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The Cattle Price Cycle: An Exploration in Simulation

The simulation of commodity prices has been undertaken using a myriad of techniques, with some omitting the cyclical component and others ignoring the presence of inter-temporal relationships expressed as autoregressive errors. This study examines the periodicity of cattle prices and the modeling of the cattle cycle for simulation purposes. The AIC criterion is used to determine lengths of various cycles to be included in a harmonic model, with a chained modeling approach providing the best representation of the cattle cycle.

Keywords: cattle Price cycle, harmonic model, simulation.

Introduction

The popularity of electronic, computer simulation modeling has continued to grow with the development of simulation spreadsheets such as SIMATAR and @Risk. Some of the most commonly incorporated stochastic variables in economic simulation models are commodity prices. The most recent events in the corn market have demonstrated how volatile commodity markets can be, making the simulation of commodity prices challenging. Cattle prices have the additional challenge of repetitive cyclical periodicity and inter-temporal relationships expressed as autoregressive errors. While cattle price simulations have been presented using a myriad of methods, none have been consistent in their modeling, with some omitting the cyclical component and others ignoring the presence of autocorrelation.

The literature is replete with the study of the effects of autocorrelation, non-spherical errors, on the parameter estimates, and volumes have been written on the various methods of compensation by using estimators other than OLS estimators. However, one is hard pressed to find studies that provide a basis for simulating the actual autocorrelation effects.

The primary objective of this study is to examine the simulation of the repetitive component of cattle price cycles. While a key component of cattle price simulation is dealing adequately with the stochastic components, particularly when an autocorrelation process is present, this extension of the modeling process will be addressed in subsequent research.

Several techniques will be used in this analysis to attempt to capture the true nature of the data and to properly specify a cattle price model. A harmonic model similar to those used first by Franzmann, then by Franzmann and Walker, and most recently by Van Tassell and Whipple, will be constructed using several competing methods. The first method is best described as a structural method, (SM) where the model parameters are suggested by economic reasoning. The other methods are best designated as atheoretical methods (AM). These AM procedures derive information present in the data, and determine the appropriateness of the parameters based on a comparison of loss function values, in this case the Akaike Loss Criterion (AIC).

The final step in the analysis will be to determine if there is an advantage to any one of the forgoing methods in simulating the cattle price cycle. The outcome will provide the method that will be used in a much more comprehensive model to simulate market effects on individual representative ranch firms and various other models that require a cattle price simulation as a component.

Literature Review

In 1955, Breimyer summarized research related to cattle price and inventory cycles. His work cited references as far back as 1926 and included data as early as 1912. Breimyer, interestingly, describes the history of the study of the cattle cycle as first being an assessment of the price cycle, which later became a study of the inventory of cattle numbers. Some extension and popular press publications written for livestock producers describe the relationship between the cattle inventory and cattle price cycles (Anderson; Petry). However, most academic journal articles define the cattle cycle in terms of changes in cattle inventory (Aadland; Bobst and Davis; Rosen, Murphy, and Scheinkman; Rucker, Burt, and LaFrance) with a few referring to the price patterns (Foster, Havenner, and Walburger; Franzmann; Franzmann and Walker; Van Tassell and Whipple).

Breimyer also identifies two schools of thought that had been used to explain these cycles. The first was that the cycles were the result of alternating over and under production in response to high or low price signals. These cycles were identified as being a direct effect of the lag between recognition of the price signal provided by the market to its execution resulting from the biological constraints of production. The second school of thought theorized that cattle cycles occur as a consequence of outside stimuli. These divergent ideas have continued to be propagated and each has found its way into most current economic work and discussion, with the most recent example found in 2000 with the publication of Hamilton and Kasten's work.

The cattle cycle literature can be further divided into several other branches. Some articles have focused on strategies for exploiting the price cycle (Bentley, Waters, and Shumway; Trapp) and others that have used the cattle cycle as an example for various statistical procedures (Fanchon and Wendel). These studies make no effort to explain the cycle but use it as an integral part of the model, making the assumption that the cycle exists. Because the subject of the present study is the cyclical nature of cattle prices, the above articles are only presented as examples rather than as part of an exhaustive review.

The works with the greatest relevance to this study are those pieces that specifically pertain to the explanation of the cattle price cycle. Probably the two most notable among the very few on this particular topic is the work by Franzmann and Franzmann and Walker.

Franzmann not only describes earlier studies and their attempts to calculate the length of the cattle price cycle, but is the first to use harmonic estimation of these prices. As with many economists, Franzmann points out the challenges associated with describing a cycle's exact beginning and end. Determining which observation is the cycle's low or

high is complicated, given seasonal variation and random noise. To overcome these challenges, Franzmann employed two techniques: a spectral analysis and the application of the Fourier Theorem, developed around 1800 by J. B. Fourier, a French mathematician. The spectral analysis provided specification of the main cycle length within the price series. The Fourier Theorem allowed for the inclusion of other cycles of varying lengths to be integrated in the model. Franzmann describes the theorem as follows:

“The Fourier Theorem, in its simplest form, states that any periodic variation fulfilling certain conditions regarding continuity can be considered as the sum of a number of sinusoidal variations whose periods exhibit a simple relationship.”

Or simply, cycles of different lengths, when combined together in a linear equation, produce a unique function.

After deflating cattle prices, Franzmann employed the following model (using his notation) which included a sine and a cosine function to achieve periodicity, with the cosine function expressed in terms of the sine function as:

$$(1) \quad P = \beta_0 + \beta_1 t + \sum_k \beta_k \sin(\omega t + \theta_k) + \varepsilon$$

K = 2,3,4,.....

P = deflated cost per hundred pounds of cattle slaughtered

t = month from origin

ω = angular velocity equal to 2π times the frequency of the fundamental

β = parameters to be estimated.

His results, using OLS to estimate parameters, resulted in an estimated coefficient of determination (R²) of 0.8701 and with the coefficients of the linear, cyclical, and seasonal trends all being significant at the greater than the one percent level. The length of this estimated cycle was ten years. However, the statistical power of his t-test may be suspect in light of non-spherical errors which probably existed in the data.

