Papers of the 1992 Annual Meeting

Western Agricultural Economics Association

Colorado Springs, Colorado
July 12-15, 1992

EXAMINING STRUCTURAL CHANGE AND CYCLICAL LENGTH IN THE U.S. SHEEP INDUSTRY

Larry W. VanTassell and
Glen D. Whipple
University of Wyoming

Abstract

The cyclical nature of the sheep industry was examined from 1924-1990. Tests for structural change were also conducted. Results indicate that cyclical length in inventory and prices has decreased over time with a current 10- and 27-year cycle for stock sheep and a 10- and 25-year cycle for lamb prices.

Business cycles are recurring variations in production and/or prices of a year or more in length. Production and price cycles have been found to exist for several agricultural commodities. The well known beef cattle cycle occurs every nine to twelve years, with a 10-year average cycle a well known phenomenon (Franzmann 1971; Ginzel). A pronounced 4-year cycle and 28-year cycle has been identified in the hog industry (Franzmann 1979), and a 5-year to 7-year cycle in the landings and prices of oceanic fish (Waugh and Miller).

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 any recurring sheep inventory cycles. The purpose of this research was to determine if a recurring cyclical element has existed in lamb prices and in inventory levels of U.S. stock sheep.

Methodology and Data

Harmonic regression models have been used by several researchers to project potential cyclical paths for cattle prices (Franzmann and Walker, Gutierrez, Little and Ray). 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:

$$(1)\quad P_t = B_o + B_1 2\pi t + B_2 Sin(2\pi t/L1) + B_3 Cos(2\pi t/L1) + B_4 Sin(2\pi t/L2) + B_5 Cos(2\pi t/L2) + \mu$$

where P_t is the predicted price or inventory level in time period t (with N time periods), B_o 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 residual error term. Longer cyclical trends, such as a 28 year trend in hog prices, can be included by adding another pair of sine-cosine terms with the accompanying specified cyclical length (L). In the case of stock sheep numbers, a seasonal variation cannot be determined because only January 1 inventory data is available. With yearly data, lengths (L) are specified in years and not months.

When examining cyclical behavior of stock numbers and prices over several decades, the distinct possibility exists that at least one structural change may have occurred. A structural change can occur as a result of changes in consumer preferences, government policies, production practices, or a myriad of other occurrences. While structural changes may not always change the cyclical nature of stock numbers or prices, they can very easily change the nature of price movements, making it difficult to accurately forecast movements in the commodity (Akiba and Waragai 1989b).

To identify particular points of structural change in stock sheep numbers and in lamb prices, MAIC [minimization of the AIC, Akaike's Information Criterion] (Akiba and Waragai 1989a) was utilized. This method employs an autoregressive (AR) model, making it especially useful in determining structural change when the causality relationships with other variables are ambiguous or unknown. Using the MAIC criterion in determining 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 criterion is to eliminate any time trend components in the data. The residuals (μ) from the harmonic regressions meet this criteria. Following Akiba and Waragai (1989a), it is assumed that the random process $\{\mu(t)\}$ could be generated from an AR model of order p. Akiba and Waragai (1989a) suggest that the order of the AR model be determined by choosing the order that gives the lowest AIC, since AIC is "an information measure that indicates the poorness of fit" (Akiba and Waragai, 1989b, p.29).

To determine structural change, the best fit AR model is first determined for $\mu(t)$, and AIC_{FULL} is determined for the process. Second, a tentative point of structural change, defined at (M), is identified and an AR process is divided into two subprocess at time M. Let $AR_1(p_1)$ be the model best fitted to the data before M and $AR_2(p_2)$ be the model best fitted to the data after M. The AIC_M for the new process is defined as $AIC_1 + AIC_2$, the sum of the AIC's for each model. Structural change is assumed to occur at M^*, where M^* is the minimum AIC_M found from checking all contemplated points of structural change. If min $AIC_{M^*} < AIC_{FULL}$, it can be concluded that a structural change has occurred at M^* and the process can be divided into two subprocess.

