VERTICAL INTEGRATION IN THE CHICKEN BROILER INDUSTRY

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Abstract

This paper analyzes three hypotheses concerning supply in the U.S. chicken broiler industry: (a) there has been a cycle in the industry of approximately 27-36 months length; (b) the seasonal and other periodic components, as well as relations between variables, have changed as a result of vertical integration in the industry; (c) the effects of vertical integration in the industry were counteracted in the early seventies by such forces external to the industry as domestic and international economic conditions.

The hypotheses are analyzed using new monthly, non-seasonally adjusted time series data for chick placement, wholesale broiler prices, chicks hatched and net returns. Exploratory analysis using three different spectrum analysis methods, shows that there is evidence to confirm those hypotheses. Using that information, forecasting models are constructed, and their performance is compared to the performance of the standard distributed-lag models used by analysts of the industry.

The paper then offers robusts results concerning hypotheses that have occupied the interest of analysts of the industry for a very long time. These results indicate that as vertical integration reached maturity, broiler suppliers tended to become sales maximizers.

Key Words: periodogram, autoregressive spectrum, Bayesian, demodulation, forecasting, distributed-lag, vertical integration, sales maximization.

1 Introduction

Broilers are young chickens 7 to 10 weeks of age. Since the fifties, the broiler industry has been one of the most rapidly changing agricultural subsectors, gradually passing from being characterized by many small, independent farm flocks and small processors scattered across the country to being a highly vertically and horizontally integrated, efficient industry located in a relatively few counties ([2], [8]). This evolution has been illustrated

by descriptive trend analyses in [34], [8], [2], by the common practice of reestimating every year (to account for the changes) the distributed-lag econometric models used for policy analysis, and by traditional spectral methods [33]. Production decisions in the industry can be investigated at four stages. First, "placements" refers to the introduction of chicks or poults into the production process. The United States Department of Agriculture (USDA) reports the broiler placements (number of chicks placed) in hatchery supply flocks. Second, "testing" refers to the testing for pullorum-typhoid disease undertaken by state agencies, which report the number of broiler-type chickens in the tested flock. Testing is performed about five months after chickens are placed in the hatchery supply flock. The third stage of production is "hatching" of eggs from the hatchery supply flock. The USDA reports the number of eggs hatched in commercial hatcheries. After hatching, approximately eight weeks are required to produce a 3.8 pound liveweight broiler. The USDA publishes the "production" of broilers, or chicks hatched, the fourth stage. Placements and chicks hatched are two variables often used in studies of the response of production to other variables.

Analysts of the industry are interested in determining whether there are any predictable relations between any of those variables mentioned above, whether there are some regularities in each of them that can be used for prediction, and how the variables depend on other independent covariates, such as broiler price, vertical integration, returns and(or) costs, in particular feed cost, the most important one in the industry. Obtaining reliable answers to these questions helps design structural models of production with good forecasting performance, which in turn allows for a more effective planning and policy in the industry. In addition to that, the answers to those questions allow reaching conclusions about the objective function of broiler suppliers. In order to make the results of this paper comparable to earlier studies, I investigate the same questions about production decisions at the "placement" and "hatched" level, with new data and methods.

To update the results of earlier studies, particularly those of [33], with new data, I analyze three hypotheses concerning production. (1) There is a cycle in some time series of the industry of approximately 27-36 months length ([4], [40], [33]); (2) The seasonal and other components, as well as relations between variables, have changed as a result of vertical integration in the industry ([33], [38], [39], [20], [8]); (3) The effect of vertical integration has been counteracted by such forces external to the industry as domestic and international economic conditions ([35]).

Hypothesis (1) was very important in the pre-vertical integration period of the industry. By the nature of poultry production there was a lag between the time at which the production decision was made and the time at which the product was sold. Being the market the coordinating mechanism, prices and quantity supplied varied widely, as in all other agricultural subsectors. This led some researchers to claim that the industry exhibited a pattern of cyclical fluctuations (Bluestone [4], Tobin and Arthur [40]), namely a 30 months cycle (the time it took to complete a cycle of production). Such cycle was found significant by [4] and [40]. Rausser and Cargill [33] found that a cycle of that length

during the fifties and sixties was significant only for price, not for quantity. The existence of this cycle is still questioned, and is relevant to determine whether stabilization policies should be based on the existence of fixed periodic cycles.

Hypothesis (2) is widely accepted ([8], [2]). With the advent of vertical integration in the fifties, Tobin and Arthur [40] expected a dampening of the cyclical components in the price and output series. Henry and Raunikar [20], Seagraves and Bishop [38] and Seaver [39] in particular hypothesized that the amplitudes of the seasonal components of prices and output would be reduced as a result of vertical integration. This was sustained by the view that the major effect of vertical integration was to make adjustments in production and prices smoother as a consequence of increased ability of growers to plan the flow of inputs available for production. Rausser and Cargill [33] found that the seasonal in prices had dampened much faster than the seasonal in output. This, those authors claim, "conforms well with the notion that vertical integrators, although attempting to stabilize both prices and quantities, actually emphasize the former, which results in greater variability of output relative to prices" ([33], p.120). They also found little association among a set of time series after trend removal, except at the seasonal components. Hence, they concluded that during the fifties and sixties, "there is no evidence of a meaningful lead-lag pattern except at the seasonal component" ([33], p. 120). The existence of fixed time differences among the series would be significant for designing stabilization policies in the industry.