Van Tassell and Richardson modified this harmonic model as:

$$(2) P_{it} = B_o + B_1 2\pi t + \sum_{j=1}^n \left[\gamma_j \sin \left(\frac{2\pi t}{L_j} \right) + \delta_j \cos \left(\frac{2\pi t}{L_j} \right) \right] + v_t$$

with,

$$(3) v_t = \xi_t - \alpha_1 v_{t-1} - \dots - \alpha_\rho v_{t-\rho}$$

where,

B_o = intercept

B_1 = parameter estimate for the trend

P_{it} = predicted price for the i^{th} commodity in time period t

L_j = j th cycle length.

γ_j = parameter estimate for the j th sine variable

δ_j = parameter estimate for the j th cosine variable.

Franzmann provided a number of tests to determine if this model represented the cattle cycle. While presenting an interesting case for the appropriateness of his model, Franzmann examined instances when actual prices departed from model estimates, presumably due to factors external to the model, and measured how long it took for this cycle to be re-established. Using the depression of the 30's, the Korean War, and price deviations in the 50's and 60's, Franzmann concluded that whenever prices deviated from the model, the cycle quickly re-established itself. He further concluded, “[d]espite the wide array of important changes that have occurred and the timing of their appearance, the cycle has persisted for five complete revolutions” as of 1971.

The persistence of the cattle cycle has been noted by some whose research has been conducted since Franzmann's was published in the early 70's. Although studying cattle cycle inventories rather than price, Aadland demonstrated how resilient the cattle (inventory) cycle has been during periods when exogenous shocks drastically impacted our domestic economy. He specifically considered the great depression, World War II including the end of meat rationing afterwards, and the two OPEC oil shocks in 1973 and 1979.

In addition to cattle cycles persisting over the exogenous shocks to the US economy, many technological changes in the cattle industry have occurred during the past 100 years. These include the increased use of corn finishing during the 1930s, the elimination of grazing two-year old steers as was common prior to the 1960's, and the use of larger cows, different genetics, and increased weaning rates that have occurred over the past 30 years. Throughout these exogenous shocks and changes in technology, the phase length of cattle price cycles has appeared to remain amazingly stable.

Data

The price series for calves less than 500 pounds was obtained from USDA's National Agricultural Statistics Service's web-hosted data base called “Quick Stats.” This price

series is from “U.S. & All States Data – Prices – Monthly Prices Received – Calves Less Than 500 Lbs”. The data series begins August 1909 and continues through December 1990. It resumes January 1998 and continues through December 2006. Data for 1991 through 1997 was obtained from the Publication entitled “Agricultural Prices Summary”. This report can be accessed at the website <http://usda.mannlib.cornell.edu/MannUsda/homepage.do> under the subject “Economics and Management”. The monthly prices from this report were compared to the price data obtained from the “Quick Stats” data base for 1990 and 1998 and they were identical indicating that they represented the same price series.

The price series for calves less than 500 pounds was selected for this analysis based on unpublished research by Stockton, Wilson, and Bessler which indicate that light steer prices from this weight group determine the prices of the other sex-weight categories of calves.

The Consumer Price Index values used to convert these nominal prices to real prices were obtained from the U.S. Department of Labor’s, Bureau of Labor Statistics (BLS) website located at <http://www.bls.gov/cpi/>. This site provides a number of indices. The index titled “All Urban Consumers (Current Series) U.S. All items, 1982-84=100 - CUUR0000SA0” was the one chosen to convert the nominal series of prices to real prices.

Procedures and Results

Before determining cycle lengths, the nominal price data was converted into a real price series, where the base period was 1982-1984. This conversion was done using the CPI for all goods published by the BLS. The plot of the converted data (Graph 1) has a bowed shape, indicating that a quadratic function may be a more appropriate form to explain trend than the simple linear function. An Akaike Loss Criterion (AIC) score comparison between a regression model with a quadratic variable and one with only a linear variable showed a 53 point difference in favor of the quadratic. Graph 2 illustrates the trend differences between these models.

Three harmonic regression models with varying numbers and cycle lengths were created using three methods representing two distinct methodologies. The first method, structural method (SM), was based on economic observation and theory. This procedure is much like the development of a structural demand system where economic reasoning and theory guide the specification of the key components. The second method was a modified atheoretical method (MAM). The third method, identified as a limited atheoretical method (LAM), was also an atheoretical method (AM) with the number of possible cycles used in the model limited. These last two methods were so named because, like time series analysis, they use information inherent in the data itself. The AIC loss function measures the balance of the size of the sum of squared errors and the number of explanatory variables included in the model. In this case, the AIC was used to determine the number of cycles in the MAM and the length of the cycles in both the LAM and MAM.

The SM model was developed using existing knowledge and information from previous work in the cattle price and price cycle area. Past studies have identified a long term cycle (LTC) of approximately 10 years (Franzmann, Aadland). Franzmann also observed that cattle prices were shown to have a seasonal component or a short term cycle (STC) of approximately twelve months. For purposes of determining the best fit cycle to the data, the LTC was constrained to a range between 110 and 130 months and the variation of the STC was limited between 6 and 18 months. However, before estimating each possible equation, the data set was truncated at both ends (i.e., the first 107 and last 38 observations were dropped) to remove the effect any incomplete cycles might have on the explanatory parameter estimates. An AIC scoring was used to rank the 273 possible combinations of these two different cycle lengths. An LTC of 123 months and an STC of 12 months provided the combination with the lowest AIC score, indicating the best balance between the sum of squared residuals and the number of explanatory variables considered.