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 AIC's 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 AIC's and comparing those amongst themselves and with AIC_{FULL} to determine the minimum AIC.

For this study, stock sheep inventory and lamb prices were examined for structural change and cyclical length. Yearly U.S. stock sheep numbers from 1924 through 1990 were obtained from various issues of Agricultural Statistics. Average monthly lamb prices from 1924 through 1990 were obtained from selected issues of Wyoming Agricultural Statistics.

Results and Discussion

Cyclical patterns of 2 to 30 years in length were examined for the stock sheep inventory from 1924 through 1990 using harmonic regression analysis. Durbin-Watson statistics showed the presence of autocorrelation, so all equations were estimated using Yule-Walker estimation procedures (Gallant and Goebel) to correct for first-order autocorrelation. T-statistics for the sine and cosine coefficients were significant for the 10-year, 12-year,

Table 1. Generalized Least Squares Estimates of the Stock Sheep Inventory Cycle.[a,b]

[7] $NSS_{24\text{-}90} = 48182 - 100\,T - 997\,Sin(T/10) + 932\,Cos(T/10) - 2653\,Sin(T/24) - 4276\,Cos(T/24)$
(30.2) (-15.7) (-2.3) (2.2) (-3.2) (-5.2)

AIC = 1173.18 R_2 = .989 ρ_1 = -0.7978

[8] $NSS_{24\text{-}50} = 46108 - 51\,T - 3544\,Sin(T/12) - 2476\,Cos(T/12) - 2105\,Sin(T/27) - 7172\,Cos(T/27)$
(68.7)(-7.1) (-11.0) (-7.6) (-4.18) (-20.9)

AIC = 448.89 R_2 = .988 ρ_1 = -0.2990

[9] $NSS_{51\text{-}90} = 47843 - 100\,T - 691\,Sin(T/10) + 443\,Cos(T/10) + 817\,Sin(T/27) - 2891\,Cos(T/27)$
(68.7) (-43.7) (-4.2) (2.5) (3.4) (-12.7)

AIC = 613.70 R_2 = .997 ρ_1 = -0.5754

[a] t-values for each parameter are in parenthesis below parameter estimates.
[b] NSS = number of stock sheep and $T = 2\pi t$.

and 23- to 27-year cycles. A combined cyclical length of 10-years and 24-years supplied the best fit, as this combination provided the lowest AIC and also the highest R^2 over the complete time horizon (Equation [7], Table 1).

The graph of actual stock sheep numbers and the structural portion of the estimated cyclical trend equation are found in Figure 1. Upon examining the graph of actual stock sheep numbers, a structural change was hypothesized to have occurred in the vicinity of 1942 to 1952. World War II triggered several events that may have contributed to a structural change occurring during this time period, including a freeze on wool prices, reduction in the labor force, and the introduction of synthetics.

While it would be naive to suggest that the structural change occurred at a certain point in time, the MAIC methodology allows one to statistically separate the period 1924 to 1990 into two (or more) separate subprocesses, with a designated statistically optimal break point. To search for this break point, subprocesses were estimated with the contemplated points of structural change occurring in 1942, 1943, 1948, 1950, and 1952. The years 1960, 1972, and 1974 were also chosen as potential points of structural change because of the visual departure in the projected trend from actual inventory numbers. AR models of order 1 to 6 were estimated for the entire process, for each subprocess, and for two combinations of subprocesses. An AR model of order 2 routinely gave the lowest AIC, though a couple of subprocesses obtained their best fit with an AR model of order 1 or order 3.

