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The Cyclical Nature of the U.S. Sheep Industry

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The cyclical nature of numbers and prices of sheep and lambs was examined from 1924 through 1993. Tests for structural change also were conducted utilizing the minimization of Akaike's information criterion (MAIC). Results indicate that cyclical length in both stock sheep numbers and lamb prices has decreased over time, with a current 10- and 27-year cycle in stock sheep numbers and nine- and 27-year cycle in lamb prices. Structural changes occurred in 1951 and 1968 for stock sheep numbers and in 1952 and 1972 for lamb prices.

Key words: inventory and price cycles, MAIC, structural change.

Introduction

From 1942 to 1993, the sheep industry suffered an 84% decline in the number of stock sheep. While several hypotheses have been developed to explain the decline in sheep numbers, such as labor shortages, predator problems, and declining demand, few conclusions have been reached. Producer organizations and the U.S. Department of Agriculture (USDA) have initiated several studies and attempted to implement programs aimed at revitalizing the industry. To date, the decline in stock sheep numbers may have slowed down, but the sheep industry, as yet, has not returned to a growth mode. Given current legislation which eliminates the wool incentive subsidy and the proposed increases in federal grazing fees, the political environment does not appear conducive to a revitalization of the sheep industry.

A lack of information concerning the sheep industry has been cited by Purcell, Reeves, and Preston as a hindrance in developing industry policies and strategies to effectively enhance the economic viability of sheep production. The Texas Agricultural Market Research Center (TAMRC) Lamb Study Team, along with Purcell, Reeves, and Preston, suggested that further study needs to be undertaken on the demand as well as the supply side of the lamb industry. For example, the comparative profitability of sheep to other enterprises is still in question as well as the ability of a sheep enterprise to reduce risk in a whole-farm context. The possibilities of deriving extra profits from retained ownership of lambs and analysis of production alternatives are areas also in need of examination.

The purpose of this research is to determine if a recurring long-term cyclical element has existed in lamb prices and in inventory levels of U.S. stock sheep. The long-term cyclical nature of the sheep industry is an important consideration in research, forecasting, and long-term planning. Examination of production alternatives and supply responses often requires an identification of the cyclical nature of prices and/or inventories. An understanding and realization of the cyclical nature of sheep inventories and prices also could assist producers, marketers, suppliers, and consumers of sheep products in determining marketing strategies, price risk management strategies, and production decisions.

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Production and Price Cycles

Production and price cycles exist for several agricultural commodities. While little has been written concerning the cyclical nature of the U.S. sheep industry, the beef cattle cycle, which occurs every nine to 12 years with a 10-year average cycle, is a well-known phenomenon (Franzmann 1971; Ginzel). A pronounced four- and 28-year price cycle also has been identified in the hog industry (Franzmann 1979), and a five- to seven-year cycle in the landings and prices of oceanic fish (Waugh and Miller).

Livestock cycles result from lagged responses created by both biological and economic phenomena. When prices are high, producers are optimistic and retain females, which reduces supplies and further solidifies their optimism. Because of the necessary biological lag between the breeding decision and increased slaughter, increased numbers of fed livestock are delayed, but ultimately are ready for slaughter. Eventually the market is saturated, prices fall, and producers start liquidating females, which further depresses prices. After the liquidation process abates, prices are bolstered and the cycle resumes. Random factors such as weather or war also may be responsible for the initiation or modification of a livestock cycle.

A "long cycle" (28 years) associated with the regular four-year cycles in hog prices has been identified, though not explained, by Franzmann (1979). While this is the only reference to a long cycle in livestock production of which the authors are aware, the long cycle or wave phenomenon often is referred to in the business literature. The common business cycle seems to occur with regularity every four years, but is amalgamated with a longer-run cycle of 15 to 25, and even up to 54 years (Mullineux; Sherman; Stoken). Long cycles have been explained by everything from sun spots to the interaction between risk averters and risk takers [where changes in people's confidence and extended prosperity affect their willingness to undertake economic risk and/or search for pleasure, which in turn fuels economic expansions and contractions (Stoken)]. Many researchers also feel that long cycles are the result of exogenous, random shocks and are not endogenously determined (Mullineux). Sherman explains that "rather than long waves—capitalism has passed through various stages and that the business cycle shows important differences in these stages" (p. 8). He cites, as an example, the U.S. economy which was "characterized by very small economic units at one time, but is now in a stage characterized by giant corporations" (p. 9).

Methodology and Data

Harmonic Regression Models

Harmonic regression models have been used by several researchers to project potential cyclical paths for cattle prices (Franzmann and Walker; Gutierrez). These models have accounted for seasonal variation, cyclical variation, and a long-term linear trend. The general harmonic model, as adapted from Franzmann and Walker, is:

$$(1) \qquad P_t = B_0 + B_1 2\pi t + B_2 \mathrm{Sin}(2\pi t/L1) + B_3 \mathrm{Cos}(2\pi t/L1) + B_4 \mathrm{Sin}(2\pi t/L2) + B_5 \mathrm{Cos}(2\pi t/L2) + \mu,$$

where P_t is the price or inventory level in time period t (with N time periods), B_0 is the intercept, B_1 is the coefficient for the linear trend, B_2 and B_3 are the seasonal component coefficients, B_4 and B_5 are the cyclical component coefficients, $L1$ is the specified seasonal cycle length in months, $L2$ is the specified long-term cycle in months, and μ is the normally distributed error term with, following Johnston, zero expectations [$E(\mu_t) = 0$ for all t] and constant variance [$E(\mu_t^2) = \sigma^2$ for all t], with μ_t values pairwise uncorrelated [$E(\mu_t \mu_{t+s}) = 0$ for $s \neq 0$].

Several adjustments to equation (1) can be made to make it more adaptive to different situations. First, the seasonal components ($L1$) can be dropped when examining a yearly

data series such as the stock sheep inventory. Second, when more than one long-term cycle is found (e.g., a four-year and 28-year cycle in hogs), additional sine–cosine terms with the appropriate cyclical length in months (L) can be added to the equation. Third, with time-series data, serial correlation in the error term μ is often a concern. In such cases, the error term μ often follows a first-order autoregressive scheme:

$$\mu_t = \rho\mu_{t-1} + \xi_t, \tag{2}$$

where ξ satisfies the assumptions of μ in the preceding paragraph and $|\rho| < 1$ (Johnston). With monthly time-series data, the error term μ also can follow a first- and twelfth-order autoregressive scheme:

$$\mu_t = \rho_1\mu_{t-1} + \rho_{12}\mu_{t-12} + \xi_t. \tag{3}$$

A generalized least-squares (GLS) estimator typically is used to correct for serial correlation (Johnston).

