Rational price expectations and structural change in the U.S. broiler industry

by

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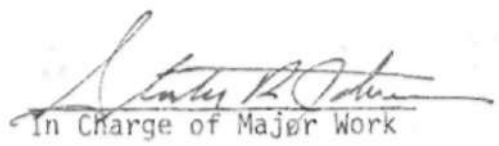
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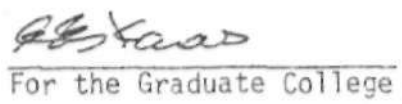
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Rational price expectations and structural change in the U.S. broiler industry

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The study broadly investigates the econometric implications of the rational price expectations hypothesis with three alternative formulations of the U.S. broiler market model, each of which was already biologically restricted in terms of the structural equations describing broiler supply. Each of the three alternative structural models reflects a different assumption about the nature of vertical integration in the broiler industry.

Each model was estimated in its restricted and unrestricted form. Resulting estimates of regression coefficients were, in most cases, consistent with economic theory predictions and statistically significant. The elasticities of response of the various broiler production activities with respect to broiler feed cost and expected broiler price variables decline in value as the broiler slaughter period approaches. In a dynamic sense, this is interpreted to mean that the closer firms are to the broiler marketing period, the less time is available for adjusting to changes in the variables affecting their decisions.

Reduced forms of the broiler supply equations in the alternative structural models were also evaluated using non-nested test procedures. Finally, the broiler sector was evaluated for structural change using time-varying parameter regressions. On the basis of the results obtained from the tests of rationality restrictions, non-nested evaluations of the models and the trend behavior of the simulated time-varying weights, the following conclusions were drawn. First, there are no strong indications that firms in the U.S. broiler industry overwhelmingly fully integrate all the broiler production activities. What appears to happen is that firms vertically integrate varying numbers of the broiler production activities in the industry. Second, provided that the information requirements are met, rational expectations hypothesis offers a promising approach to the modeling of agricultural commodity systems even when the relevant planning (expectations) horizons are longer than the current period.

CHAPTER 1. INTRODUCTION

One of the perennial problems faced in agricultural commodity modeling and policy analysis is deciding on how best to accommodate those variables which exist as expectations in econometric models. Expectations variables are widely applied in econometrics because "the optimizing economic agents, which empirical research endeavors to capture, depend in part on their views of the future" (Wallis, 1980).

The role of price expectations has been previously investigated elsewhere, both from the viewpoint of farmers themselves (Fisher and Tanner, 1978; Jesness, 1958) and from the viewpoint of agricultural policy analysts (Heady and Kaldor, 1954). Researchers have mostly focused on the allocative consequences of price uncertainty, the impact of the expectations formation patterns on the estimates of response and input use (Nerlove, 1956; 1979; Agrawal and Heady, 1972).

The existence of unobservable variables in econometric modeling of commodity systems partly arises from the fact that most agricultural production processes usually involve planning horizons that extend beyond one period. These and other phenomena must be accounted for in commodity market modeling. The point is that agricultural commodity modeling, whatever the goal, must take into consideration the known temporal, physical, economic and biological characteristics of the relevant commodity system. For example, the short production cycle in the broiler industry may have implications

for the length of the broiler price expectations horizon, the way expectations are formed and revised and the speed and magnitude of responses to changes in feed costs and expected broiler prices.

Objectives of the Present Study

This study broadly investigates the econometric implications of the rational expectations hypothesis for modeling the U.S. broiler market. The basic model specification draws from known characteristics of the industry (see Chapter III). Ordinarily, one would expect to develop a single market equilibrium model for a commodity system such as that for broilers. However, preliminary studies of this industry (market, sector and industry are used interchangeably in this study) suggest that the constituent firms, though vertically integrated, tend to differ in the number of functions they integrate. And, it is correspondingly argued that the composition of activities that firms integrate vertically will have implications for the planning horizon and equilibrium structure utilized in the modeling process. Thus, alternative broiler models are specified, with each model reflecting a different assumption about the planning horizon in the U.S. broiler industry. These alternative specifications of the broiler model reflect variations in the number of functions performed by firms in this vertically integrated industry.

The specific objectives of the study are as follows:

(i) To estimate alternative specifications of U.S. broiler model under rational expectations of broiler prices.

(ii) To estimate the elasticities of broiler demand and elasticities of broiler supply to key economic variables in each model.

(iii) To perform selected formal tests of the rationality restrictions imposed in the models.

(iv) To perform non-nested evaluations of alternative broiler supply models.

(v) To evaluate the broiler sector for structural change.