Hypothesis (3) maintains that the stabilizing effects of vertical integration were reversed since the early seventies. Several events occurring outside of the industry in that decade, such as world feed shortages, changes in the exchange rate regime and oil crisis, affected the cost structure of the industry, forced producers to adjust their energy use patterns [35] and made them more aware of agricultural export demand conditions [13], [9], [30], [29]. The industry became, again, more vulnerable to external markets conditions and instability. The large increase in the variability of broiler prices originating during the seventies is associated with that increasing dependence on the instability of international markets. It was then believed that this would lead to another restructuring of the broiler industry to accommodate to the new situation [35] The changes occurring in the industry after the energy crisis, can provide evidence on the new managerial policies of broiler firms, and can suggest what their objectives are, as vertical integration reaches maturity.

The three hypotheses described above are analyzed in this paper using methods of spectrum analysis new in econometrics, and new data. These allow the updating and reevaluation of results obtained by other authors. Using several methods to analyze the data is recommended by Parzen [31] and Brockwell and Davis [6]. The data support the conclusion that broiler integrators are sale maximizers.

Following the advice in Engle [11], I use the spectral methods to aid in the specification of time domain models, and then use standard time domain methods to estimate, and forecast with, them. The objective is to determine whether univariate time series models, based on the spectral analysis, improve the forecasting performance of the distributed-lag

models usually used to forecast in the broiler industry.

2   The Data

To make research with new data and methods comparable to older research, it is important to use the same variables other authors have used. For this reason, the four time series chosen in this paper for the study of supply in the broiler industry are the most widely used in published research that has addressed the same hypotheses. They allow studying the change in structure of the industry, the change in the relation between the most important variables used in the forecasting models and the 30 month cycle. As seen in the introduction, the two output series represent key steps of the production process. The price and return series are covariates that are usually included as explanatory variables in structural models. The time series are:

(I) Pullet chicks placed in broiler hatchery supply flocks, January 1960 to December 1986, thousands. Source: [41]

(II) Wholesale broiler prices, January 1964 to December 1986. Monthly 12-city composite, cents per pound, Ready to Cook (RTC). Source: [42].

(III) Chicks hatched: Broiler type in U.S. commercial hatcheries, January 1960 to December 1986, thousands. Source: [41].

(IV) Young Chicken: Net returns, January 1967 to December 1986, cents per pound, RTC. Source: [10].

These data are domestic United States, monthly and not seasonally adjusted.

Price and returns, as well as the output series, are shown in Figure 1. Series (I) has 324 observations. Just by looking at the data, it can be discerned that there is a trend in mean, a change in the variability of the commodity's seasonal amplitude and a long wave. The period 1960 to 1968 is the most variable. Wholesale broiler prices, series II, were fluctuating mildly until 1973. After this year, however, not only did amplitudes of fluctuations increase considerably, but also the trend in mean took a sudden jump and increased at a higher rate than previously. The number of observations is 276. Series III shows that chicks hatched, in contrast to the other series, does not show any marked change in variability at first glance. The number of observations in this series is 324. Finally, net returns, series IV, displays a large variability since the seventies, similar to that of wholesale prices.

3   Is there a Thirty Months Cycle in the Broiler Industry?

One of the hypotheses that concern me in this paper is the existence of a cycle of approximately 30 months length in the broiler industry, a question investigated by Rausser and Cargill using the same time series for up to the early 1960s. This question, is there evidence for cycles?, is best answered by univariate sample spectral methods.

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The predominant approach to spectrum estimation in Econometrics is the Blackman-Tuckey method of spectrum analysis [14],[12],[16], [26], [15], [11], [33]. This method consists of smoothed periodograms which are asymptotically consistent but lack resolution in the detection of frequencies [24], [23]. Rausser and Cargill ([33]) used the smooth periodogram, after differencing and log regression, to detrend their chick placements and wholesale price series, and found no significant evidence for a cycle in placements, but they found a significant 30-month cycle in prices. My data covers a period different from that analyzed by Rausser and Cargill [33], and the methods used are different. The three methods used here are: periodogram (without smoothing) , autoregressive and Bayesian spectrum analysis [36].

The periodogram without smoothing can be defined as

$$
\begin{aligned}
\tilde{C}(\omega) &= \frac{1}{N} \left| \sum_{t=1}^{N} X(t) e^{i\omega t} \right|^2 \\
&= \sum_{\tau=-N}^{N} \hat{R}(\tau) e^{-i\omega\tau}
\end{aligned}
\tag{1}
$$

where $C(\omega)$ is the Fourier Transform of the data, $X(t)$, or the inverse Fourier transform of the autocorrelation function of the data, R.

An alternative approach to spectrum estimation is the Autoregressive spectrum estimator [21]. Assume that the time series we are interested in, $X(t)$, is an autoregressive process of order p

$$
X(t) = \sum_{k=1}^{p} a(k) X(t-k) + u(t)
\tag{2}
$$

where $\{u_t\}$ is a white noise process of zero mean and variance σ^2, and $a(k)$ are the autoregressive parameters. Then, the power spectrum when $T \to \infty$, takes the specific form [17], [24] :

$$
C(\omega)_{AR} = \frac{\sigma^2}{|1 + \sum_{k=1}^{p} a(k) \exp(-i\omega k)|^2},
\tag{3}
$$

Substituting in equation (3) sample estimates of σ^2 and $a(k)$, and finding p, the order of the model, by some criterion, the autoregressive estimator $\hat{C}_{AR}(\omega)$ can be found ([24], [23]). I use the Burg algorithm to estimate $a(k)$ and σ^2 ([23], [24]). The order of the process is chosen using the Criterion Autoregressive Transfer Function (CAT).