Determining Structural Change

When cyclical behavior of stock numbers and prices over several decades is examined, the possibility exists that at least one structural change may have occurred. Because basic variables that affect lamb supply and demand are not specified and a structural model estimated (see Whipple and Menkhaus), shifts in economic or production variables cannot be examined. Rather, structural change "should be interpreted as having purely statistical meaning, although the statistical meaning would have economic meanings" (Akiba and Waragai 1989a, p. 28). While structural changes may not always change the cyclical nature of stock numbers or prices, they very easily can change the nature of price movements, making it difficult to accurately forecast movements in the commodity price or inventory (Akiba and Waragai 1989b).

To identify particular points of structural change in stock sheep numbers and in lamb prices, minimization of Akaike's information criterion (MAIC) was utilized (Akiba and Waragai 1989a). This method employs an autoregressive (AR) model, which is especially useful in determining structural change when causality relationships with other variables are ambiguous or unknown. Using the MAIC method to determine structural change also helps eliminate "arbitrariness arising from determination of the significance levels, since the MAIC is a powerful alternative to the test of hypothesis method, and arbitrariness arising from specification of regression models, since only a time series model is employed" (Akiba and Waragai 1989b, p. 27).

The first step in implementing the MAIC method is to eliminate any time trend components in the data. The residuals (μ) from the harmonic regressions meet this criterion. Following Akiba and Waragai (1989a), it is assumed that the random process [$\mu(t)$] could be generated from an AR model as:

$$\mu(t) = \sum_{i=0}^{p} a_i\mu(t - i) + \epsilon(t), \tag{4}$$

where p is the order of the AR model; a_i denotes the coefficients; and the disturbance, $\epsilon(t)$, is white noise, $N(0, \sigma^2)$. Akiba and Waragai (1989b) suggest that the order of the AR model be determined by selecting the order with the lowest AIC, since AIC is "an information measure that indicates the poorness of fit" (p. 29). AIC is defined as:

$$AIC = N\log(\hat{\sigma}^2) + 2p, \tag{5}$$

where $\hat{\sigma}^2$ is the estimate of the variance of the white noise or innovation.

To determine structural change, the best-fit AR model is determined for $\mu(t)$, and AIC_{FULL} is obtained for that process. Second, a tentative point of structural change, defined at V, is identified and an AR process is divided into two subprocesses at time V. Let $AR_1(p_1)$ be the model best fitted to the data before V, and $AR_2(p_2)$ be the model best fitted

to the data after V. AIC_V for the new process is defined as $AIC_1 + AIC_2$, the sum of the AICs for each model. Structural change is assumed to occur at V^*, where V^* is the minimum AIC_V found by checking all contemplated points of structural change. If $AIC_{V^*} < AIC_{FULL}$, it can be concluded that a structural change has occurred at V^* and the process can be divided into two subprocesses.

If structural change is suspected at two or more localities (S points) in time, MAIC can be applied by fitting an AR model between each supposed point of structural change and summing the AICs from each subprocess to obtain AIC_{TOT} for the total process. If $AIC_{TOT} < AIC_{FULL}$, then structural change is assumed to have occurred at each hypothesized point, and S models should be specified. Any number or combination of suspected points of structural change can be tested by determining a series of combination AICs and comparing those among themselves and with AIC_{FULL} to determine the minimum AIC.

Data

For this study, stock sheep inventory and lamb prices were examined for structural change and cyclical length. January 1, U.S. breeding stock sheep inventories from 1924 through 1993 were obtained from various issues of *Agricultural Statistics* (USDA). Continuous monthly series of lamb prices for specific grades and weights at a particular market were not available. A continuous series of average monthly lamb prices from 1924 through 1993 was available in selected issues of *Wyoming Agricultural Statistics* (Wyoming Department of Agriculture). These prices are not reported for a particular grade, weight, or market, but are an average of lamb prices received throughout Wyoming. Lamb prices were deflated using the consumer price index (U.S. Department of Commerce), with 1993 serving as the base year.

Results

Lamb Prices

The cyclical nature of monthly lamb prices was examined by testing harmonic regression patterns from two to 30 years in length. A monthly seasonal pattern also was included in each equation. Durbin–Watson statistics showed the presence of serial correlation in the monthly lamb price harmonic regressions. A first- and twelfth-order autoregressive process was found to be significant in each equation. All equations were therefore estimated using Yule–Walker estimation procedures (Gallant and Goebel) to correct for the presence of serial correlation.

Presence of individual 10-, 12-, 13-, 24-, and 27- to 30-year cyclical trends was indicated by the significance of each parameter's t-statistic. A monthly seasonal pattern was significant in the majority of equations. The shorter cycles were combined with the longer cycles to see if an amalgamated cycle was significant [as Franzmann (1979) found in hog prices]. The 10- and 28-year cyclical combination gave the lowest AIC statistic and the highest R^2 value of any of the cyclical combinations when the long cycle effect was examined. After correcting for serial correlation, the coefficient on the 10-year sine parameter was not significant at a 90% confidence level, but was retained since it is required to complete the sinusoidal pattern [equation (6) in table 1].

The graph of actual lamb prices and the structural portion of the estimated cyclical trend equation are found in figure 1. The predicted values were generated on a monthly basis, but for clarity, average annual prices are plotted. Several points of departure between actual lamb prices and the estimated 10- and 28-year cyclical trend are noticeable.