The two AM procedures were more involved than the SM process. The AM process was designed to let the data best explain itself by using the AIC loss criterion in order to specify the number of cycles to include in the estimation process as afforded by the Fourier theorem, and to determine the size or length of those cycles. The first constraint on this method was to exclude cycles larger than half the length of the data set to assure that all possible cycles are repeated in the breadth of the data. Failing to remove the chance that a non-repeating cycle may result in identifying a false cycle could be compared to hypothesis testing when making a type II error. To reduce the chance of including spurious cycles, only cycles that are repeated at least once (i.e., less than 565 months in length) are considered, while allowing the quadratic trend to continue to account for a cycle-like trend in the data.

A second challenge with the AM procedure was dealing with the large number of possible cycle combinations that could occur. For example, there are 29,742,164 possible combinations of three cycles after limiting the length of the longest cycle at 564 months. The number of cycles combinations examined, therefore, needed to be limited given the time and computing power needed to search the full range of possibilities and to determine the lowest AIC score. In light of these two obstacles, two different approaches were initiated, the MAM and the LAM.

The MAM approach is best described as an iterative, additive elimination technique. The first iteration starts by estimating Equation 4 for all 564 possible cycle lengths ($j = 1, \dots, 564$). The estimate with the lowest AIC score is then selected as the new base model, adding two new variables to the model.

(4)

$$P_{it} = B_o + B_1 2 \pi t + B_2 (2 \pi t)^2 + \sum_{j=1}^n \left[\gamma_j \sin \left(\frac{2 \pi t}{L_j} \right) + \delta_j \cos \left(\frac{2 \pi t}{L_j} \right) \right] + v_t$$

Where π is 3.1415926535, t is the numeric month number, and L is the cycle length in months.

The second iteration repeats the procedure of the first with the exception that the new base model includes the two new variables, (equation 5). This is the additive part of the technique. The second iteration estimates, and accompanying AIC scores, are again calculated over the possible 563 cycle lengths ranging from 1 to 564, excluding the cyclical length of the new variables added from iteration 1.

$$P_{it} = B_o + B_1 2\pi t + B_2 (2\pi t)^2 + \gamma_1 \sin\left(\frac{2\pi t}{L_1}\right) + \delta_1 \cos\left(\frac{2\pi t}{L_1}\right) +$$

$$(5) \sum_{j=2}^n \left[\gamma_j \sin\left(\frac{2\pi t}{L_j}\right) + \delta_j \cos\left(\frac{2\pi t}{L_j}\right) \right] + v_t$$

This process is repeated with each of the successive iterations while excluding the cycle lengths present in the sine and cosine variables found in all previous iterations. The iterative process concludes when the AIC scores obtained from adding one additional cycle is less than the AIC of the existing model that includes the cycle's lengths chosen to that point.

For this example, the MAM procedure added 19 cycle lengths to the model. Table 3 summarizes the order and length of the 19 added sine and cosine variables. Because of memory constraints with the econometric package Shazam, the expressions containing $(2\pi t)$ were truncated down to the closest integer for by simply removing any decimals. The last 38 and the first 107 observations were eliminated from consideration to remove any effect partial cycles might have on the results. This also reduced the largest possible cycle length from 564 to 491 months.

The second AM approach, LAM, limited the number of cycles added to the model to three, excluding the seasonal cycle, and applied the assumption that all examined cycles must be repeated, i.e., cycle length was limited to 564 or less (Equation 6). Given these assumptions, all 29,742,164 combinations of quadratic regressions with three cycles were estimated and AIC scores calculated. The model with the lowest AIC score occurred with cycle lengths of 125, 440, and 564 months.

$$P_{it} = B_o + B_1 2\pi t + B_2 (2\pi t)^2 + \gamma_1 \sin\left(\frac{2\pi t}{L_1}\right) + \delta_1 \cos\left(\frac{2\pi t}{L_1}\right) + \gamma_2 \sin\left(\frac{2\pi t}{L_2}\right)$$

$$(6) + \delta_2 \cos\left(\frac{2\pi t}{L_2}\right) + \gamma_3 \sin\left(\frac{2\pi t}{L_3}\right) + \delta_3 \cos\left(\frac{2\pi t}{L_3}\right) + v_t$$

Examining the graphs of the three models tells an interesting story. The SM (Graph 3) and LAM (Graph 4) models reflect only general similarities between the predicted values and the data, and thus, have larger residuals in absolute terms. The MAM predicted values (Graph 5), conversely, are a much better likeness and have smaller overall residuals. Graph 6 illustrates the difference in residuals.

It was apparent from visual inspection and the AIC scores that the MAM model, with its 19 cycles, provides a better explanation of the data. However, if one considers that the more simple models, the LAM and the SM, may be correct specifications because the major portion of the residuals are the result of special events such as WWII, great depression, Nixon's price freeze, and/or structural change, the models can be estimated for each cycle separately. Van Tassell and Whipple used a method referred to as the minimized Akaike information criterion, MAIC, to determine structural change. They compared the AIC over the data stream as a whole (TAIC) to the sum of the AIC's (SAIC's) of selected periods, with structural change being indicated when the SAIC was less than the TAIC. More directly, if the sum of the parts was less than the whole, they concluded that structural change had occurred. In mathematical terms, the difference of the two results measures the efficiency of the change in the parameter estimates versus the change in residuals for the data set as a whole, and the effect of allowing the parameter estimates to change over parts within the whole.

Before applying the MAIC test to assure consistency between the SAIC and TAIC, the variable t (month number) was changed from a single string that ranged from 1 to 1128, to a recursive string count of 1 to 123, which produced an interval representative of a 10 year, 3 month cycle. The recursive month count started with the 108th month, the lowest point of the first full cycle, through the 1090th month, the 123rd point of the last full cycle. This recalibration of the month numbers is one way of considering each individual LTC separately with the whole string being a chain of the individual cycles. The new chained version of the SM and LAM models will be referred to as chained SM (CSM) and chained LAM (CLAM) models

Applying the MAIC method to the SM and LAM models resulted in the SAIC scores being less than the TAIC scores. This difference indicates that individually estimated cycles resulted in a model that better explained the data, supporting the proposition that the major portion of the residuals are the result of special events, and/or structural changes, and that the model is best estimated for each cycle separately. While this result is not conclusive, it does provide the basis to build alternative methods for simulating the cattle price cycle. Graph 7 shows the predicted values of the CSM model versus the actual real prices. The new residuals of the CSM model versus the SM residuals can be seen in Graph 8, where the CSM residuals appear to be much less volatile, and have a smaller variation.