A third method used to determine the existence of the cycle is the Bayesian frequency parameter estimation method [5]. To apply this method, I assume a polynomial trend plus harmonic model for the data $X(t)$.

$$
X(t) = T(t) + A \sin \omega t + B \cos \omega t + e_t
\tag{4}
$$

where

$$T(t) = \sum_{i=1}^{r} \beta_i t^i \tag{5}$$

is a polynomial in time, r is the degree of the polynomial and e_t is an error term normally distributed with mean μ and variance σ^2. The results of a Bayesian analysis depend on the model and the prior information assumed. Bretthorst [5] uses noninformative prior distributions. Given these and the likelihood function implied by the model given above, applying Bayes theorem, and integrating out the trend parameters and the amplitudes, we obtain the marginal posterior probability of the frequency parameter ω and the variance σ^2. Because noninformative priors are used, the result is an induced marginalized likelihood of the frequencies and the variance of the noise ([5], [43]). The degrees (r) of the polynomial trend integrated out from each series are:

Series	Degree of the Polynomial
I	7
II	7
III	6
IV	5

To apply the three methods to the time series, I first subtracted from the data the polynomial trend suggested by the Bayesian method. The seasonal and its harmonics plus a mass of power concentrated around the 30-month cycle are the most important components of the series, according to the periodogram of the detrended data and the autoregressive spectrum. Most of the variance, however, is carried by the seasonal component. The 30-month cycle is only significant for the price time series.

Figure 2 shows the Bayesian $\log_{10}$ of the marginal posterior probability of a harmonic frequency of the time series after integrating out the trend parameters. The most important peaks observed correspond to the seasonal component (period=12) and its first harmonic (period=6). There are also other—relatively much smaller—peaks which correspond to the other three harmonics of the seasonal component, namely 4, 3 and 2.4 months. The cyclical component at 35.99 months, is favored by Bayesian model selection [43] only in the return series.

In order to see if the importance of the cyclical and the seasonal component change over time, I also divided the time series into several time intervals. As was predicted, given the rather nonstationary nature of the series, there are some periods in which the 30-month cycle is significant and other periods in which it isn't. The results in the following section provide more information about the structural change that this implies.

4   Have Components of the Industry and the Relations Among them Changed ?

Hypothesis 2 stated that vertical integration in the broiler industry led to a decrease in the amplitudes of the cyclical and seasonal components of the industry. Hypothesis 3 stated that this effect had been counteracted by the events taking place in the early seventies. These two hypotheses can be studied simultaneously using the methods of this section. The first thing to do is to detect the change in the variability of the detrended time series, in particular whether the series variability decreased during the sixties (hypothesis 2) and then it increased during the seventies (hypothesis 3). We can do this using complex demodulation. Thus, following ([3], [15]) I demodulate-remodulate series I, II, III and IV at the seasonal frequency and three harmonics. The results, as illustrated in Figure 3, reveal that the amplitudes of the fluctuations of the seasonal component of each series has not been constant over time. This is a sign of nonstationarity. The graphs in Figure 3 measure the amplitudes of the time series in base points.

The degree of nonstationarity varies for each series. Thus, the remodulated chick placements reveals that the amplitudes of the seasonal have decreased over time. The amplitude of the seasonal component of chicks hatched does not vary as much as the amplitude of the other three series. It has been more stable during the sixties than during the seventies and eighties, but not drastically. Price and returns suffered by far the largest increase in variability during the seventies, compared to the output series. Overall, the evidence obtained from the complex demodulation of the series reveals that the seventies altered the stabilizing effects of vertical integration on prices and returns achieved in the sixties (hypothesis 3), as shown by the decrease in variability in the latter period and the increased in variability in the former.

Seeing how each individual series of the broiler industry has changed gives some evidence on the hypotheses stated earlier. However, more relevant for modeling purposes is to know whether the lead-lag structure in the relation between series has been altered. To study this, I apply periodogram and autoregressive cross-spectral analysis to the two time intervals: 1964-1972 and 1973-1984. The cross-spectral results reveal that the coherence, or degree of association between the series, is lower in the 1973-1984 interval than earlier, particularly at the seasonal periods (12 months and lower). This is more noticeable in the relation between prices and output than in the relation between outputs. The cross-periodograms for the former relations can be found in Table 1 and in Table 2. Notice that in those tables, if the coherence is less than 0.5 it is not reported, a standard practice. The phase or lead-lag pattern also changes. Leads and lags become smaller in the 1973-1984 interval, for all the nonseasonal frequencies, and all series pairs. At the seasonal frequencies, it becomes larger for price-output relations (although it is still very small) in the seventies, but it is not significant. Chicks hatched and chicken placements, however, had no lag in either time interval, although they are very highly associated in both time intervals.