Points of structural change were examined throughout the entire process. This was accomplished by dividing the process at each year (e.g., 1944) and estimating an AR model for each subprocess (e.g., 1924–43 and 1944–93). The AIC for the entire process then was compared to the combined AICs for the two subprocesses. AR models of order

Table 1. Generalized Least Squares Estimates of the Lamb Price Cycle

(6)
$$LP_{24\text{-}93} = \underset{(22.5)^{**}}{103.60} - \underset{(.697)}{.001T} + \underset{(6.05)^{**}}{3.637}\mathrm{Sin}(T/12) - \underset{(5.57)^{**}}{3.344}\mathrm{Cos}(T/12) + \underset{(1.41)}{4.216}\mathrm{Sin}(T/120)$$
$$- \underset{(2.97)^{**}}{8.698}\mathrm{Cos}(T/120) - \underset{(4.73)^{**}}{15.66}\mathrm{Sin}(T/336) + \underset{(5.77)^{**}}{18.55}\mathrm{Cos}(T/336)$$
$$AIC = 5{,}464.19, \quad R^2 = .935, \quad \rho_1 = -.9144, \quad \rho_{12} = .0061$$

(7)
$$LP_{24\text{-}51} = \underset{(13.93)^{**}}{71.56} + \underset{(5.83)^{**}}{.025T} + \underset{(6.33)^{**}}{4.541}\mathrm{Sin}(T/12) - \underset{(4.96)^{**}}{3.545}\mathrm{Cos}(T/12) + \underset{(3.79)^{**}}{13.18}\mathrm{Sin}(T/156)$$
$$+ \underset{(1.92)^{*}}{6.263}\mathrm{Cos}(T/156) + \underset{(2.39)^{**}}{9.014}\mathrm{Sin}(T/288) + \underset{(5.89)^{**}}{19.82}\mathrm{Cos}(T/288)$$
$$AIC = 2{,}018.34, \quad R^2 = .970, \quad \rho_1 = -.9195, \quad \rho_{12} = .0327$$

(8)
$$LP_{52\text{-}71} = \underset{(10.25)^{**}}{206.28} - \underset{(5.03)^{**}}{.035T} + \underset{(1.90)^{*}}{1.396}\mathrm{Sin}(T/12) - \underset{(6.56)^{**}}{4.796}\mathrm{Cos}(T/12) + \underset{(5.54)^{**}}{7.745}\mathrm{Sin}(T/96)$$
$$- \underset{(2.22)^{**}}{2.985}\mathrm{Cos}(T/96) - \underset{(6.29)^{**}}{21.30}\mathrm{Sin}(T/324) + \underset{(2.32)^{**}}{5.898}\mathrm{Cos}(T/324)$$
$$AIC = 1{,}452.45, \quad R^2 = .875, \quad \rho_1 = -.7501, \quad \rho_{12} = .1321$$

(9)
$$LP_{72\text{-}93} = \underset{(3.40)^{**}}{116.63} - \underset{(.56)}{.004T} + \underset{(3.83)^{**}}{4.620}\mathrm{Sin}(T/12) - \underset{(1.58)}{1.891}\mathrm{Cos}(T/12) + \underset{(3.82)^{**}}{7.967}\mathrm{Sin}(T/108)$$
$$+ \underset{(8.29)^{**}}{17.76}\mathrm{Cos}(T/108) - \underset{(3.37)^{**}}{9.841}\mathrm{Sin}(T/324) + \underset{(4.86)^{**}}{22.13}\mathrm{Cos}(T/324)$$
$$AIC = 1{,}851.25, \quad R^2 = .919, \quad \rho_1 = -.7066, \quad \rho_{12} = .0645$$

Notes: Absolute value of the t-statistic for each parameter is in parentheses below the parameter estimate, with * = significant at $\alpha = .10$ and ** = significant at $\alpha = .05$. LP = monthly lamb price, $T = 2\pi t$, Sin = sine, Cos = cosine, AIC = Akaike's information criterion, ρ_i = autoregressive parameter estimate for lag i, and R^2 = total R^2 (SAS Institute, Inc.).

1 to 15 were estimated for the entire process and for each subprocess. An AR model of order 1 or 13 generally gave the lowest AIC.

The lowest combined AIC was obtained when the process was broken at 1972. The AIC for 1924–71 was 3,495 and the AIC for 1972–93 was 1,851. This gave a combined AIC_{TOTAL} of 5,346, which, when compared with an AIC_{FULL} of 5,464 for 1924–93, implied that a structural change occurred between 1971 and 1972. While it is naive to suggest that structural change occurred at a certain point in time, the MAIC methodology allows the period 1924–93 to be separated statistically into two subprocesses.

Data in each process (1924–71 and 1972–93) were detrended and the individual subprocesses again were examined. The lowest AICs in the 1924–71 process occurred between 1944 and 1952, with 1952 being chosen as the breaking point with an AIC of 3,470. Separating the entire process into three subprocesses (1924–51, 1952–71, and 1972–93) provided an AIC_{TOTAL} of 5,322. Additional subprocesses failed to improve on the AIC_{TOTAL} or were too short in length to successfully establish a cyclical trend.

Harmonic regressions were estimated over the three periods of 1924–51, 1952–71, and 1972–93 [equations (7), (8), and (9) in table 1]. Cycles of 13 and 24 years, eight and 27 years, and nine and 27 years, respectively, provided the best fits for the three time periods. A graph of actual lamb prices compared to the estimated cyclical trends is shown in figure 2. Cycles were estimated using the structural portion of their respective GLS equations. Compared to figure 1, where no structural change was assumed, the actual cyclical nature of lamb prices was emulated more closely by models considering structural change, as seen by the lower AICs and by personal observation of figures 1 and 2.

Examination of individual cyclical trends, with the time trend and intercept values removed, showed distinct differences in the amplitude of the cycles among the three time