Organization of the Present Study

The remainder of the study is arranged as follows. Chapter II discusses the applications of rational expectations hypothesis in commodity modeling. The emphasis is on how previous applications of this expectations formation pattern has affected model specifications, estimation, hypothesis testing and prediction. Chapter III presents some relevant characteristics of the U.S. broiler industry, followed by specifications of the alternative models. Also discussed in Chapter III are the sources of data for the study. In Chapter IV, parameter estimates for the broiler models and the accompanying elasticities of demand and supply for broilers, along with the results of selected rationality tests, are presented, discussed and compared, when applicable, to previous studies. Chapter V reviews some of the theoretical foundations for applying non-nested hypothesis test procedures to alternative specifications of models. This is followed

by applications of the test procedures to alternative broiler models. Chapter VI presents the evaluation of structural change in the broiler sector, while Chapter VII summarizes and concludes the study.

CHAPTER II. THE RATIONAL EXPECTATIONS HYPOTHESIS IN COMMODITY MARKET MODELING

The problems posed by expectations variables in commodity modeling, estimation and policy analysis have long been of interest to agricultural economists (Crowder, 1972; Cromarty and Myers, 1975; Askari and Cummings, 1977; Blake and Clevenger, 1984; Brandt and Bessler, 1981). Alternative hypotheses have been suggested for providing observable proxies for expectations variables, especially commodity prices. These include the static expectations hypothesis (Ezekiel, 1938; Walsh, 1944; Bean, 1929; Smith, 1928), the extrapolative expectations hypothesis (Powell and Gruen, 1966; Goodwin, 1947) and the adaptive expectations hypothesis (Nerlove, 1956, 1979; Askari and Cummings, 1977; Nowshirvani, 1971).

The Nerlovian hypothesis has been the most widely applied in agricultural commodity modeling. This expectational hypothesis has also exhibited especial success in cases where the relevant planning (or expectations) horizon is the current period. However, the adaptive expectations hypothesis tends to be seriously handicapped when the relevant planning horizon is longer than the current period.

Under a well-defined, often restrictive set of assumptions (Fisher, 1982; Wallis, 1980; McCallum, 1976a, 1976b; Colander and Guthrie, 1980; Decanio, 1979; Handa, 1982; Chavas and Johnson, 1982a), the rational expectations hypothesis has shown promise of being applicable to cases in which the production planning horizon extends

beyond the current period. However, as will be shown later in this study, the econometric procedures involved are very much conditional on the information available to the 'rational' forecasters. Thus, the amount of information available for forming expectations in the Muth's (1961) sense is the single most important determinant of the ultimate worth of the rationality hypothesis in agricultural commodity modeling.

This chapter is organized as follows. The econometric implications of rational expectations are first illustrated with emphasis on cases in which the planning horizon is longer than the current period. Two of the three broiler models analyzed in this study belong to this category, while the third is a current-period model. Next is the assessment of how previous applications of this expectational hypothesis have affected model specifications, estimations and predictions. Also, procedures which have provided joint tests of model specifications and the rationality restrictions are examined. The third section outlines some of the salient development in the present study over previous applications of the rationality hypothesis to broiler models.

An Illustrative Commodity Market Model

Expectations are often formed in the present about future values of variables that enter objective functions of economic agents. The rational expectations, as presently understood, require complete knowledge of the economic structure (Muth, 1961; Handa, 1982;

McCallum, 1980; Conway and Barth, 1983). In an agricultural commodity market setting, this assumption implies that consumers are aware of supply determinants (e.g., weather) and that suppliers recognize the variables conditioning demand (e.g., consumer income) in addition to knowing those variables which affect their respective production and marketing.

The illustrative commodity model presented below is an abstraction of the broiler models analyzed in the present study. To motivate the presentation, consider a commodity model consisting of a demand equation, a supply equation and a third equation representing an activity which previously conditioned the current level of marketed supply. Ignoring the respective intercept terms for the moment, this simple commodity model can be summarized as follows:

$$P_t = a_2 Y_t + a_3 M_t + u_{1t} \quad \text{(demand)} \tag{2.1}$$

$$X_t = a_4 Z_{t-i} + u_{2t} \quad \text{(supply)} \tag{2.2}$$

$$Z_t = a_5 P^*_{t+i} + a_6 Z_{t-h} + a_7 C_t + u_{3t} \quad \text{(supply structure)} \tag{2.3}$$

where

P_t = current market price of the agricultural commodity,

Y_t = quantity demanded,

M_t = an exogenous variable affecting demand,

X_t = marketed supply,

Z_{t-i} = level of some activity which predetermines X_t, t-i periods earlier,

C_t = an exogenous variable affecting the level of Z_t and

P^*_{t+i} = price of the commodity expected to prevail in period t+i, $i \geq 0$ when the commodity is marketed.