These results, combined with those of the complex demodulation, are preliminary

evidence on the sales maximizing behavior of broiler suppliers. Lower relation between price and output and longer lags, plus higher variability in prices in the seventies, together with a relative maintenance of the stability of output, all reveal that the response of suppliers to the crisis in the seventies was to stabilize output and not let supply respond to prices. This implies that they pursued sales maximization instead of profit maximization as an objective. This attitude contrasts with that found by Rausser and Cargill in the sixties, namely that vertical integration had stabilized price more than output. If the evidence found here was further confirmed, then it would imply that there has been a change of managerial goals in the industry as a result of the crisis in the eighties.

5   Forecasting Models

Modeling of supply in the broiler industry is usually done by means of distributed-lag adjustment models (see Judge *et al.* [22], p. 350 for characterization of these models). The economic theoretical counterpart of those models in agricultural sector modeling is the Nerlovian dynamic supply framework, which consists of an adaptive expectations equation for price, an adjustment equation for output and a supply function that depends on price and some exogenous variables ([27], [28]). Although this economic-theoretical approach has been questioned on several grounds (Nerlove [25], Askari *et al* [1] and Heady *et al* [18]), it is still the standard justification for empirical broiler supply modeling ([7], [19]).

A standard econometric model for broiler supply is, for example, that of Chavas and Johnson [7]. These authors, using quarterly observations from 1965 to 1975, obtain by least squares the following equation ([7], p. 560):

$$
\begin{aligned}
B1 \ = \ & 4787 + 162.9PBL2 - 5.83FCL2 + .2732B1L4 + 1317.9DV2 \\
& + \ 45.2DV3 - 28.5DV4 - 65.6TT
\end{aligned}
\tag{6}
$$

where

$B1$ = Chick Placements.

$PBL2$ = Wholesale Broiler Prices lagged two quarters.

$FCL2$ = Feed Cost lagged two quarters.

$B1L4$ = Chick placements lagged 4 quarters.

DVI = Seasonal Dummies.

TT = Linear trend.

According to [7] the estimated elasticities are significant and have the expected sign and the R^2 is .87, two criteria that lead the authors to consider the regression equation appropriate. The lags for feed cost (FC) and wholesale price (PB) were chosen by preliminary testing. The coefficient in $B1L4$ indicates that 73 percent of the adjustment in placements occurs from one year to the next. Models similar to (6) can be found in [19].

The objective of the work presented in this section is to see whether univariate time series models obtained from the preliminary data analysis described above forecast chick

placements better than an updated distributed-lag adjustment model. Because structural change seems to have occurred in a noticeable way since 1973, the forecasting models have as estimation period December 1973 to December 1984. After conducting the analysis described earlier, focusing only on this time interval, I translate the results (trend, cycles, autoregressive order of the series) into two types of time–domain models (harmonic and autoregressive) with two different assumptions about the type of coefficients of the autoregressive model. Under the first assumption, the models and forecasts have a single unobserved coefficient vector β but it is assumed that more information allows the obtention of a better estimate of the parameters, and better forecasts. Under the second, models and forecasts allow the coefficient vector to change over time. All the models incorporate the trend.

1st Assumption: a single vector updated

Under this assumption, the types of models fitted and used for prediction are: a) a harmonic model for chick placements; b) an autoregressive model for chick placements.

The total number of observations for the estimation period are 133. That is, $t = 1 \cdots 133$ in the estimated equations. Of course, in order to allow for lags in the autoregressive models, the actual estimation uses as current data the data from $t = p + 1$ to 133, where p is the autoregressive order. Using these equations, I forecast the next 24 months, i.e., from January 1985 to December 1986, as follows: First, using the equations mentioned above, and taking the data from the data series (both the estimation and the prediction interval data, depending on whether I forecast with the autoregressive or the harmonic model) I compute one month ahead forecasts. This is called "static out-of-sample" forecasting. As I obtain additional observations, the coefficient estimates are reestimated and the value of the dependent variable for the next month is forecasted. Doing this is equivalent to assuming that the coefficient vectors are constant through time but that adding new information helps to obtain better estimates of them. The recomputation of the regressions after a new observation is added is done very rapidly since I use the Kalman filter. How the Kalman filter updates the estimates at each month from their value at time $t = $ December 1984 to $t + 24$ is described in ([32], p. 11-14). The coefficient estimates obtained with the Kalman Filter in this situation, however, are identical to those that I obtain if I compute each of the regressions by ordinary least squares.

2nd Assumption: Time-Varying Coefficients

I assume now that the coefficient vector in the autoregressive equations follows the process $\beta_t = \beta_{t-1} + v_t$, where var $v_t = M_t$ and v_t is independent of e_t, the latter being the error term in the regressions of chick placements. Using the Kalman filter in this situation, as described in ([32], p. 19-3), I first obtain an estimate of β using observations for the time interval March 1975-December 1978. These time intervals are chosen as base periods to start the coefficient update with the Kalman filter, hence it makes sense to use them as sources of the a priori information used to apply the filter. Having obtained

the prior covariance matrices from the regression for those time intervals, the Kalman filter updates the coefficient vector β as additional months are added to the estimation period.

Using these models I forecast the next 24 months (January 1985 to December 1986) following the same process explained above with one exception: the model coefficients are updated as I add new observations in the same manner that they were updated during the estimation period. That is, in contrast with the procedure followed above under the assumption that there is only a vector of coefficients, the assumption behind the forecasts with the time varying models is that the coefficients change not only because new information is obtained but because they follow the random walk behavior described above.