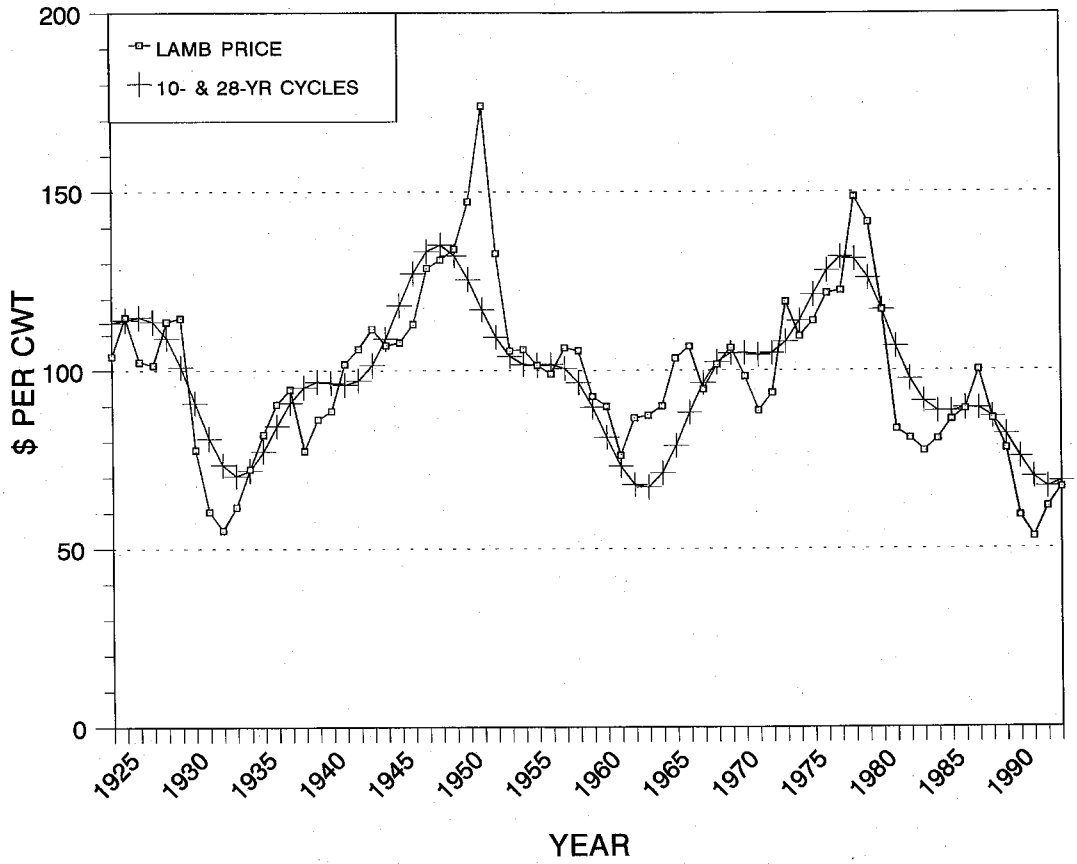

Figure 1. Lamb prices and estimated cycles

periods (figure 3). As indicated by the magnitude of the coefficients on each cyclical parameter and as shown by their individual simulations in figure 3, the variation of the shorter eight- to 13-year cycle decreased from the 1924–51 to the 1952–71 time periods, but again increased in the 1972–93 time period. The amplitude of the "long cycle" remained relatively constant throughout the three time periods.

Stock Sheep Inventories

Cyclical patterns of two to 30 years in length were examined for the stock sheep inventory from 1924 through 1993 using harmonic regression analysis. The seasonal terms in equation (1) were excluded because only yearly stock sheep data were available. Durbin–Watson statistics showed the presence of serial correlation, so all equations were estimated using Yule–Walker estimation procedures (Gallant and Goebel) to correct for first-order serial correlation. T-statistics for the sine and cosine coefficients were significant for the 10-year, 12-year, and 23- to 27-year cycles. As with lamb prices, the shorter 10- and 12-year cycles were combined with the longer 23- to 27-year cycles to test for a significant amalgamated cycle. A combined cyclical length of 12 years and 26 years supplied the best fit, as this combination provided the lowest AIC and also the highest R^2 over the complete 1924–93 process [equation (10), table 2].

Graphs of actual stock sheep numbers and the structural portion of the estimated cyclical trend equation are found in figure 4. Several points of departure between actual stock sheep numbers and the estimated 12- and 26-year cyclical trend are noticeable. In accordance with the MAIC methodology, points of structural change were examined through-

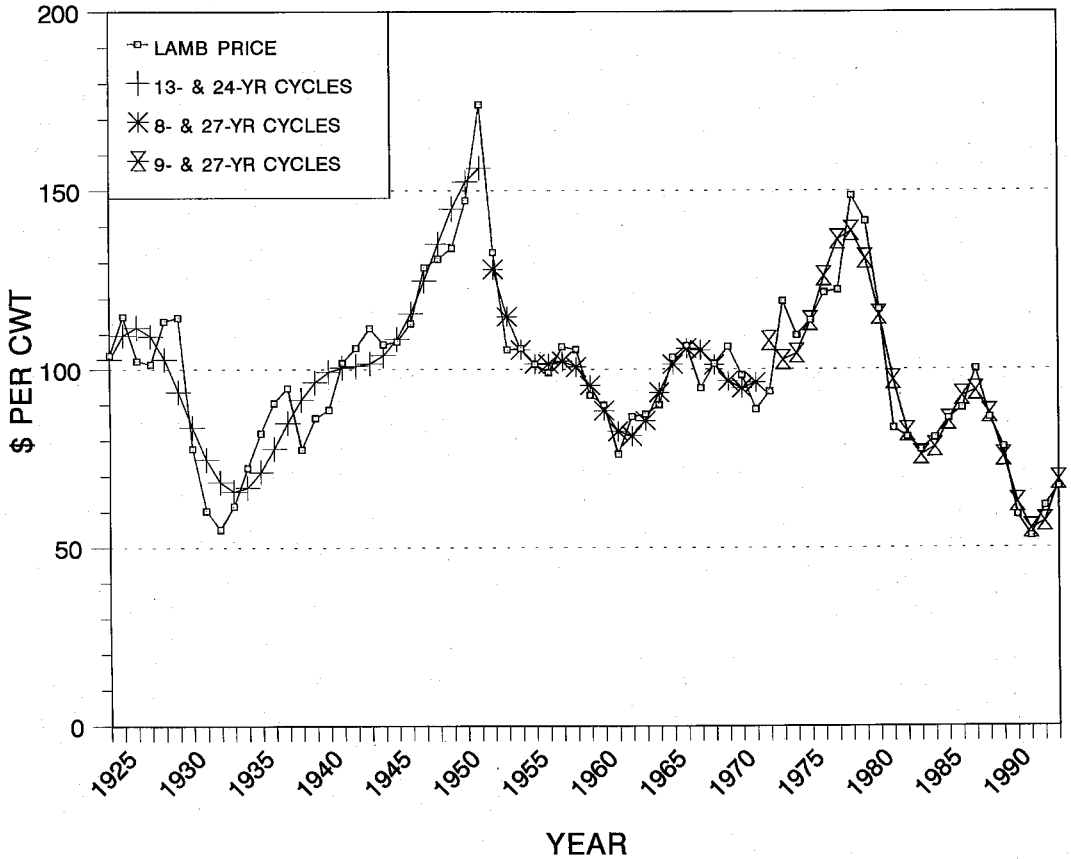

Figure 2. Lamb prices and estimated cycles with structural changes in 1952 and 1972

out the entire process. This was again accomplished by dividing the entire process at each year and estimating an AR model for each subprocess. AR models of order 1 to 6 were estimated for the entire process and for each subprocess. An AR model of order 2 generally gave the lowest AIC, though a few subprocesses obtained their best fit with an AR model of order 1 or order 3.