Summary and Conclusions

While progress has been made toward identifying a model that will provide a representative simulation basis, more work needs to be done making this paper far from complete.

To summarize briefly, three harmonic regression models with varying numbers and cycle lengths were created to examine the periodicity of cattle prices. The structural method (SM) relied upon on economic observation and theory to suggest the length of the cycles contained in the model. The modified atheoretical method (MAM) and the limited atheoretical method (LAM) relied upon the AIC loss function to determine the number of

cycles in the MAM, and the length of the cycles in both the LAM and MAM, with the LAM being limited in the number of possible non-seasonal cycles examined to three.

The SM identified a short term cycle (STC) length, or seasonal component, of 12 months, and a long term cycle (LTC) length of 123 months. The MAM procedure included 19 cycles in the model, with cyclical lengths ranging from 12 months to 302 months. The LAM approach limited the number of cycles to a seasonal cyclical length of 12 months and three longer cycles of 125, 440, and 564 months. By visual inspection and the measurement of the MAIC score, the MAM predicted values provided the best fit for the cattle prices examined.

Chained versions of the SM and LAM models were also estimated, where each cycle within the identified 123 month period was estimated separately. These chained models appear to track the individual cycles much closer as is seen visually and by the MAIC scores.

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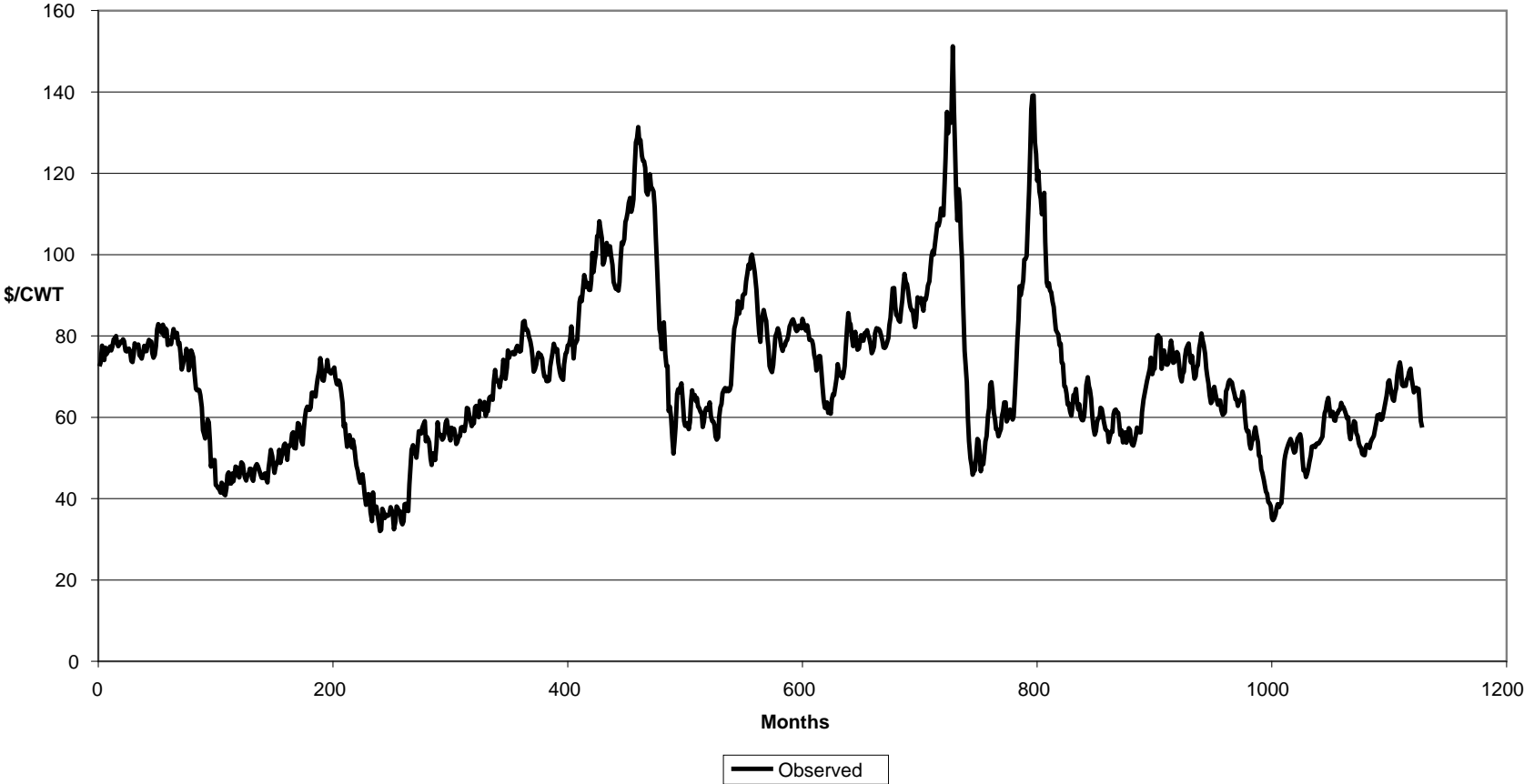
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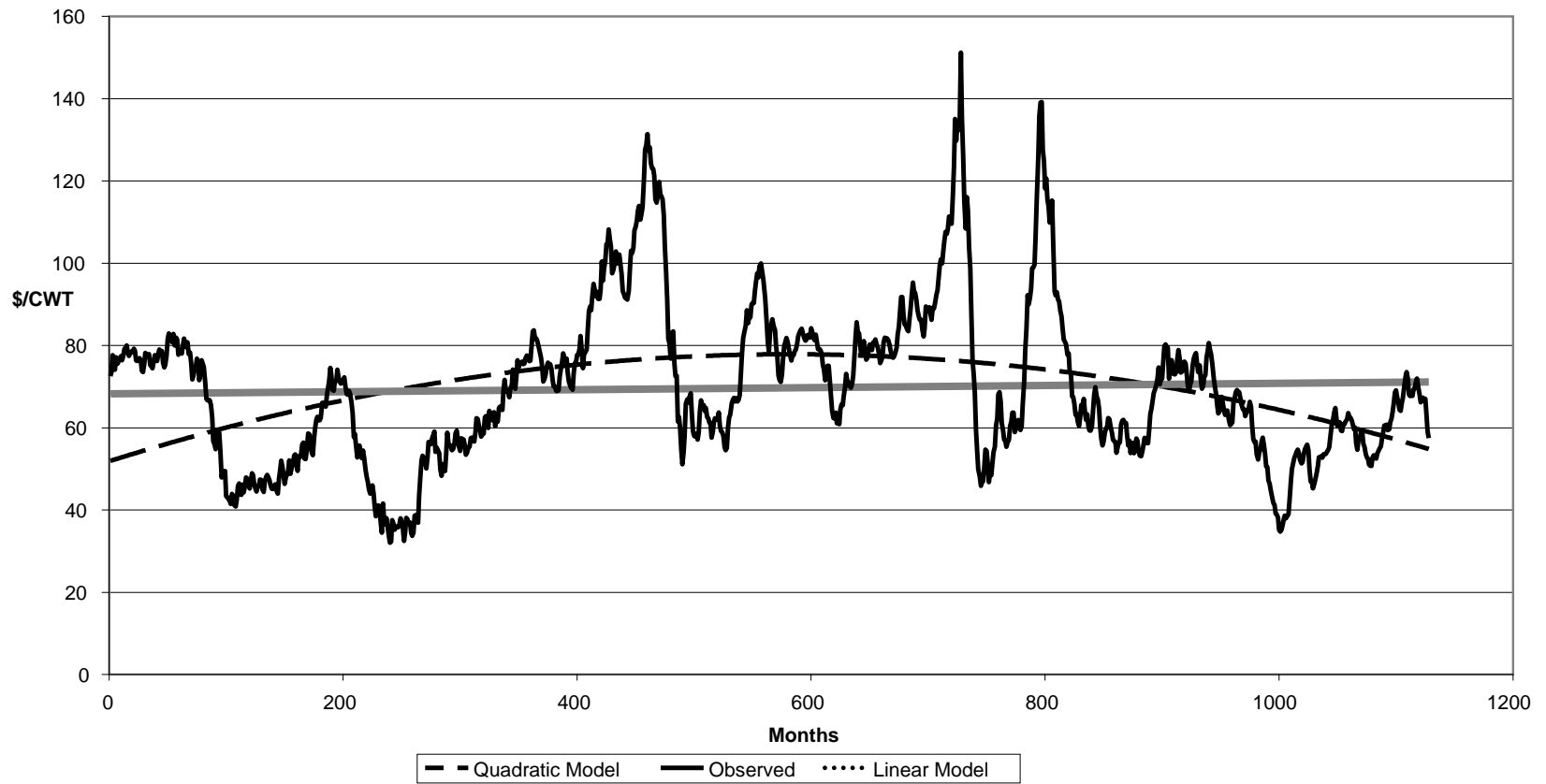
**Table 1 The modified atheoretical method
(MAM) Cycle Order and Lengths**