It is noted that the current level of Z(t) is partly determined autoregressively, a situation that may arise if the production cycle begins with activity Z. The model is closed by assuming that the commodity market clears in each period ($Y_t = X_t$). Then, it remains to derive a set of rational expectations solutions within the equilibrium framework. Since this equilibrium is assumed to hold in each period, the equilibrium condition as viewed from period t-i is that

$$P_{t+i} = a_2 a_4 Z_t + a_3 M_{t+i} + a_2 u_{2,t+i} + u_{1,t+i} \qquad (2.4)$$

where, by assumption,

$$E(u_{j,t+s}) = 0 \text{ for all } s \text{ and } j=1, 2, 3$$

$$E(u_{j,t+a}\, u_{j,t+b}) = \begin{cases} 0 & \text{for } a \neq b \\ \sigma^2 & \text{for } a = b \end{cases} .$$

Also, the contemporaneous covariance matrix of the disturbance terms is positive definite.

Returning to Eq. (2.4), Z_t is endogenous in period t-i and can, therefore, be eliminated using Eq. (2.3) to obtain a more complicated form of the equilibrium condition.

$$P_{t+i} = a_2a_4a_5\, P^*_{t+i} + a_2a_4a_6\, Z_{t-h} + a_2a_4a_7\, C_t$$

$$+ a_3\, M_{t+i} + (a_2a_4\, u_{3t} + a_2u_{2,t+i} + u_{1,t+i}) \qquad (2.5)$$

where the relevant planning (expectations) horizon is t+i with reference to the time activity Z was performed. To derive the rational predictor of P_{t+i}, the following additional assumptions are required:

$$E_t\, P_{t+i} = P^*_{t+i} \text{ for all } i \geq 0$$

$$E_t\, M_{t+i-1} = \begin{cases} \hat{M}_{t+i-1} & \text{for } i-1 > 0 \\ M_{t+i-1} & \text{for } i-1 \leq 0 \end{cases}$$

$$E_tC_{t-i} = C_{t-i} \text{ and } E_t\, Z_{t-h-i} = Z_{t-h-i} \text{ for } i \leq 0 \ .$$

The foregoing assumptions on M(t+i-1), C(t-i) and Z(t-h-i) are called the assumptions of "weak consistency" of expectations (Chavas and Johnson, 1982a).

Together with the earlier assumptions on the structural disturbance terms, the rational price predictor for the commodity can be verified as given by

$$P^*_{t+i} = (1-a_2a_4a_5)^{-1} (a_3 \hat{M}_{t+i} + a_2a_4a_6 Z_{t-h} + a_2a_4a_7 C_t) \quad (2.6)$$

subject to the requirement that $a_2a_4a_5 \neq 1$.

If one was interested in merely providing a consistent estimator for a_5, then the following two-stage estimation procedure can be pursued:

Stage 1 - observed vector P_{t+i} is regressed on $\hat{M}_{t+i}$, Z_{t-h} and C_t. By definition,

$$E(P_{t+i} \mid \hat{M}_{t+i}, Z_{t-h}, C_t, 1) = P^*_{t+i} = \hat{P}_{t+i} \quad .$$

Stage 2 - The second stage involves a rather straightforward regression given by

$$Z_t = a_5 \hat{P}_{t+i} + a_6 Z_{t-h} + a_7 C_t + u^*_{3t} \quad .$$

This estimation procedure, which utilizes either derived instruments (Huntzinger, 1979) or arbitrary instruments (McCallum, 1976a), has had applications in various economic structures. The main drawback to this two-stage instrumental estimation (2SIVE) procedure is that it does not permit the researcher to test for the imposed rationality restrictions.

In the present study, the rational price predictor, Eq. (2.6), is substituted back into the structural model to obtain nonlinear expressions in Z_t, X_t and P_t, respectively, all of which are linked by testable sets of cross-equation restrictions. The

estimation procedures pursued beyond this point usually depend on the declared goal of commodity modeling exercise. Parenthetically, it is noted here that the relevance of the rationality restrictions imposed on the structural model depends largely on the ability of economics agents to forecast the exogenous variables in the system. In the present illustrative model, the only projection required is for $\hat{M}_{t+i}$. The general argument is that $\hat{M}_{t+i}$ must be generated outside the model (Chavas and Johnson, 1982a; Wallis, 1980; Fisher, 1982). Also, the usual assumption is that $\hat{M}_{t+i}$ is generated by vector autoregressive integrated moving average (ARIMA) structures (a detailed analysis of ARIMA processes can be found in Box and Jenkins, 1976 and Pankratz, 1983).