AICs for the majority of the subprocesses examined were less than the 1,210 obtained for AIC_{FULL} over the entire process of 1924–93. The lowest AICs were obtained when the process was broken at 1951 (AIC_{TOTAL} of 1,142) and at 1968 (AIC_{TOTAL} of 1,138). Breaking the entire process into three subprocesses of 1924–50, 1951–67, and 1968–93 provided an AIC_{TOTAL} of 1,066, which was lower than the entire process or any subprocess separately. Further breaking the subprocess 1968–93 into two additional subprocesses (1968–82 and 1983–93) lowered the total AIC by 13, but it was difficult to have a high degree of confidence in the AR estimates with only 11 data points in the 1983–93 regression.

Harmonic regressions were examined for each of the three subprocesses, with a combined cyclical trend of 13 and 25 years being most appropriate for the 1924–50 time period [equation (11) in table 2], 10 and 26 years for the 1951–67 period [equation (12) in table 2], and 10 and 27 years for the 1968–93 period [equation (13) in table 2].

Actual stock sheep numbers compared to the 13- and 25-year cycles for 1924–50, the 10- and 26-year cycles for the years 1951–67, and the 10- and 27-year cycles for 1968–93 are graphed in figure 5. The estimated cycles shown in figure 5 were combined based on the structural portion of their respective GLS equations. Compared to figure 4, where no structural change was assumed, the actual cyclical nature of stock sheep inventories is better emulated using models which accommodated structural change.

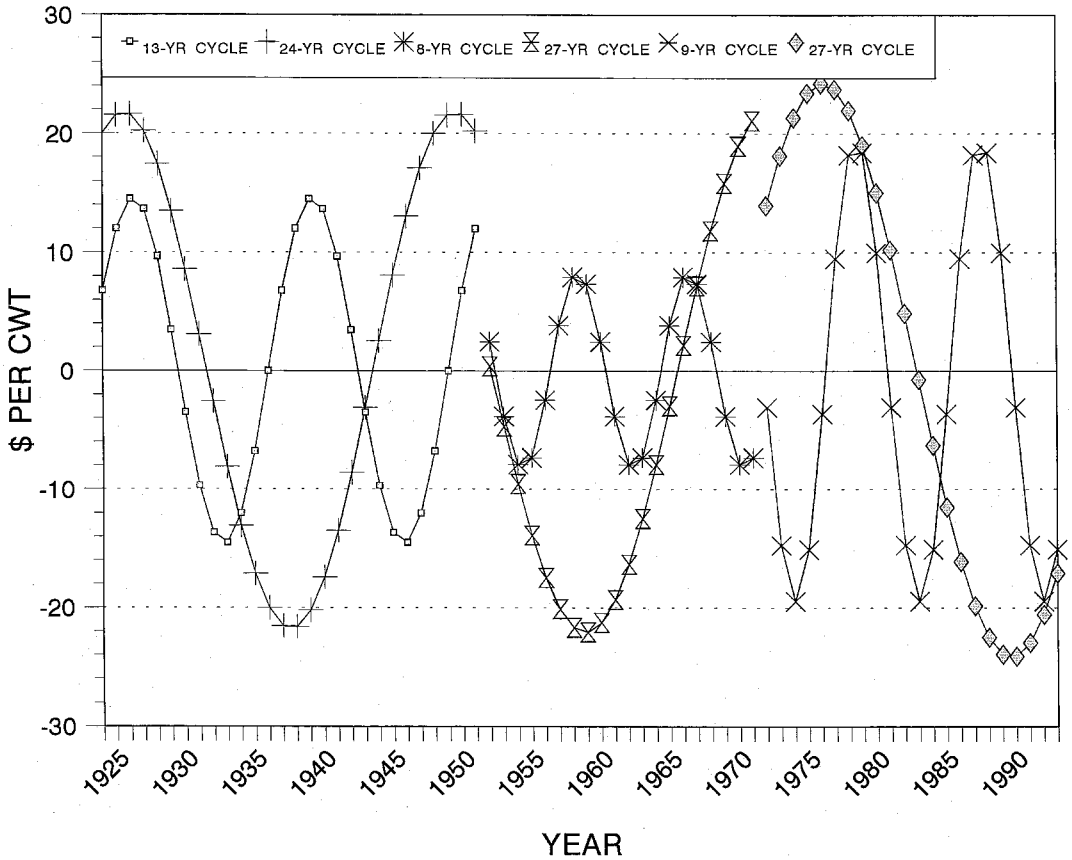

Figure 3. Cyclical amplitude differences in lamb price cycles

When individual cyclical trends were examined with the time trend and intercept values removed, the amplitude of the cycles showed distinct differences among the three time periods (fig. 6). Prior to 1951, stock sheep inventories exhibited wider inventory shifts compared to inventories after 1950.

Discussion

As previously discussed, the term "structural change" is utilized in a statistical context to divide the time series into separate subprocesses. The time-series methodology utilized in this study precludes an identification of factors that contributed to the structural changes identified. Results do suggest that the nature of sheep cycles has been statistically altered over time. The major changes have occurred around the late 1940s to early 1950s, and again during the late 1960s and early 1970s.