Order of Selection	Months Per Cycle Length
1	123
2	302
3	87
4	65
5	110
6	286
7	43
8	79
9	160
10	110
11	71
12	60
13	37
14	41
15	45
16	12
17	48
18	54
19	34

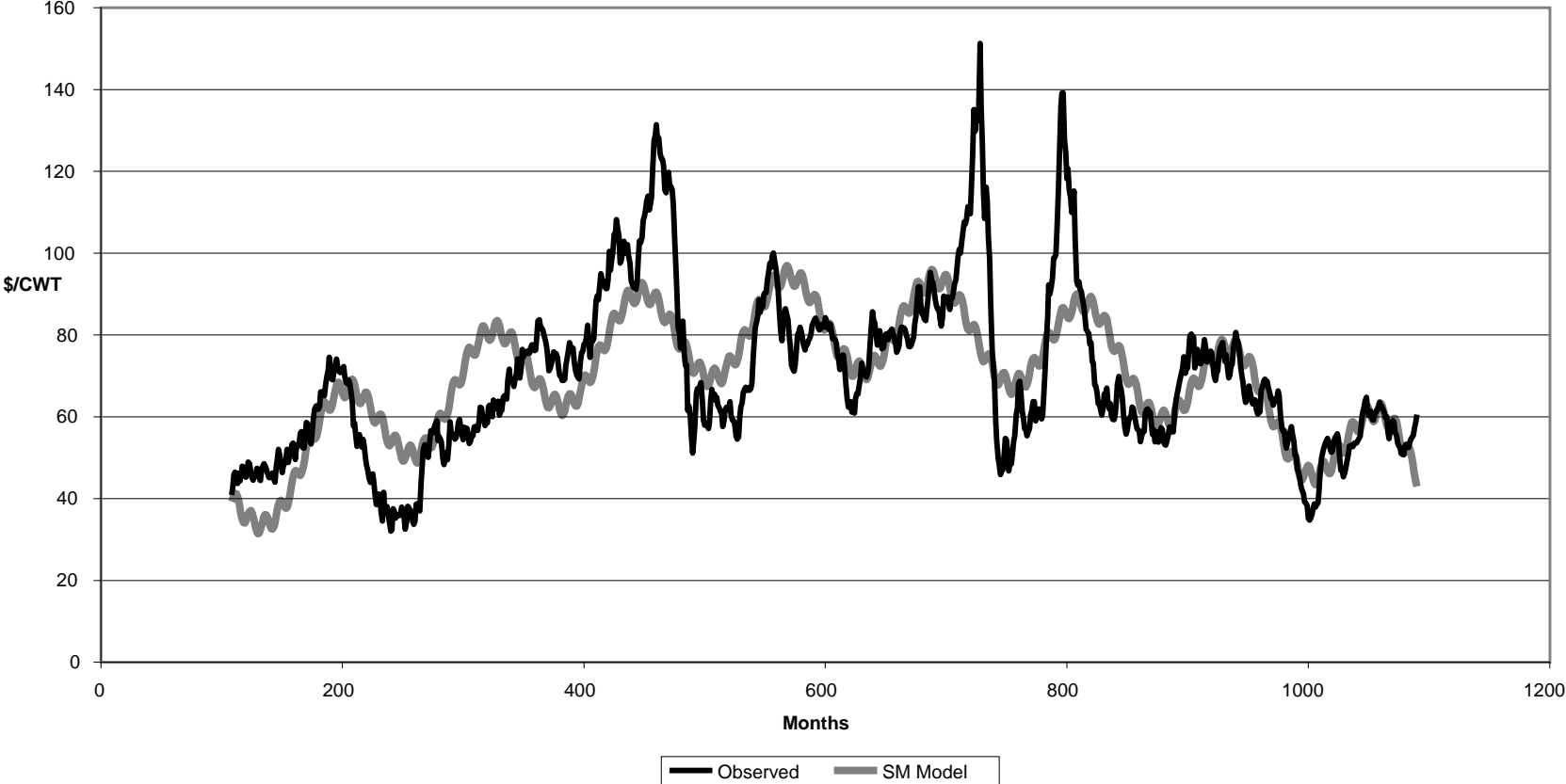
Graph 1: Real Prices For 500 Lbs or Less Calves