As indicated earlier, the goal of agricultural commodity modeling exercise could determine the estimation methods for models incorporating rational expectations hypothesis. For example, given suitable forecasts of $\hat{M}_{t+i}$, if the initial goal is to forecast the endogenous variables in the model, the following unrestricted equations may be appropriate:

$$P_t = b_2 Z_{t-h-i} + b_3 C_{t-i} + b_4 M_t + u^{**}_{1t} \tag{2.7}$$

$$X_t = b_5 Z_{t-h-i} + b_6 C_{t-i} + b_7 M_t + u^{**}_{2t} \tag{2.8}$$

$$Z_t = b_8 Z_{t-h} + b_9 C_t + b_{10} \hat{M}_{t+i} + u^{**}_{3t} \tag{2.9}$$

where

$$u^{**}_{1t} = u_{1t} + u_{2t} + a_4\, u_{3,t-i}$$

$$u^{**}_{2t} = u_{2t} + a_4\, u_{3,t-i}$$

$$u^{**}_{3t} = u_{3t}\ .$$

If the goal of the research is to test the rationality restrictions, there are alternative large sample testing procedures available. Treating the restricted and unrestricted forms of a model as non-nested (Husted and Kollintzas, 1984), the most common test procedures include the C-, J- and P-tests (Davidson and Mackinnon, 1981) and the likelihood ratio tests (Hoffman and Schmidt, 1981; Hansen and Sargent, 1980; Sargent, 1978a, 1978b, 1979; Taylor, 1979). The steps involved in the application of Davidson-Mackinnon's tests are presented in Chapter V. For the likelihood ratio tests, the unrestricted equations (Eqs. 2.7 - 2.9) are first estimated to obtain the corresponding log likelihood function L(u). Next, these equations are reestimated subject to the cross-equation restrictions:

$$b_2 = a_2a_4a_6/D, \quad b_3 = a_2a_4a_7/D, \quad b_4 = a_3/D$$

$$b_5 = a_4a_6/D, \quad b_6 = a_4a_7/D, \quad b_7 = a_4a_5a_3/D,$$

$$b_8 = a_6/D, \quad b_9 = a_7/D, \quad b_{10} = a_5a_3/D \text{ and } D = 1 - a_2a_4a_5\ .$$

Let the log likelihood function corresponding to the restricted model be L(r). Then, the relevant test statistic is given by

$$-2\{L(r) - L(u)\} \sim \chi^2_{(q)}$$

where q is the number of restrictions. Other test procedures, which tend to vary in terms of the level of computation and data requirements, include the Pierce (1975) predictive R-square, futures market tests (Goodwin and Sheffrin, 1982) and the N-test (Pesaran, 1974).

The above discussion has included several simplifying assumptions. The models are likely more complicated in practice, especially if the production process involves many quantifiable stages. For example, available information (see Chapter III) shows that four major intermediate functions or activities are performed before broiler chickens attain the slaughter weight. Also important are the information requirements for the modeling exercise and estimation procedure. To obtain estimates which are of policy relevance, the exogenous variables in the model must be accurately projectable.

Previous Empirical Studies

As is often the case, the goals of commodity modeling tend to be closely tied to the way the econometric model is formulated, the variables introduced and the estimation techniques utilized. One of two approaches has generally been adopted in the analysis of commodity models which incorporates rational expectations hypothesis. Both of

these approaches have had earlier applications in macroeconomic models (Sargent, 1978a; McCallum, 1976a; Taylor, 1979).

Agricultural land allocation models tend to posit quadratic objective functions on the part of farmers, from which the equilibrium movements of commodity price, production and land allocation rules are obtained analytically (Eckstein, 1980, 1981, 1984; Tegene, 1983). This approach has also received applications in the modeling of commodity import demand under rational expectations (Husted and Kollintzas, 1984). Optimal supply and storage decision rules have been derived theoretically by Huntzinger (1979).

A second approach to rational expectations modeling of commodity systems is to impose the rationality restrictions on a subset of the econometric model with an a priori structure known, at least provisionally. To facilitate the empirical phase of the study, it is assumed that the market for the relevant commodity clears in each period. Some possible justifications for the market clearing assumption for the U.S. broiler model are the relative simplicity of the market, the short shelf life of broiler meat and the continuing dominance of domestic consumption of broilers (see Chapter III). Econometrically, the assumption of market clearing also ensures that the price expectations variable in the supply block of the structural model has a counterpart variable in the demand equation. Otherwise, we have the price expectations variable existing in isolation in the supply block, and the rational expectations solution becomes trivial, if not degenerate.