The forecast period starts in January 1985 and ends in December 1986.

Distributed-lag adjustment structural model

It is interesting to see whether the forecasts obtained with the models mentioned above are better or worse than those that would be obtained with a standard chicken broiler supply model like (6) presented above. This would establish the usefulness of studies like the one done in this paper for both understanding and forecasting in the industry. To find out, I translate the quarterly lag structure of (6) into a monthly lag structure and obtain the following model:

$$
\begin{aligned}
B1_t^{\text{standard}} = \ & 874.56 + 3.99TT1 + 0.396B1L12 - 11.25FCL6 \\
& + \ 11.25PBL6 + 134.34DV1 + 7.67DV2 - 30.73DV3 + 230.69DV4 \\
& + \ 334.53DV5 + 256.11DV6 + 73.42DV7 - 3.68DV8 - 8.55DV9 \\
& + \ 72.88DV10 - 42.12DV11
\end{aligned} \tag{7}
$$

Summary of Forecast Results

With the 24 values of the one-step-ahead percentage forecast errors and the predicted and actual values of the series, I compute the "Mean Absolute Percentage Error" (MAPE) statistic for the forecasts of the 7 models of placements. The MAPE is defined (in percentage) as

$$
\text{MAPE} = \frac{1}{k} \sum_{t=1}^{k} \left| \frac{\text{forecast}_t - \text{actual}_t}{\text{actual}_t} \right| \tag{8}
$$

where k is the number of forecasts and t is the forecast month (I assume that $t = 1$ for the first month of the forecasting period.)

The summary of the results can be found in Table 3. The summary statistics in Table 3 show the MAPE of the one-step-ahead forescast (MAPE(1)) and the MAPE for other

lags. MAPE(6), MAPE(12) and MAPE(24) are considerably smaller for the distributed-lag model than for any of the other models assumed to forecast chick placements. Thus, the univariate time series models forecast worse than a standard supply model when the forecast is 6, 12 or 24 months ahead. They forecast better, however, for less than 6 months ahead.

6   Summary and Conclusions

The first hypothesis, the existence of a 30 months cycle in the series would reflect that the cycle of production takes approximately that much time. It was investigated using periodogram, autoregressive and Bayesian spectrum analysis. The thirty months cycle is significant in returns, with a Bayesian and frequentist approach and in price with a frequentist approach. The cycle is not significant in the output series for the whole length of the series analyzed, although it is significan during some intervals. The existence of the thirty months cycle in the price confirms Rausser and Cargill's result [33]. They found a 30 month cycle in prices using data for the fifties and the sixties. Its appearance in returns just reflects that it is there in prices. However, because the cycle in output series is not a constant feature of the data, it is not recommended to base policy on its existence although not ignoring its existence in output series at times, and in prices, accounting for its nonstationarity, can help improve the forecasting performance of models. A closer analysis of other components of the time series and their evolution after the energy crisis supports these recommendations.

Concerning hypothesis 2, the stabilizing effect on seasonal amplitudes of vertical integration is very noticeable in the placement series, not so noticeable in the hatched series, during the sixties. Seasonal amplitudes aldo decreased in the price and return series. Suggestions by a number of researchers as to the effects of vertical integration on seasonality are supported by these results. The energy crisis in the seventies, however, altered this statibilization.

While the cost crisis in the seventies increased considerably the amplitude of the seasonal components of price and returns, such crisis had no effect on the amplitudes of the seasonals in output. This reflects that vertical integrators, althouth attempting to stabilize both prices and output, were most successful at stabilizing output during the whole period studied. Changes in feed and oil costs and increases in demand were reflected in the industry by the alterations in prices and returns but not in output. This may imply that broiler producers maximize sales and transfer changes in cost and demand only to prices. This contradicts the conclusions reached by Rausser and Cargill. Their evidence led them to believe that broiler suppliers emphasize price stabilization, instead of output stabilization. But it appears that this is not the case. The evidence on the changes in the series in the eighties found in this paper does not support it.

The cost shocks of the early seventies drastically altered the stabilization of prices and returns that the industry experienced in the sixties. Once those shocks disappeared, however, the industry did not return to the levels of stabilization in the seasonal of prices

that it had in the sixties. The financial and international changes of the eighties have also altered the stabilization of the sixties; however, because interest costs is not one of the major cost items in the industry, the changes in the eighties did not affect poultry supply as much as they altered the stabilization of prices and returns. Thus variability in costs were also translated into variability in prices, which supports further the conclusion that broiler suppliers are sales maximizers.

The analysis of the relations between variables (i.e., the degree to which they move together) indicates that such association decreases considerably at the seasonal components. The price-output pairs and the output-output pairs are less related in the 1973-84 interval than earlier. The fact that the decrease in the relation price-output is much more noticeable, indicates also sales maximization behavior when added to the univariate evidence that price amplitudes stabilized less than output in 1973-1984. This conclusion is further supported by the insignificant lead-lag pattern in this time interval.

The change in the relation at the cyclical components and the change in the lead-lag pattern at those frequencies is less conclusive. There is some slight evidence that this relation remained strong for the price-output pairs, and that the lead-lag pattern was significant. This phenomenon helps explain the better forecasting performance of the structural model relative to the univariate time series models in the larger than 6 months ahead forecasts.