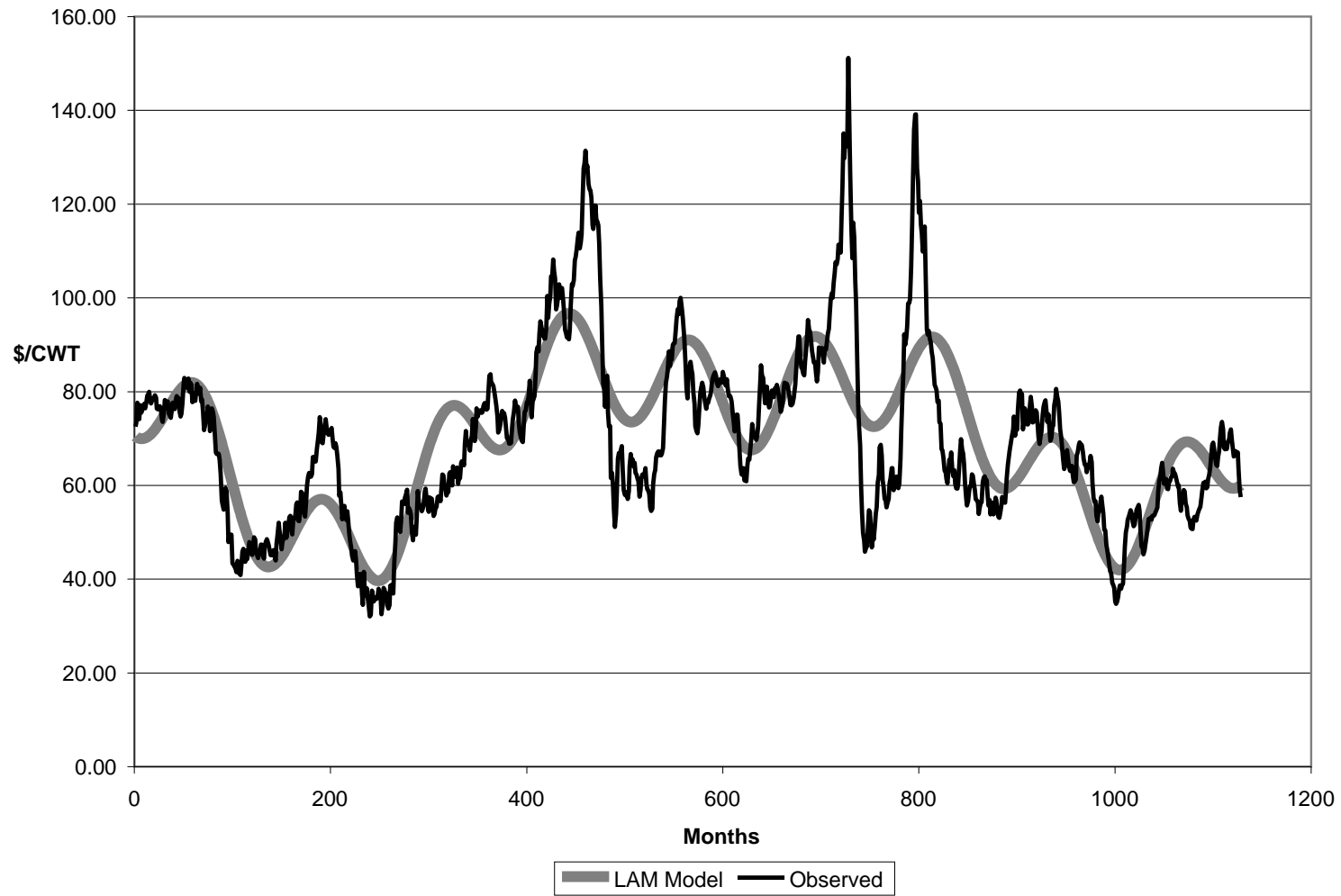
Graph 2: Comparison Between the Quadratic and Linear Models