Applications of rational expectations to agricultural commodity modeling are still limited when compared to the wide range of studies for macroeconomic systems. However, even the few available studies do present challenging analytical as well as policy implications. For example, the quadratic land allocation models have been demonstrated to yield estimating equations which are observationally equivalent to the Nerlovian reduced forms. However, resulting parameter estimates differ in terms of their policy implications (Eckstein, 1985). On the basis of alternative large-sample test procedures, Goodwin and Sheffrin (1982) could not reject the rationality restrictions imposed on U.S. broiler model. However, the study by Husted and Kollintzas (1984) on the importation of four commodities into the U.S., including cocoa and coffee, was unable to accept the rationality restrictions imposed on the basis of Davidson-Mackinnon's C-test statistic.

The foregoing suggests that there is still no conclusive evidence in favor of economic agents behaving according to the rationality hypothesis. Perhaps, what is clear at the present time is that the reliability of parameter estimates and the robustness of the test results may ultimately depend on such considerations as the nature of the commodity being modeled, the physical and biological characteristics of production, the temporal aggregation of the available data (weekly, monthly, quarterly or annual), and the modeling approach adopted.

The Present Study

This study investigates a method for modeling the broiler market subject to two restrictions, namely, biological restrictions on broiler supply and rationality restrictions on the broiler price expectations formation pattern. The specification utilized has benefited especially from the studies by Huntzinger (1979), Goodwin and Sheffrin (1982) and Chavas (1978). However, these studies and the present study also share interesting differences.

The study by Huntzinger (1979) utilizes weekly data and approximated broiler supply by weekly placements of chicks in the feeding flocks. Biologically, this calls for a planning horizon of 8-10 weeks, beginning from the time the chicks are placed. Thus, Huntzinger's study partly accounted for biological influences on broiler model specification. However, the use of the 2SIVE procedure, while ensuring the consistency of the estimates, did not allow for testing the imposed rationality restrictions.

The study by Goodwin and Sheffrin (1982), which utilized monthly broiler data, ignored all forms of biological restrictions on broiler supply. The structural model was overly dependent only on variables suggested by economic theory. However, the study offers alternative large-sample procedures for testing rationality restrictions in agricultural commodity models. Chavas (1978), who utilized quarterly broiler data, provides an illuminating attempt at incorporating biological restrictions into the U.S. poultry models.

In order to restrict the relevant planning horizons to temporally manageable ranges, the present study is based on quarterly broiler data. As a case in point, the placement of chicks in the hatchery supply flock, which is one of the activities involved in broiler production, calls for a planning horizon of 36 weeks, 9 months or 3 quarters, respectively, depending on whether one chooses to utilize weekly, monthly or quarterly data. In addition to modeling the broiler industry subject to the restrictions indicated above, non-nested procedures are used to evaluate alternative specifications of the equations making up the supply block of the models. Finally, the broiler sector is evaluated for structural change using a combination of varying parameter and composite forecasting techniques.

CHAPTER III. ALTERNATIVE BROILER MODEL SPECIFICATIONS

The success with which an agricultural commodity system can be modeled depends largely on the degree of familiarity with the physical, economic and biological characteristics of the commodity. This chapter begins with the description of salient features of the U.S. broiler market. Next follows the discussion of the sources of data for the study. The alternative specifications of the broiler model and the derivation of the associated estimating equations for each structural model are then provided.

Economic, Technological and Biological Features of U.S. Broiler Market

Broilers are young chickens, 8-10 weeks of age and generally, weigh from 2.5-4.8 pounds. Per capita consumption of broilers has increased over time, partly due to a general rise in real per capita disposable income (Benson and Witzig, 1977). Quoting actual figures, per capita consumption of broilers rose from 13.8 pounds in 1955 to 48.6 pounds in 1981. However, pork and beef continue to compete strongly with broilers as substitute sources of protein (Hein, 1976).