The superior forecasting performance of the distributed-lags model for longer step-ahead forecasts, with lag structure reflecting the cyclical lead-lag patterns for which there is slight evidence, suggests that there is still some relation between price and quantity that could perhaps be exploited by stabilization policy conducted in the industry. The variability of this relation and the nonstationarity of the cyclical component, suggest nevertheless that we can not rely on a fixed estimated model, but rather that these models need to be continuously reestimated.

The analysis done in this paper is useful to design univariate time series models for short-term forecasts.

Acknowledgments

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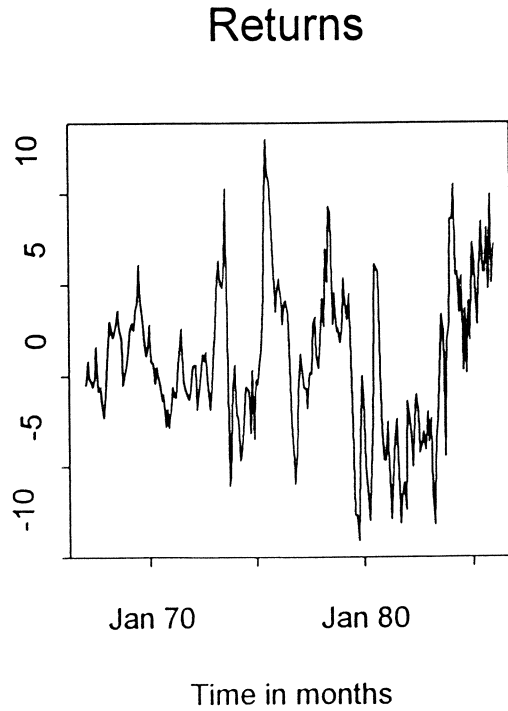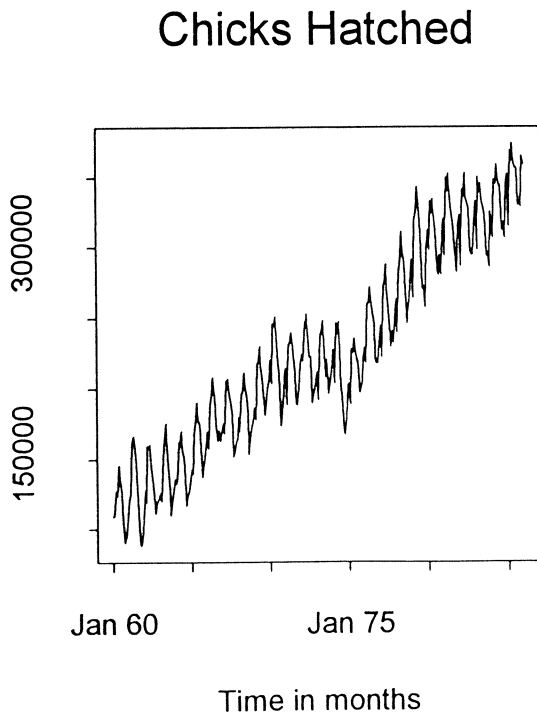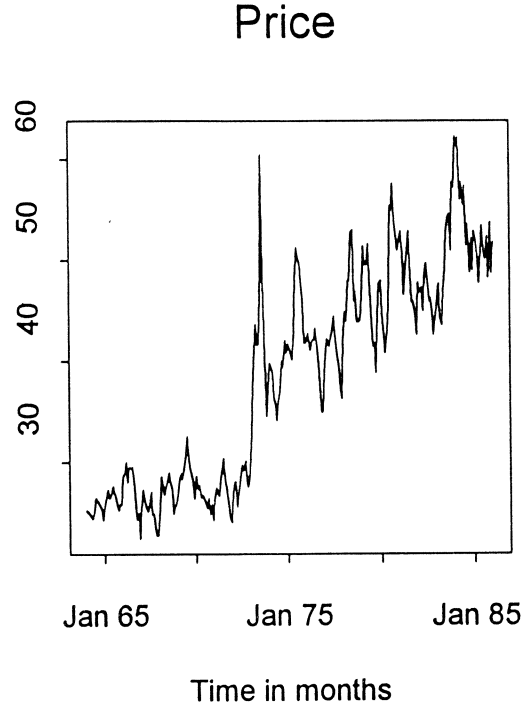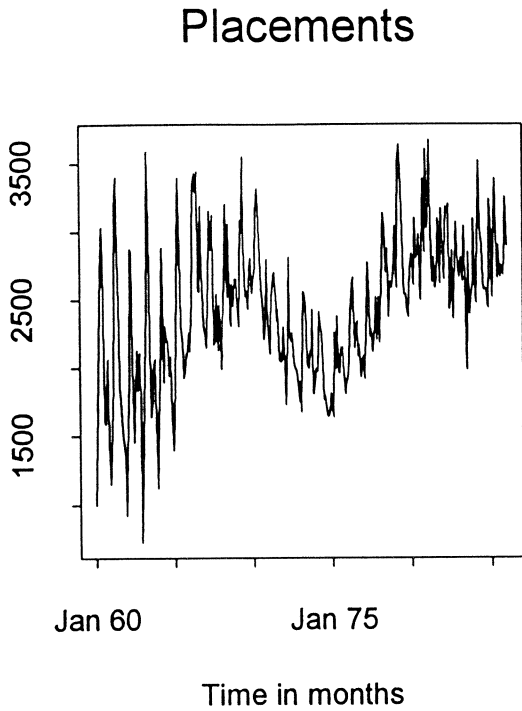
Figure 1.- The Data

Placements

Time in months

Price

Time in months

Chicks Hatched

Time in months

Returns

Time in months

Figure 2.- Log_10 of the posterior probability of one frequency accounting for trend: (A) Net Returns; (B) Placement; (C) Price; (D) Chicks hatched.