World War II triggered several events that may have contributed to a structural change occurring during the late 1940s and early 1950s. Kilker and Koch gave the following description of the events associated with World War II that adversely affected the U.S. sheep industry:

> This situation began after Pearl Harbor Day—December 7, 1941—when wool prices were frozen at the December 6 level, which also happened to be at a low point in the business cycle. Civilian use of wool was restricted; war technology sparked an increase in synthetic fabrics; and fashion changes were discouraged. Also sheepmen were called upon to provide meat and wool to the military, even though their labor force was decreasing as sheepherders entered the armed forces. . . . [C]onsequently, fewer

Table 2. Generalized Least Squares Estimates of the Stock Sheep Inventory Cycle

(10)
$$NSS_{24\text{-}93} = \underset{(28.4)^{**}}{47{,}827} - \underset{(15.4)^{**}}{98T} - \underset{(3.30)^{**}}{1{,}483\,\mathrm{Sin}(T/12)} - \underset{(2.00)^{**}}{860\,\mathrm{Cos}(T/12)}$$
$$- \underset{(2.20)^{**}}{1{,}792\,\mathrm{Sin}(T/26)} - \underset{(5.90)^{**}}{4{,}721\,\mathrm{Cos}(T/26)}$$
$$AIC = 1{,}209.96, \quad R^2 = .992, \quad \rho_1 = -.8379$$

(11)
$$NSS_{24\text{-}51} = \underset{(72.2)^{**}}{45{,}808} - \underset{(6.50)^{**}}{43T} - \underset{(4.90)^{**}}{1{,}737\,\mathrm{Sin}(T/13)} - \underset{(13.50)^{**}}{4{,}374\,\mathrm{Cos}(T/13)}$$
$$- \underset{(8.10)^{**}}{3{,}681\,\mathrm{Sin}(T/25)} - \underset{(19.5)^{**}}{6{,}860\,\mathrm{Cos}(T/25)}$$
$$AIC = 444.26, \quad R^2 = .990, \quad \rho_1 = -.3878$$

(12)
$$NSS_{51\text{-}67} = \underset{(5.80)^{**}}{30{,}872} - \underset{(1.00)}{25T} - \underset{(6.10)^{**}}{1{,}157\,\mathrm{Sin}(T/10)} + \underset{(3.70)^{**}}{622\,\mathrm{Cos}(T/10)}$$
$$+ \underset{(3.1)^{**}}{2{,}129\,\mathrm{Sin}(T/26)} - \underset{(2.70)^{**}}{1{,}629\,\mathrm{Cos}(T/26)}$$
$$AIC = 251.91, \quad R^2 = .984, \quad \rho_1 = .0345$$

(13)
$$NSS_{68\text{-}93} = \underset{(40.1)^{**}}{39{,}315} - \underset{(28.2)^{**}}{76T} - \underset{(7.5)^{**}}{770\,\mathrm{Sin}(T/10)} + \underset{(3.9)^{**}}{399\,\mathrm{Cos}(T/10)}$$
$$- \underset{(2.4)^{**}}{345\,\mathrm{Sin}(T/27)} - \underset{(11.9)^{**}}{1{,}791\,\mathrm{Cos}(T/27)}$$
$$AIC = 370.29, \quad R^2 = .995, \quad \rho_1 = -.3084$$

Notes: Absolute value of the t-statistic for each parameter is in parentheses below the parameter estimate, with ** = significant at $\alpha = .05$. NSS = number of stock sheep, $T = 2\pi t$, Sin = sine, Cos = cosine, AIC = Akaike's information criterion, ρ_i = autoregressive parameter estimate for lag i, and R^2 = total R^2 (SAS Institute, Inc.).

> replacement ewes were returned to flocks. . . . [A] number of men . . . did not return to ranch and farm life . . . [and] those who remained in agriculture turned to less-demanding crops and cattle rather than sheep (p. 129).

It also has been suggested that demand was permanently affected as a result of the military feeding poorly-prepared Australian mutton to South Pacific soldiers. Many military personnel made the resolve that neither they nor their families would ever eat lamb again (Kilker and Koch).

According to Kilker and Koch, the effect of these aforementioned events was not immediately felt in the industry, but took a heavy toll in the intervening years. As a result of the circumstances surrounding World War II, sheep numbers started a dramatic decline from their historic pinnacle in 1942 until the decline ceased in 1950. Prices began a steady climb after the rationing days of World War II and continued for several years after the sheep liquidation of the 1940s recessed.

Several events occurred in the early 1970s that may rationalize the structural change identified in 1968–72. A disruption in sheep prices occurred as a result of inflationary pressure that developed in unison with the oil embargo, along with accompanying meat price controls. Periods of acute grain shortage brought about by a myriad of weather problems also may have been a factor in the increased variability in lamb prices.

Additional events occurring throughout the decade of the 1960s that were concurrent with the sharp decrease in stock sheep inventories include a notable labor shortage, a substantial growth of the synthetic fiber industry, and an increase in lamb and wool imports. During the late 1960s and early 1970s, the industry's adversity continued with an increase in federal grazing fees and an executive order that banned the use of toxicants for predator control on federal lands. These latter events were offset by advances in