A large portion of all broilers is marketed as either ready-to-cook (RTC) whole birds or as cut-up whole birds. More than 90 percent of the RTC broilers are chilled, while less than 10 percent are frozen. The major outlets for broilers are the households, institutions, processing and exports. However, broiler exports account for 3 percent or less of total disappearance (see Figure 1). Domestic consumption of

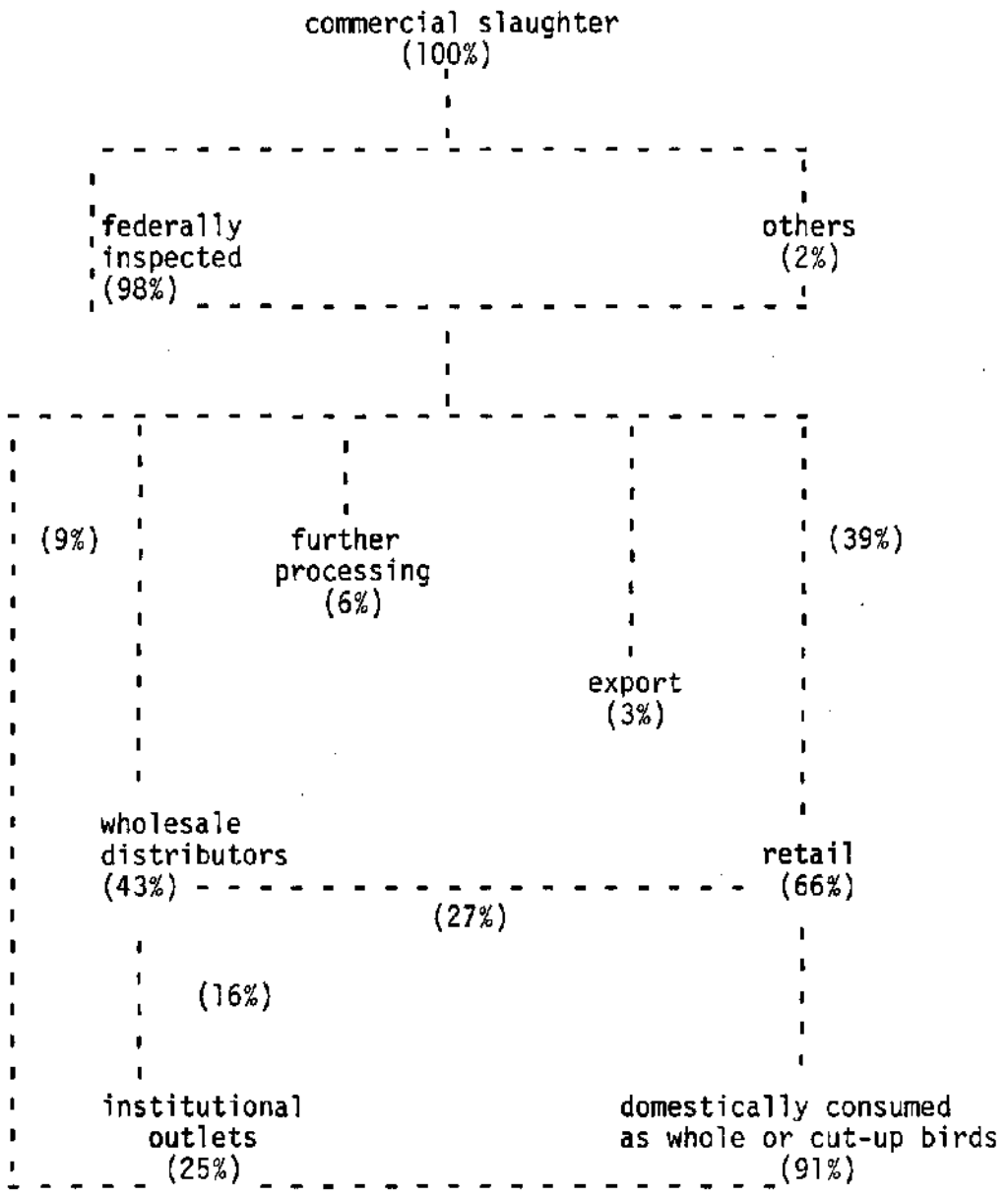


Figure 1. Major marketing channels for ready-to-cook broilers (Benson and Witzig, 1977)

broilers is seasonal, being higher during the second and third quarters and lower during the first and fourth quarters of the year. Huntzinger (1979) also indicates that consumption of broilers tends to decrease on major holidays.

The marketing channels for RTC broilers are such that there are not direct sales of broilers to the ultimate households (Figure 1). Thus, it has been strongly argued (Huntzinger, 1979; Goodwin and Sheffrin, 1982) that broiler demand equations in the U.S. broiler models actually represent the demand for broilers by retail stores and other related outlets. The rationale for this interpretation is that the retail stores, fast food businesses and others purchase broilers with the goal of maximizing their profits from resale to consumers (Huntzinger, 1979). Thus, profit maximization compels these intermediate buyers to be fully aware of those factors affecting consumer demand for broilers. A further implication is that the derived demand of retail stores and other related outlets should, over time, closely approximate the demand of the ultimate consumers.