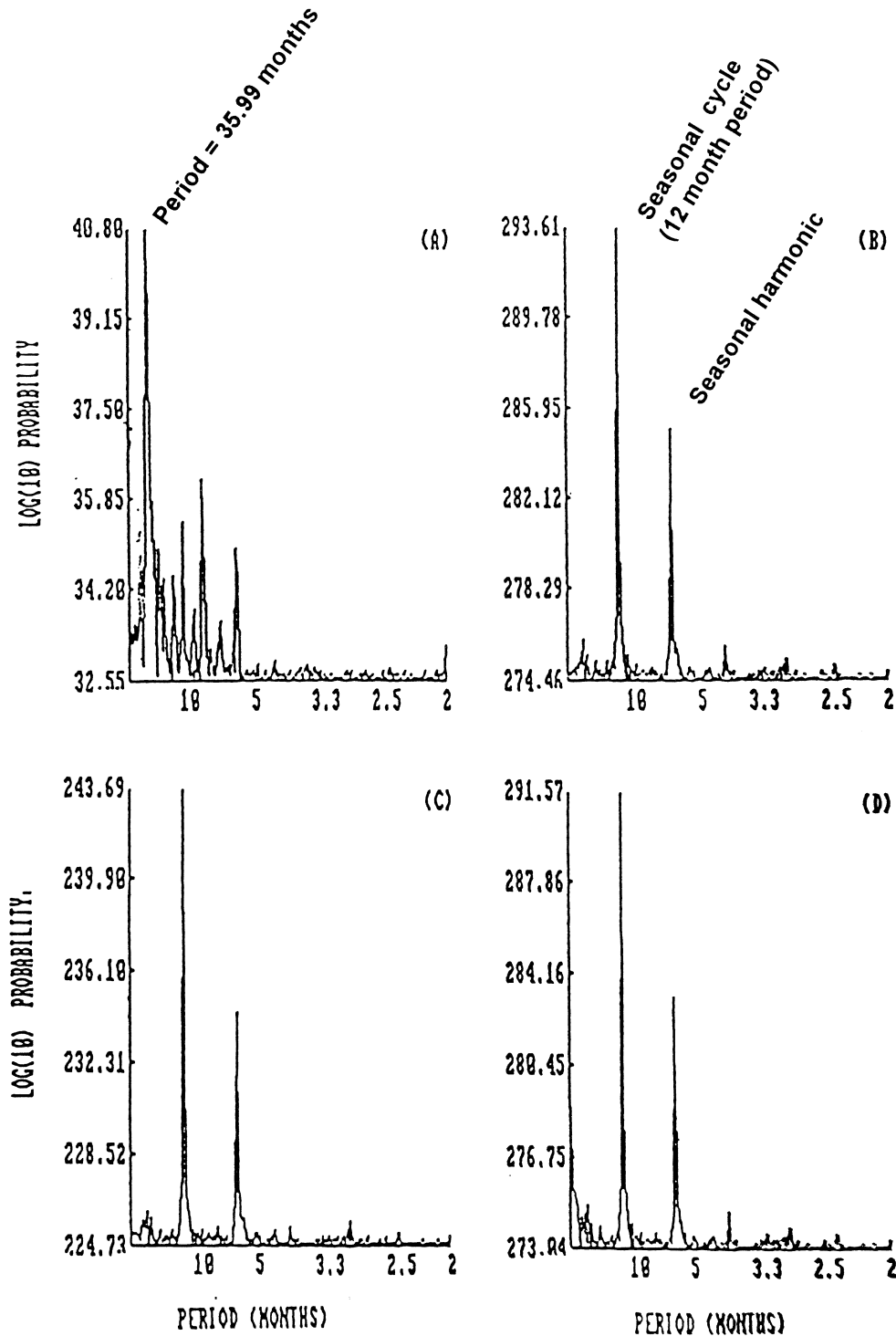## Figure 3.- Demodulated-remodulated data at the seasonal frequency (12 months period) and its harmonics
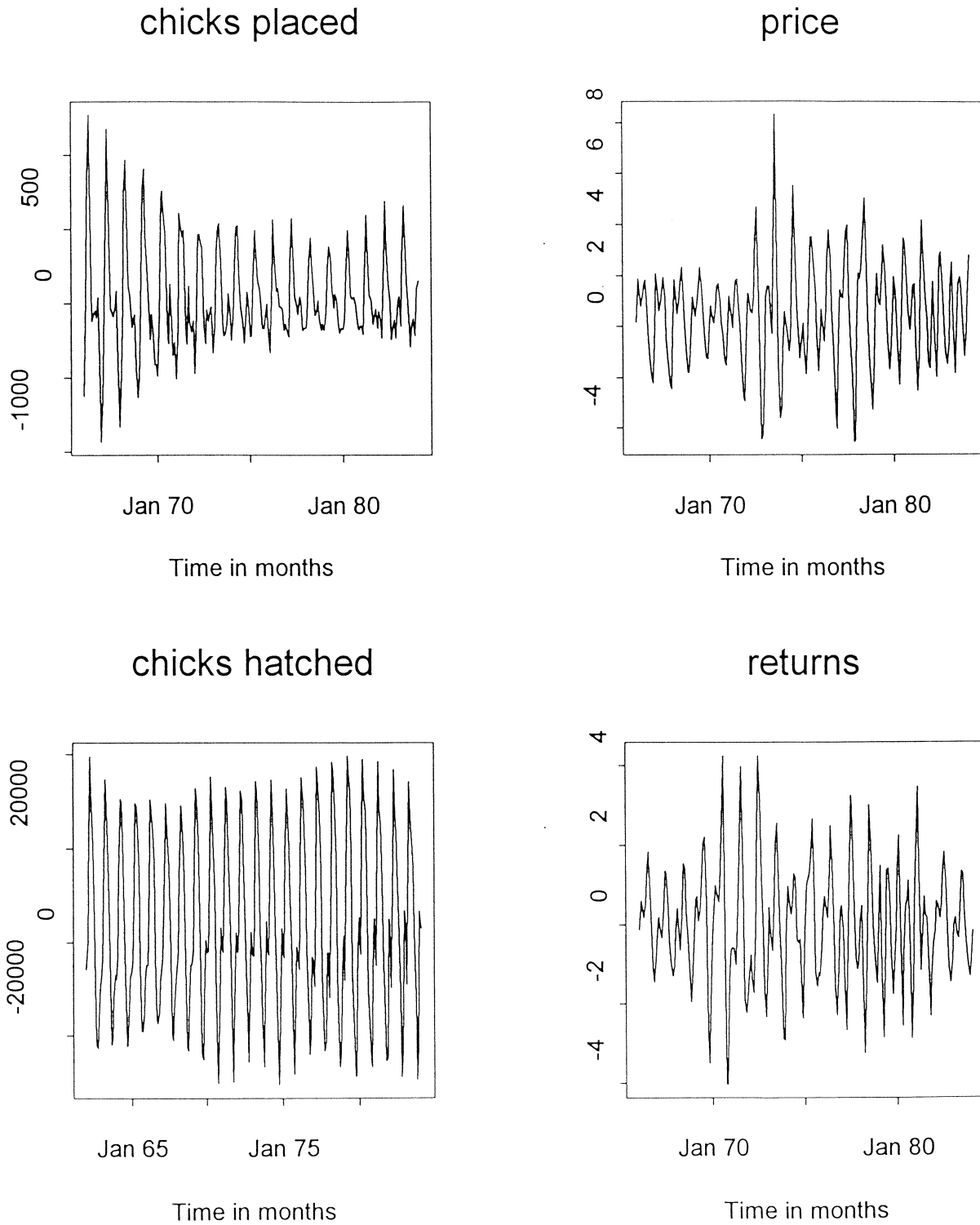
chicks placed