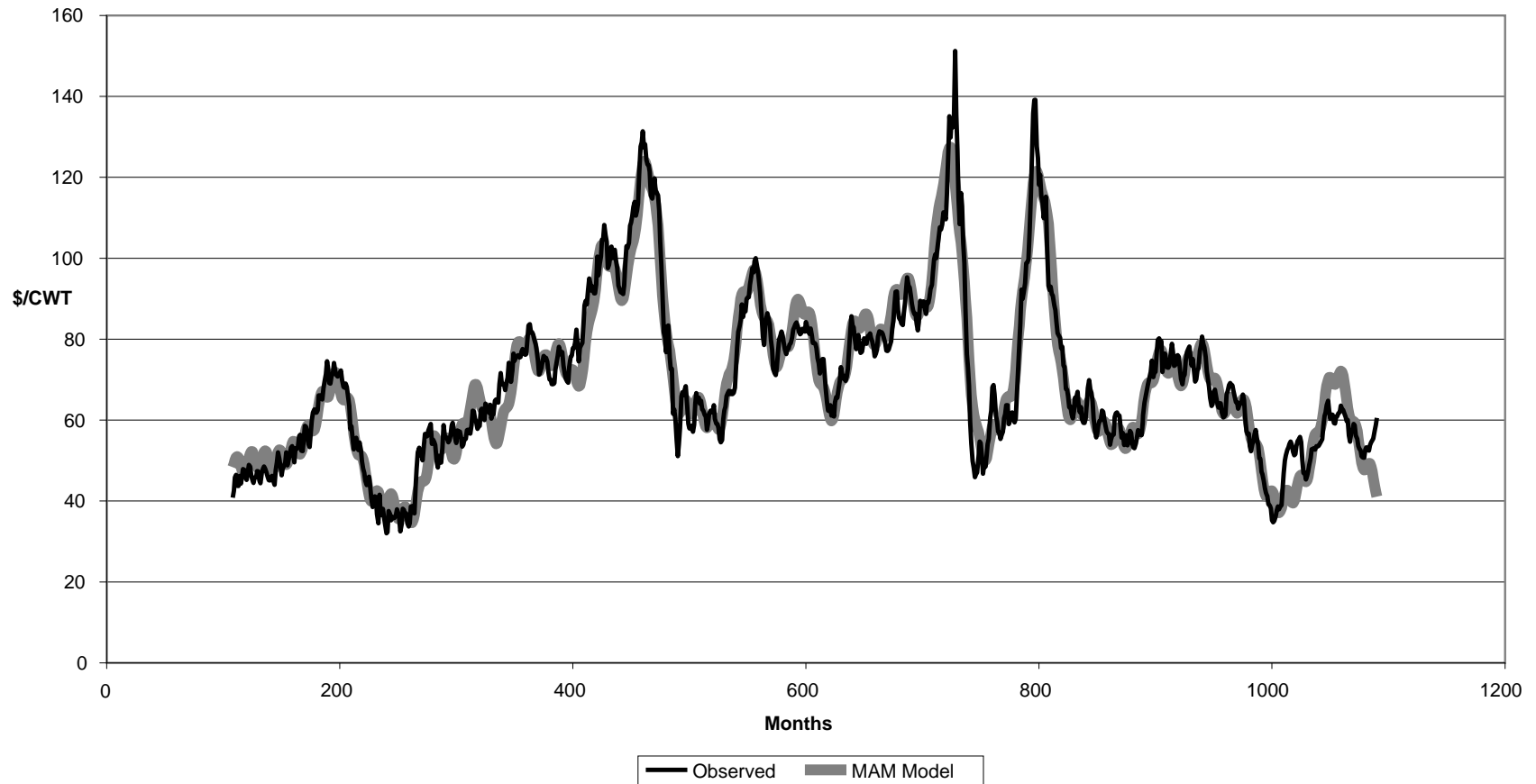
Graph 3: Real Prices Verses The Structural 2 Cycle Model (SM)



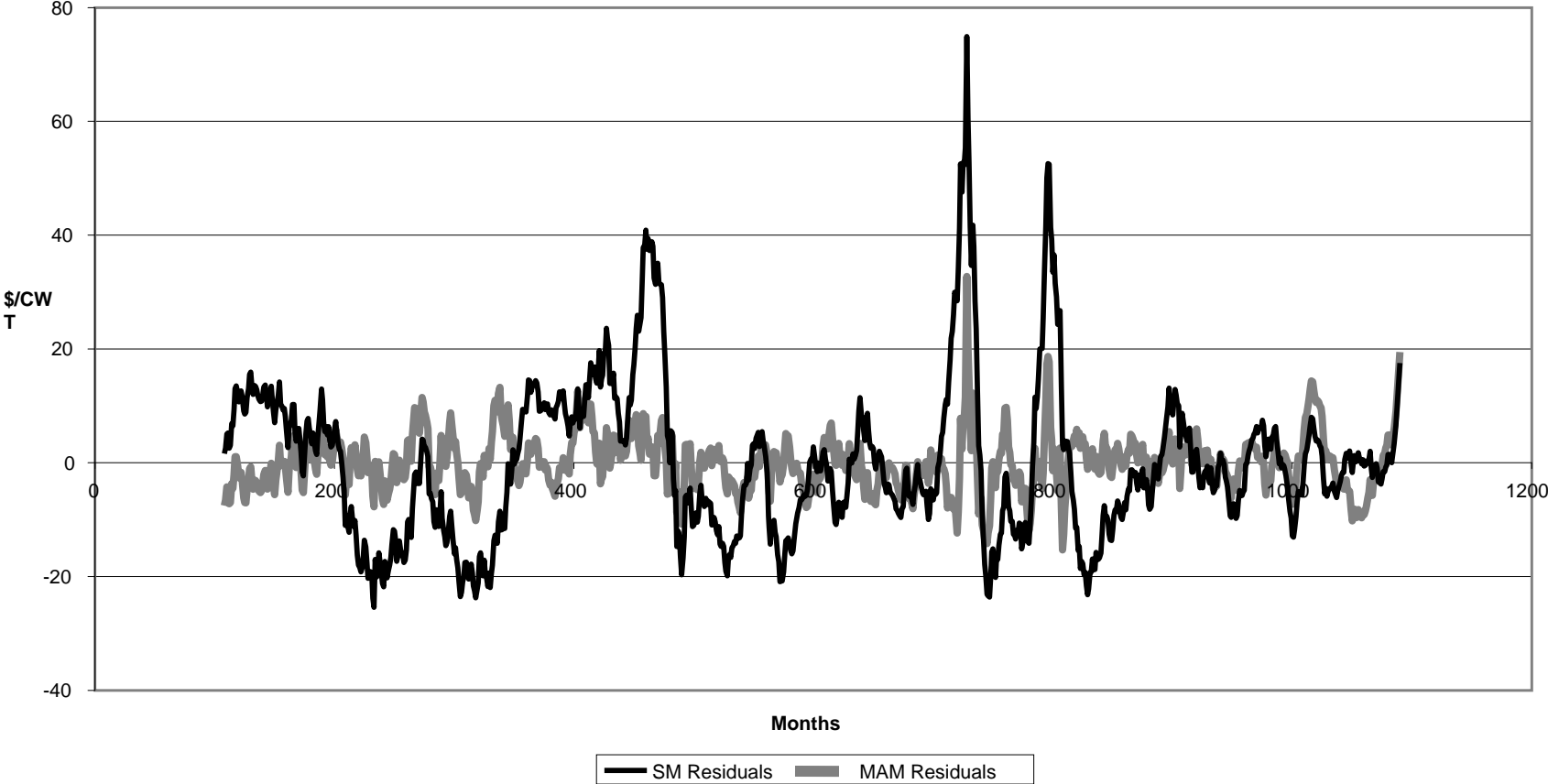
Graph 4: Real Prices Verses the Limited Atheoretical Model (LAM)