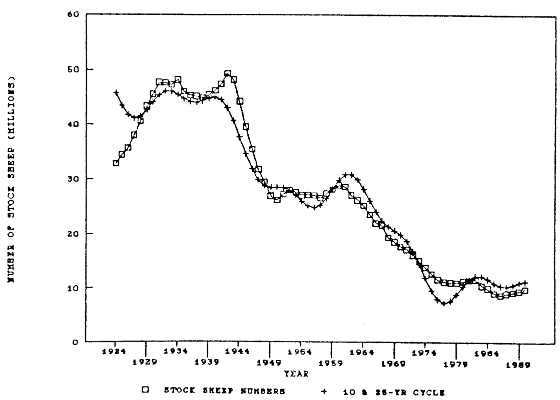

Figure 1. Stock Sheep Inventory and Estimated Cycle.

The AIC_M's for each suspected point of structural change were less than AIC_{FULL} for the entire process. This indicates that a structural change occurred between 1924 and 1990, with one point that can statistically separate the time periods. AIC_{M*} occurred when the subprocess were estimated from 1924 to 1950 and 1951 to 1990. Harmonic regressions were examined for each of these two subprocess, with a cyclical trend of 12-years and 27-years most appropriate for the 1924 through 1950 time period (Equation [8], Table 1), and 10-years and 27-years chosen for the 1951 through 1990 period (Equation [9], Table 1). A 9-year and 27-year cyclical trend was also significant for the later time period, but the 10-year and 27-year cyclical trend provided a slightly better fit as determined by AIC (AIC of 613.70 compared to 621.78).

The graph of actual stock sheep numbers compared to the 9- and 27-year cycle for 1924 through 1950 and the 10- and 27-year cycle for 1951 through 1950 are shown in Figure 2. The estimated cycles are from the structural portion of their respective GLS equations. Compared to Figure 1, where no structural change was assumed, the actual cyclical nature of stock sheep inventories can be emulated much better after the structural change has been identified.

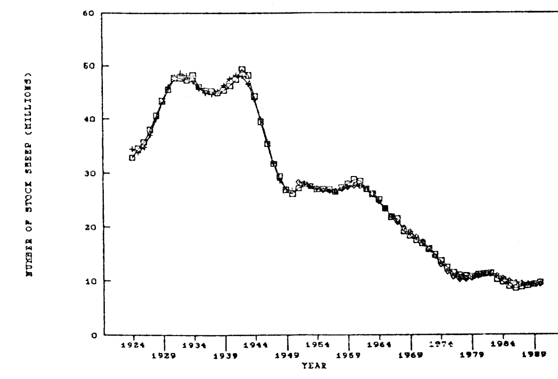

Figure 2. Stock Sheep Inventory and Estimated Cycles.

When the individual cyclical trends were examined with the time trend and intercept values removed, the amplitude of the cycles showed distinct differences between the two time periods (Figure 3). Prior to 1951, stock sheep inventories exhibited wider inventory shifts compared to the cyclical nature of stock sheep inventories after 1950. The decrease in total sheep numbers occurring over time would alone account for much of the decrease in the amplitude in the 1951 to 1990 stock sheep cycle. Another factor that may have a dampening effect upon cyclical nature of the stock sheep inventory is that sheep producers have been found to rely on nonfinancial reasons for expanding or contracting their herd sizes. Purcell, Reeves, and Preston found that the main reason producers expanded their sheep inventories over the past decade was because of a personal preference for sheep and the most prevalent factor governing contraction was limited range or pasture. Given that a large percentage of producers have left the sheep industry since 1942, those producers remaining perhaps are responding less to the economics governing the typical livestock cycle and more to nonfinancial reasons.

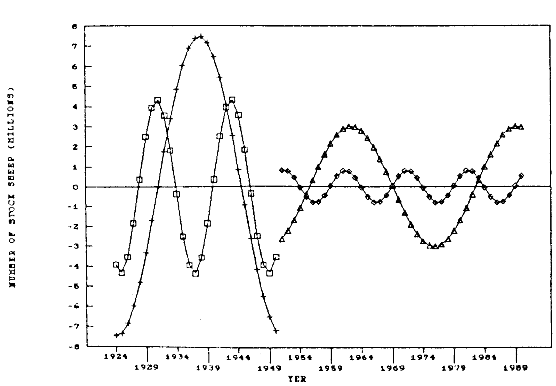

Figure 3. Cycles for Stock Sheep.