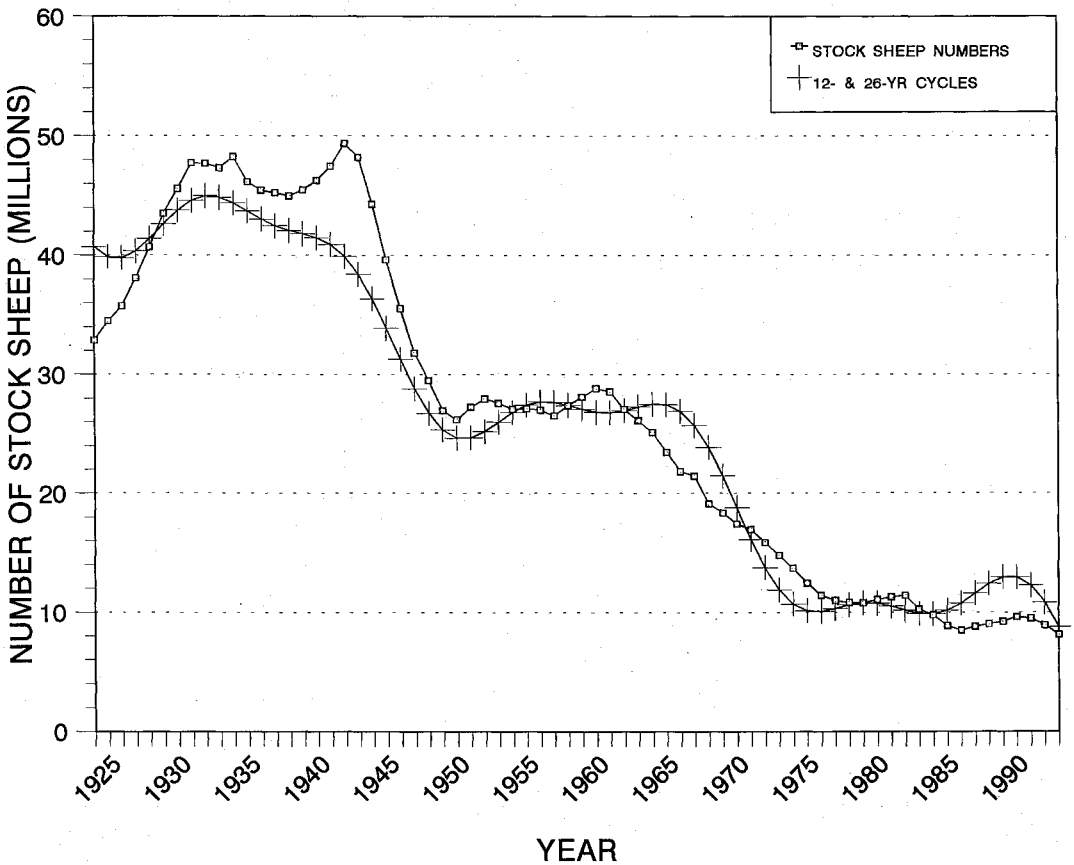

Figure 4. Stock sheep inventory and estimated cycles over the full sample

production technology, wool manufacturing developments, and the implementation of marketing cooperatives (Kilker and Koch).

The sheep industry appears to exhibit the same general cyclical behavior as the beef industry, i.e., eight- to 13-year price and inventory cycles. Initially it was hypothesized that the sheep industry would exhibit shorter cycles than those of cattle because of the multiple births that occur in sheep and the shorter period from birth to market. These production characteristics apparently contributed to only a slightly (if any) shorter sheep than cattle cycle.

As Franzmann (1979) observed in hog prices, an apparent "long cycle" of 24 to 28 years was amalgamated with the shorter eight- to 13-year sheep inventory and prices cycles. While further research is required to determine their rationality, we have no reason to dispute Sherman's judgment that long cycles capture random effects influencing the sheep industry and are not internally created by participants in the sheep industry.

A decline in the cyclical length of both inventories and prices over time also was observed. Several factors may contribute to this phenomenon (Williams). First, technological advances, especially in reproductive efficiency, may have shortened the biological lag and quickened the production response to changes in prices. Second, the increased education and improved understanding of ranchers and farmers concerning prices and markets may have increased the accuracy of their perceptions. Third, improved market reporting and information gathering and dissemination may have improved ranchers' decision-making abilities. Fourth, the decrease in cyclical length may have resulted from increased responsiveness of producers and markets to economic pressures brought about by increasing costs and more erratic product prices.

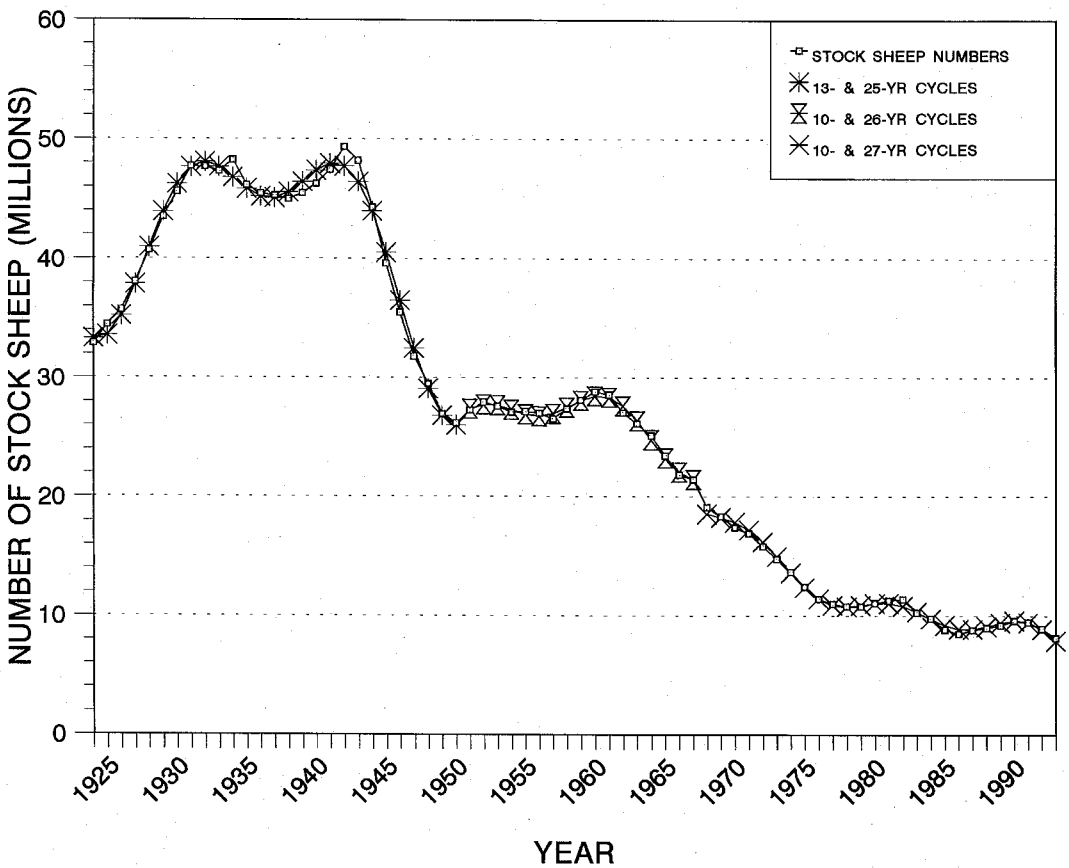

Figure 5. Stock sheep inventory and estimated cycles with structural changes in 1951 and 1968

Along with the shortening of the cyclical length, changes in the amplitude of cycles also were identified. The amplitude of the inventory cycles has decreased, while the opposite has occurred with the price cycles. The decrease in total sheep numbers over time may account for much of the decrease in the amplitude of stock sheep cycles. Another factor that may have had a dampening effect upon the cyclical nature of the stock sheep inventory is that sheep producers have predominately used nonfinancial reasons for expanding and contracting their flock sizes over the past decade (Purcell, Reeves, and Preston). Once flocks were reduced, Purcell, Reeves, and Preston hypothesized that an irreversible supply response occurred; i.e., once the contraction in size of operation occurred, economic incentives were not available to stimulate a subsequent investment. Given that a large percentage of producers have left the sheep industry since 1942, those producers remaining may not be responding as readily to the price changes comprising the typical livestock cycle.