Closely related to broiler consumption is the issue of the shelf life of broilers. A shelf life of about 7 days is used in commercial stores and represents the maximum time allowable between slaughter at the processing plant and purchase by the consumer. This short shelf life makes it difficult to estimate the quantity of broilers in storage and in fact, makes storage an unimportant economic function in the marketing system.

Broilers are grown all seasons. Feeds are the major cost items, accounting for 70-75 percent of production cost (Lasley, 1983). Virtually all commercial broilers are grown under contract, with the implication that the farm-level price of broilers has significantly lost its allocative influence. The contract arrangement is usually between an integrated firm and a grower. While the typical contract grower provides such inputs as housing, labor, and heating, the typical contractor provides the chicks and feeds, assembles the broilers for slaughter and processes and delivers to retailers and related outlets.

Vertical integration of the broiler industry has been rapid over the past two decades, with small flocks giving way to larger ones. Farms with sales of more than 100,000 broilers accounted for 82 percent of all broilers sold in 1978 (Lasley, 1983). The phenomenon of vertical integration has greatly concentrated market power at the wholesale level (Chavas, 1978). This probably explains why more than 90 percent of the annual changes in broiler prices at the retail level are caused by wholesale price changes (Lasley, 1983).

Broiler production decisions typically are made in successive stages. Each stage corresponds to the performance of a particular function. While these stages together constitute a single production process, ability to quantify each activity tends to improve the policy relevance of the model (Chavas and Johnson, 1982a).

The chicks from the primary breeder flock are introduced (or placed) into the hatchery supply flock. These young female chicks are tested for pollurum disease, without which infected young females produce

infected eggs and resulting chicks die in only a matter of days. The eggs produced by the hatchery supply flock are hatched and the chicks are introduced (or placed) into the feeding flock, where they are grown to slaughter weight. The activities implied by this brief description are illustrated in Figure 2. It is noted that, in practice, not all the firms are as fully vertically integrated as Figure 2 suggests. In many instances, a firm may vertically integrate the performance of only two or three functions (Benson and Witzig, 1977). It is even reported that some firms choose to horizontally integrate the performance of a single function.

An important assumption in the present study is that there are profit motives behind the performance of each of these broiler production activities. This assumption is apparently supported by Benson and Witzig, who indicate that firms tend to drop some of their contract growers (especially the less efficient ones) whenever the expected selling price of broilers requires a downward revision (Benson and Witzig, 1977). These authors have also pointed to cases in which some firms respond to broiler price risks by spacing out the frequency of chick placement in the feeding flock. The planning horizon for performing the various functions tends to vary by the functions performed. For example, using quarterly data, chick placement in the feeding flock is a current-period activity, while chick placement in the hatchery supply flock occurs approximately three quarters before slaughter. However, since published data do not reflect these and other possibilities, it was considered necessary to experiment among