The cyclical nature of monthly lamb prices was examined by testing harmonic regression patterns from 2 to 30 years in length. A monthly seasonal pattern was also included in each equation. As with the stock sheep equations, autocorrelation was present in all the monthly lamb price harmonic regressions. A first and twelfth order autoregressive process was found to be significant in each equation. All equations were estimated using Yule-Walker estimation procedures (Gallant and Goebel) to correct for the presence of autocorrelation.

Presence of a 9-, 10-, 12-, 25-, 27-, and 30-year cyclical trend was indicated by the significance of each

Table 2. Generalized Least Squares Estimates of the Lamb Price Cycle.[a,b]

[10]
$$LP_{24\text{-}90} = -\underset{(-0.14)}{0.746} + \underset{(6.64)}{0.011}\,T - \underset{(-1.91)}{0.736}\,Sin(T/12) - \underset{(-0.60)}{0.231}\,Cos(T/12) + \underset{(1.60)}{1.403}\,Sin(T/120) - \underset{(-3.37)}{2.970}\,Cos(T/120) + \underset{(1.81)}{3.878}\,Sin(T/324) + \underset{(3.05)}{6.333}\,Cos(T/324)$$

AIC = 4123.21 R_2 = .977 ρ_1 = -0.760 ρ_{12} = -0.207

[11]
$$LP_{24\text{-}51} = \underset{(2.01)}{2.633} + \underset{(8.60)}{0.009}\,T - \underset{(-0.81)}{0.152}\,Sin(T/12) - \underset{(-1.03)}{0.193}\,Cos(T/12) + \underset{(3.28)}{1.894}\,Sin(T/156) + \underset{(1.69)}{0.974}\,Cos(T/156) + \underset{(2.73)}{2.614}\,Sin(T/324) + \underset{(7.17)}{5.686}\,Cos(T/324)$$

AIC = 991.08 R_2 = .974 ρ_1 = -0.771 ρ_{12} = -0.154

[12]
$$LP_{52\text{-}71} = \underset{(4.41)}{45.547} - \underset{(-2.29)}{0.003}\,T - \underset{(-2.61)}{0.750}\,Sin(T/12) - \underset{(-2.83)}{0.809}\,Cos(T/12) - \underset{(-2.66)}{1.631}\,Sin(T/144) + \underset{(1.96)}{1.473}\,Cos(T/144) - \underset{(-3.63)}{7.097}\,Sin(T/312) + \underset{(1.95)}{1.524}\,Cos(T/312)$$

AIC = 851.65 R_2 = .836 ρ_1 = -0.649 ρ_{12} = -0.142

[13]
$$LP_{72\text{-}90} = \underset{(1.14)}{47.016} + \underset{(0.14)}{0.002}\,T - \underset{(-1.50)}{1.681}\,Sin(T/12) + \underset{(-0.21)}{0.230}\,Cos(T/12) + \underset{(2.56)}{4.241}\,Sin(T/120) - \underset{(-4.86)}{9.695}\,Cos(T/120) + \underset{(2.34)}{6.294}\,Sin(T/300) - \underset{(-2.32)}{11.289}\,Cos(T/300)$$

AIC = 1419.64 R_2 = .866 ρ_1 = -11.491 ρ_{12} = -3.014

[a] t-values for each parameter are in parenthesis below parameter estimates.
[b] LP = monthly lamb price and $T = 2\pi t$.

parameters' t-statistic. A monthly seasonal pattern was not significant, but was included in the models so as not to introduce any specification bias. The 10-year and 27-year cyclical combination gave the lowest AIC statistic and the highest R^2 value of any of the cyclical combinations. After autocorrelation was corrected for, the coefficient on the 10-year sine parameter was not quite significant at a 90 percent confidence level, but was retained as it is required to complete the sinusoidal pattern (Table 2, Equation [10]).