Jan 70   Jan 80

Time in months

price

Jan 70   Jan 80

Time in months

chicks hatched

Jan 65   Jan 75

Time in months

returns

Jan 70   Jan 80

Time in months

Table 1.- Cross-periodogram of Chick Placement and Broiler Price

	1964-1972			1973-1986	
PERIOD	COHERENCE	PHASE	PERIOD	COHERENCE	PHASE
100	0.679	20.69	100	0.719	-0.11
66	0.766	12.35	66	0.604	-0.49
50	0.811	8.35	50	0.687	4.10
40	0.818	6.04	40	0.822	4.60
33.3	0.769	4.60	33.3	0.866	4.12
13.3	0.825	-0.10	13.3	0.589	-2.60
12.5	0.891	-0.43	12.5	0.703	-2.48
11.7	0.915	-0.63	11.7	0.680	-2.08
10.5	0.875	-0.90	10.5	0.512	-1.68

Table 2.- Cross-periodogram of Chicks hatched and Broiler Price

	1964-1972			1973-1986	
PERIOD	COHERENCE	PHASE	PERIOD	COHERENCE	PHASE
100	0.820	36.30	100	---	---
66	0.803	21.20	66	---	---
50	0.782	8.38	50	---	---
40	0.757	0.34	40	---	---
33.3	0.727	10.03	33.3	0.610	8.80
13.3	0.855	-0.68	13.3	0.574	-2.33
12.5	0.929	-0.76	12.5	0.715	-2.07
11.7	0.958	-0.79	11.7	0.717	-1.90
10.5	0.928	-0.90	10.5	---	---

Table 3.- Summary of the Forecast Statistic for all models at 1, 6, 12 and 24 Step Ahead Forecasts.

Type of Model, Assumption about parameters and Dependent Variable	MAPE(1)	MAPE(6)	MAPE(12)	MAPE(24)
Harmonic, Fixed parameter, Chicks	13.7	9.19	10.24	9.74
Autoregressive, Fixed par., Chicks	6.6	6.70	5.95	5.46
Autoregressive, Variable par, Chicks	5.2	8.2	7.54	7.57
Structural traditional, Chicks	1.87	4.69	3.65	4.64