The increased amplitude in the price cycles may, in part, be attributed to changing consumer demand, increased variability in processor and retailer margins for lamb, internationalization of agriculture, and increased uncertainty and variability initiated by inflationary impacts of the early 1970s. Malaska et al. called the 1970s "the decade of great change," characterized by increasing uncertainty and unpredictability (p. 45). Inflationary events surrounding the oil crisis sent prices on an inflationary trek in almost every industry. The sheep industry seems to have been no less affected.

Tomek and Robinson have also noted that the cyclical behavior for prices is typically more erratic than for quantity variables. This is facilitated by the interaction of supply and demand. This same phenomenon was affirmed by irregularity of lamb prices compared

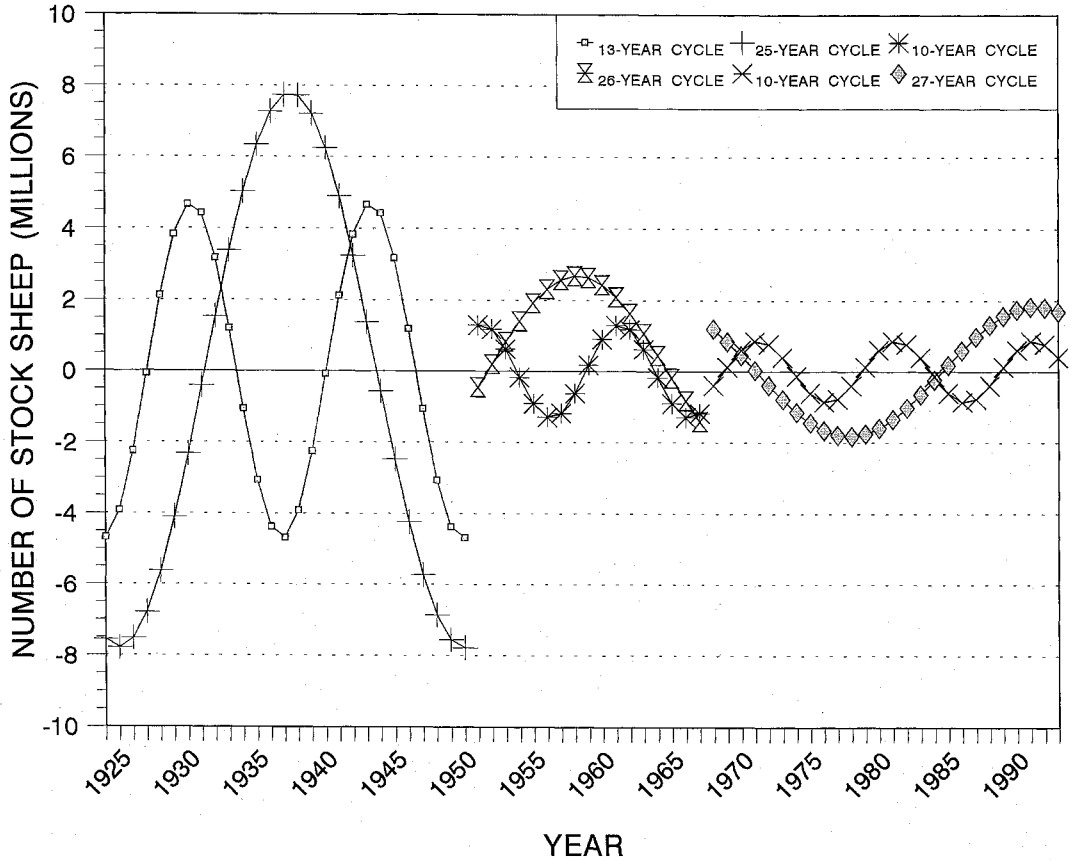

Figure 6. Cyclical amplitude differences in stock sheep inventory cycles

to stock sheep inventories. Simulated inventory cycles are more consistent with actual inventory data (fig. 5) than simulated price cycles are to the actual price data (fig. 2).

Conclusions

Little has been written concerning the cyclical nature of the U.S. sheep industry. Perhaps the long-term decline in sheep numbers over the past five decades has overshadowed the perceived importance of recurring sheep inventory cycles. The purpose of this article was to analyze the long-term cyclical nature of stock sheep inventories and lamb prices using harmonic regressions. This objective also included investigating a "long cycle" such as the 28-year cycle found by Franzmann (1979) in hog prices. The MAIC methodology was used to detect structural change as the cyclical nature of both stock sheep numbers and lamb prices changed over time.

Results indicate that cyclical length in both stock sheep numbers and lamb prices has decreased over time. Both a regular eight- to 13-year long-term cycle and an amalgamated long cycle were found to be significant. A 13- and 25-year cycle in stock sheep numbers existed from 1924–50, but subsequently, a 10- and 26- or 27-year cycle in the stock sheep inventory has occurred. For lamb prices, a 13- and 24-year cycle occurred from 1924–51, an eight- and 27-year cycle from 1952–71, and a nine- and 27-year cycle from 1972–93.

Cycles in cattle and hog inventories are topics of extensive discussion and research. Early anticipation of cyclical trends in the cattle and hog industries has provided producers

with guidance in appropriate price risk management strategies and decisions. Depending upon the position of the cycle, producers can make more informed decisions concerning cash pricing or using commodities markets for downside price protection. Cyclical trends also provide information concerning the optimal weights at which to market livestock. While several of these pricing strategies could be used by sheep producers, the lack of a futures or options market for lambs and the seasonal nature both of supply and demand, limit the use of these marketing techniques. An understanding of the cyclical nature of the sheep industry could benefit producers in their investment decisions concerning the liquidation and replacement of breeding stock.

The results of this study provide a foundation for further research into inventory and price projection for the sheep industry. This statistical analysis also provides limited insight into the cause of changes in cycle length and amplitude or the structural changes that were found. A more thorough analysis of the industry is needed to determine the specific reasoning behind the transformations that have occurred.

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