Plots of actual lamb prices and the 10-year and 27-year cyclical pattern are shown in Figure 4. The predicted values were generated on a monthly basis, but for clarity, yearly average prices were plotted in the figures. After examining the graph, two main areas of structural change were suspected, the 1950 period, and the 1970 period. The 1950 departure coincides with the events surrounding World War II. The 1970 departure developed in unison with the oil embargo and the wage and price freeze of 1973.

To test this hypothesis of a structural change having occurred either

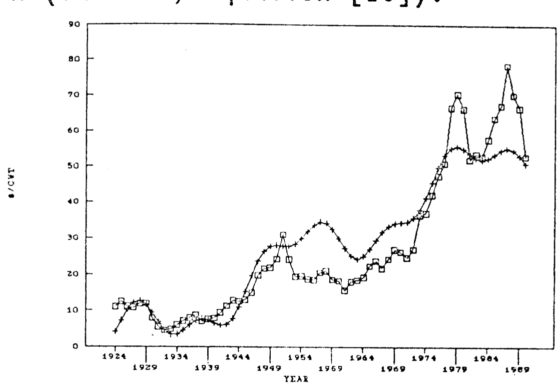

Figure 4. Lamb Prices and Estimated Cycle.

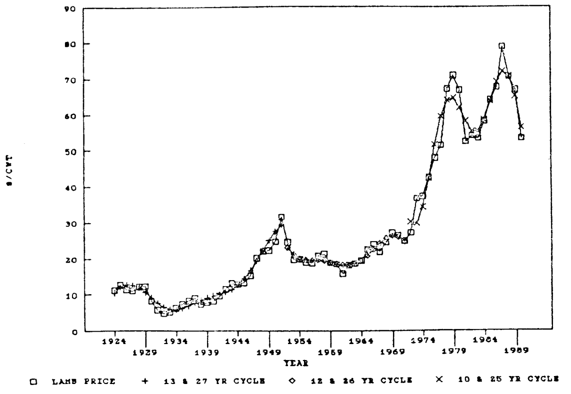

Figure 5. Lamb Prices and Estimated Cycles.

before or after World War II, six subprocesses were examined, with the breaks being at 1938, 1944, 1950, 1951, 1952, and 1953. AIC_M was obtained at 1951, with the AIC statistics continually declining up to that year and increasing afterwards. The hypothesized structural change of the 1970's was examined by evaluating subprocesses with the divisions occurring at 1971, 1972, 1973, and 1975. AIC_M was obtained with the subprocesses extending from 1924 to 1971 and from 1972 to 1990. To validate that AIC_M indeed did occur at 1971, subprocesses were also examined during the 1960's. It appeared that a declining trend in AIC values occurred throughout the 1960's, with 1971 the culminating low point.

A subprocess with both the 1951 and 1971 structural change occurring was examined. AIC for the 1924-1951 period was 972.40, for the 1952-1971 period was 876.53, and for the 1972-1990 period was 1,428.98, for a total of 3,277.91. In accordance with Akiba and Waragai's MAIC criterion, structural change was assumed to have culminated at the end of 1951 and 1971.

Harmonic regressions were estimated over the three periods from 1924-1951, from 1952-1971, and from 1971-1990 (Table 2). Cycles of 13 and 27-years, 12 and 16-years, and 10 and 25-years provided the best fits for the three time periods, respectively (Figure 5). As occurred with the stock sheep inventory, it appears that over time, the cyclical length of lamb prices has declined. This has not been true of the amplitude of the cycles though. As witnessed by the magnitude of the coefficients on each cyclical parameter and as shown by their individual simulations in Figure 6, the variation increased only slightly from the 1924-1951 to the 1952-1971 time periods, but increased considerably in the 1972-1990 time period, mainly because of the increased uncertainty and variability created by inflationary pressures.