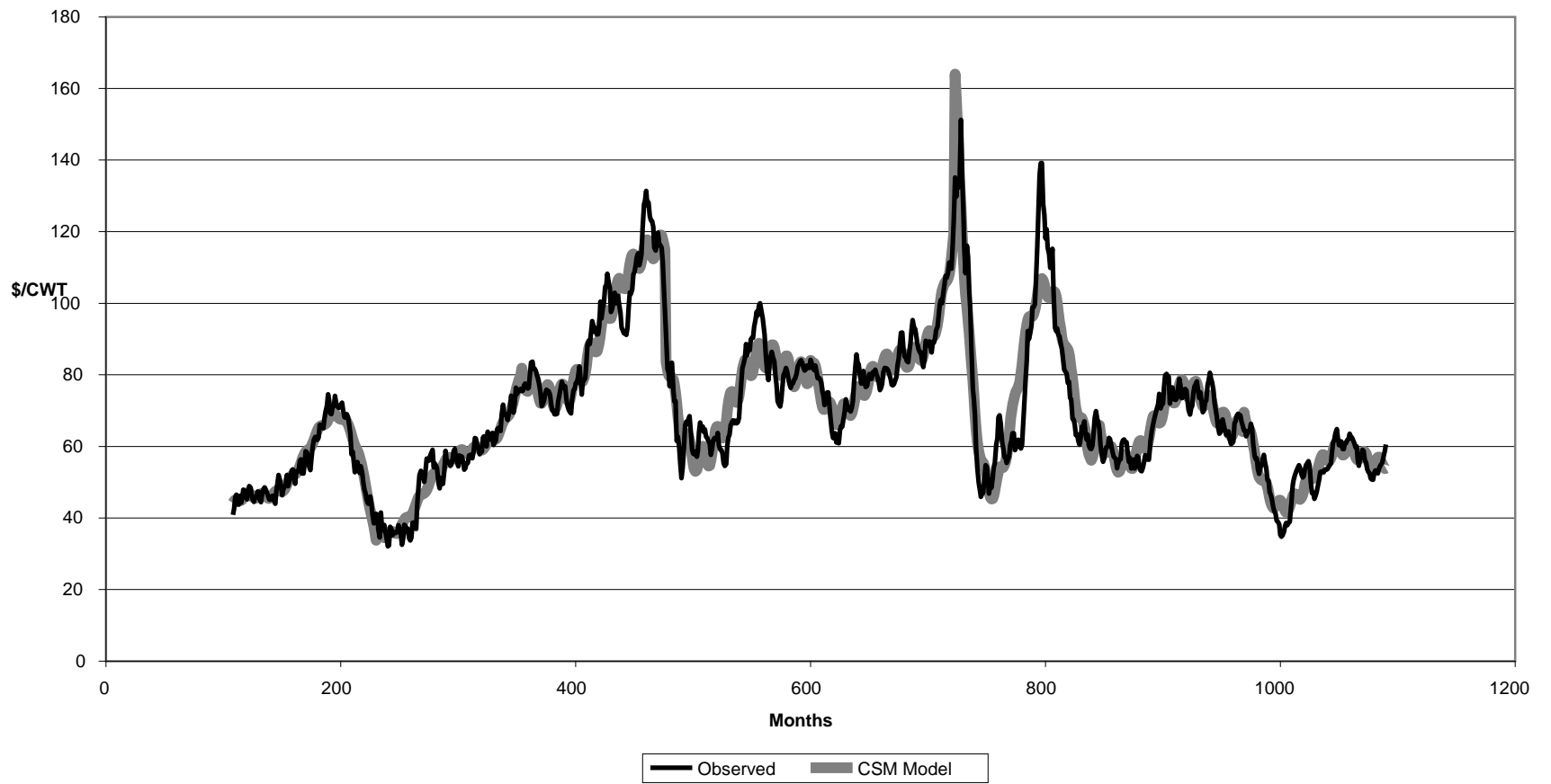
Graph 5: Real Prices Verses the 19 Cycle Modified Atheoretical Model (MAM)



Graph 6: Residuals of the SM and MAM Models



Graph 7: Real Prices Verses The Chained Structural Method (CSM)



Graph 9: Residuals of the SM and CSM Models

