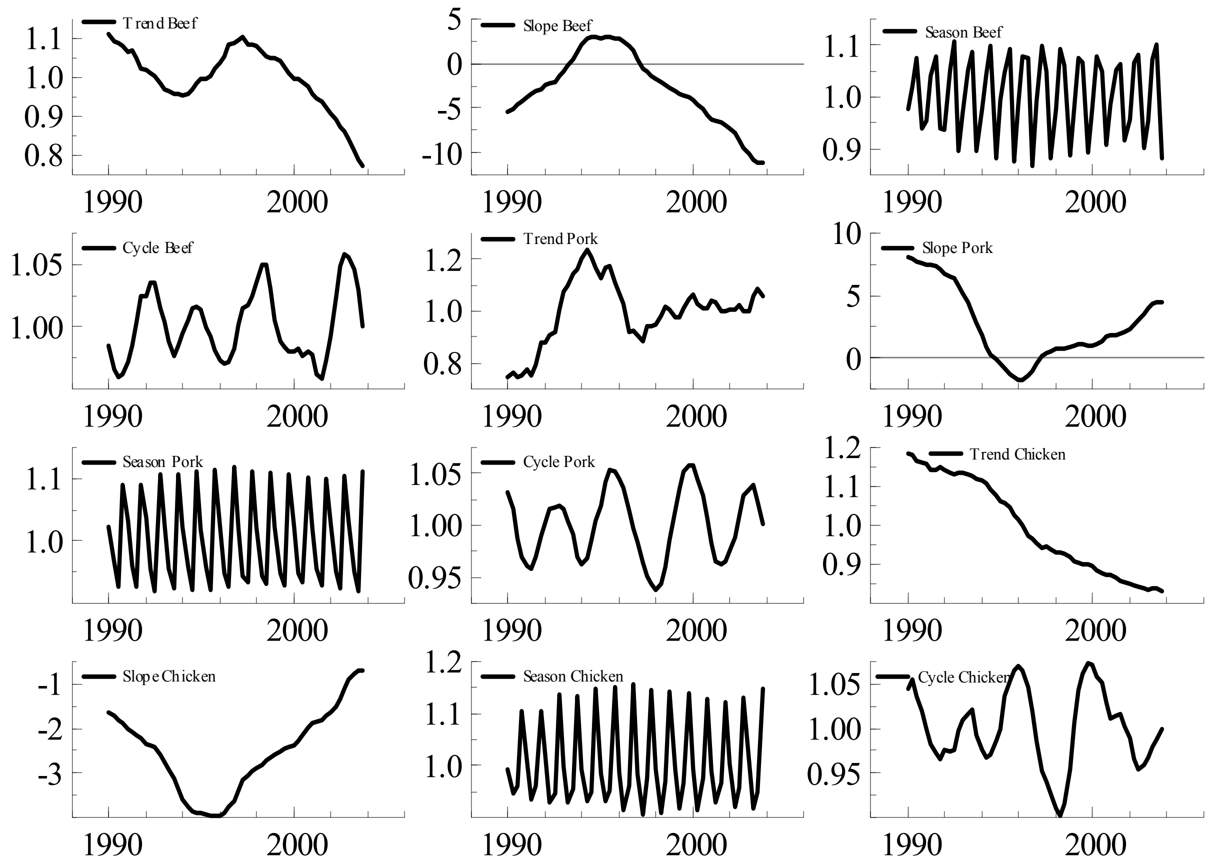

Figure 1. Estimated Trend, Slope, Cycle, and Seasonal Components of Price-costs Margins in the U.S. Meat Industry, 1990:Q1-2003:Q4