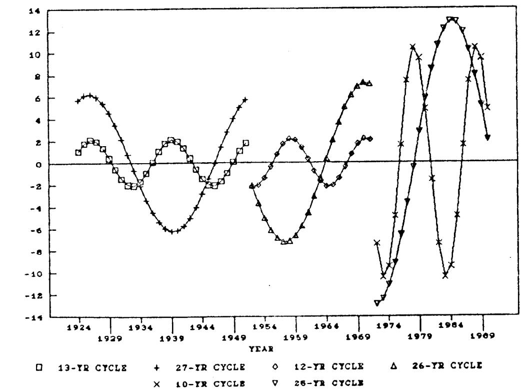

Figure 6. Lamb Price Cycles.

Conclusions

The main purpose of this paper was to evaluate the cyclical nature of stock sheep inventories and lamb prices. The MAIC criterion proved to be a valuable tool in detecting structural change, as the cyclical nature of both stock sheep numbers and lamb prices was modified as a result of structural reformations in the industry and/or economy.

Results indicate that the length of the cycles associated with stock sheep numbers and lamb prices has decreased over time. A 12-year and 27-year cycle in the numbers of stock sheep was found to have existed from 1924 through 1950, but since then, a 10-year and 27-year cycle in the stock sheep inventory has occurred. For lamb prices, a 13-year and 27-year cycle occurred from 1924 through 1951, a 12-year and 26-year cycle from 1952 through 1972, and a 10-year and 25-year cycle from 1973 through 1990. The decrease in the length of the cycles may have occurred because of the increased responsiveness of producers and markets to economic pressures.

Cycles in cattle and hog inventories have been topics of extensive discussion and research. The results of this study will hopefully lay the foundation for further research into inventory and price projection for the sheep industry. An understanding and realization of the cyclical nature of sheep inventories and prices could also assist producers, suppliers, and consumers of sheep products in determining marketing strategies, price risk management strategies, and production decisions. The existence of structural change should also prompt research to more thoroughly determine the reasoning behind the transformations that have occurred.

References

Akiba, H. and Waragai, T. "An Arbitrariness-Free Method of Detecting Structural Changes." Economic Letters. 29(1989a):27-30.

Akiba, H. and Waragai, T. "An Econometric Analysis of Detecting Structural Changes in the Seven Major Exchange Rates with MAIC Method: January, 1974 through September, 1986." Journal of International Economic Integration. 4(1989b):27-58.

Franzmann, J. R. "Cattle Cycles Revisited." Southern Journal of Agricultural Economics. 3(1971):69-76.

Franzmann, J. R. "A Long Cycle in Hog Prices--What Would It Mean to Hog Producers?" Current Farm Economics. Oklahoma Agricultural Experiment Station. 1979, p. 10-12.

Franzmann, J.R. and R.L. Walker. "Trend Models of Feeder, Slaughter, and Wholesale Beef Cattle Prices." American Journal of Agr. Economics. 54(1972):507-512.

Gallant, A.R. and J.J. Goebel. "Nonlinear Regression with Autoregressive Errors." Journal of the American Statistical Association. 71(1976):961-967.

Gutierrez, P.H. The Impact of Selected Management Practices on the Economic Survivability of a Ranch Unit: An Analysis for a Southern Plains Ranch. Ph.D. Dissertation, Oklahoma State University, 1985.

Ginzel, J. "Cyclic Patterns in the U.S. Cattle Inventory." Livestock and Poultry Situation and Outlook Report. USDA ERS, LPS-31, August 1988.

Little, R.D. and D.E. Ray. 1990. "An Evaluation of the Importance of the Net Operating Loss Carryback to Oklahoma Cow-calf Producers." Southern Journal of Agricultural Economics. 22(1990):217 (abstr.).

Purcell, W.D., J. Reeves, and W. Preston. Economics of Past, Current, and Pending Change in the U.S. Sheep Industry With an Emphasis on Supply Response. Research Bulletin 6-91, Research Institute on Livestock Pricing, Virginia Tech University, Sept. 1991.

Waugh, F. V. and M. M. Miller. "Fish Cycles: A Harmonic Analysis." American Journal of Agricultural Economics. 52(1970):422-430.