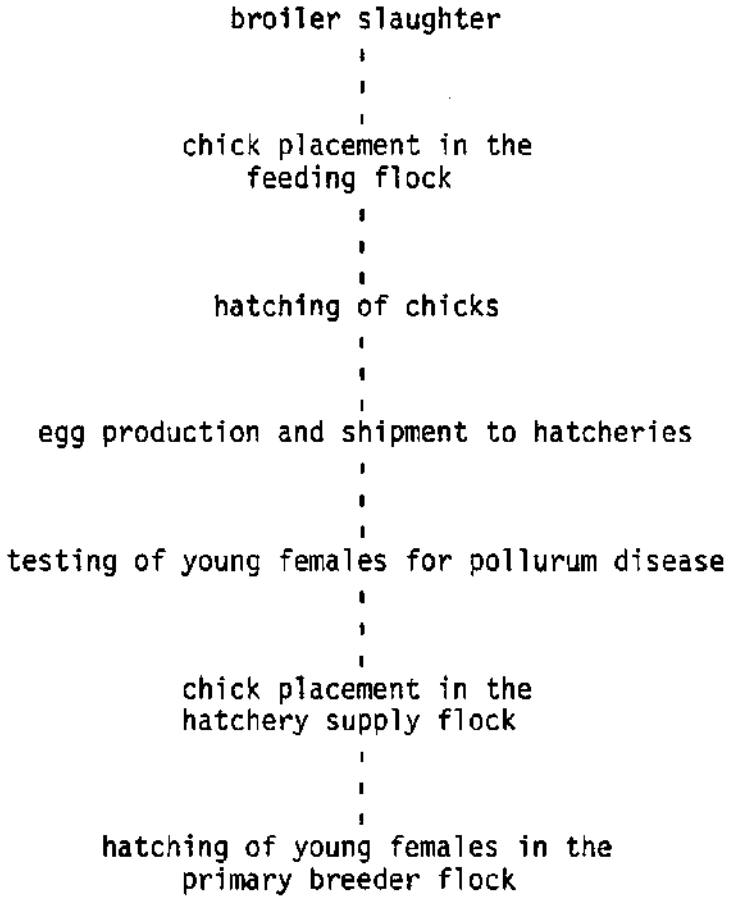


Figure 2. Vertically integrated broiler production, U.S. (Chavas, 1978)

alternative structures in the present study. Thus, Model 1 considers the case in which the integrated firm performs all the activities from chick placement in the feeding flock until broiler sale. Model 2 examines the case in which the functions performed begin with the hatching of chicks for placement in the feeding flock, while Model 3 is the case of a fully vertically integrated broiler production.

An indication of the approximate time interval between successive activities is needed for the purpose of deriving the relevant planning horizon for each activity. On the basis of the available information, Table 1 presents a summary of the approximate planning horizons utilized for each broiler production activity. Information used in the construction of Table 1 is (a) the chicks placed in the feeding flock are hatched about 6-7 months after chick placement in the hatchery supply flock, (b) broilers attain slaughter weights 8-10 weeks after chick placement in the feeding flock, (c) there is a little less than one month between egg production and chick placement in the feeding flock, and (d) each egg-production cycle lasts for about 10 months, following which is a two-month resting period (Chavas, 1978).

Broiler Data

Like most other U.S. livestock data, the broiler data are published in various sources and at varying degrees of temporal aggregation. As indicated earlier, the present study utilizes quarterly data. The Poultry and Egg Situation (PES) Report (U.S.D.A.-E.R.S., 1969-1984d) is the major source of information on variables related to broiler

Table 1. Stages of broiler production and the corresponding planning horizons, U.S.

Activity performed	Approximate time before broiler slaughter (months)	Approximate planning horizon (quarters)
Broiler slaughter	current period (t)	t + 0
Chick placement in the feeding flock	2 - 3	t + 0
Hatching of eggs from the hatchery supply flock	3 - 4	t + 1
Chick placement in the hatchery supply flock	8 - 9	t + 3

production and various forms of broiler disappearance. For example, these data sources contain information on variables such as the number of chicks placed in the hatchery supply flock, federally inspected broiler slaughter, number of chicks hatched for placement in the feeding flocks, number of chicks placed in the feeding flocks, wholesale prices of broilers, prices of yellow corn and soybean meal. Variables, such as chick placement in the feeding flock, must be computed for quarterly models as they are reported on a weekly basis. Also, the measure of broiler feed cost is calculated as a weighted combination of 70 percent yellow corn and 30 percent soybean meal, following recent recommendations.

Some of the variables indicated above have multiple sources. For example, federally inspected broiler slaughter is published in the Livestock and Poultry Outlook and Situation (LPOS) (U.S.D.A.-E.R.S., 1969-1984c), in addition to the PES Report indicated earlier. Also, retail prices of pork and beef are published both in the LPOS and Livestock and Meat Situation (U.S.D.A.-E.R.S., 1969-1984b). The number of chicks hatched is available both in the PES Report and the Eggs, Chickens and Turkeys Report (U.S.D.A.-E.R.S., 1969-1984a). Per capita disposable personal income (1972 dollars), consumer price index, wholesale price index and the cost index of items used in production including interests, taxes and wages are published in the Survey of Current Business (U.S. Department of Commerce, 1969-1984). The retail prices of pork and beef were deflated by the consumer price index. The wholesale price of broiler was deflated by the wholesale price index (Huntzinger, 1979). The price of broiler chicken feed was deflated by the cost index of items used in production including interests, taxes and wages (Lasley, 1983).

Specifications of the Alternative Broiler Models

Three alternative models are formulated for the U.S. broiler market. Each model structurally reflects a specific planning horizon for the firms performing the indicated production activities. Each model is analyzed strictly within a market equilibrium context. Except for slight notational differences on the parameters, the structure of the broiler demand equation is the same across all models.

Thus, differences among the three models lie in the number of equations making up the supply block.

Model 1

Model 1 consists of three behavioral equations: a demand equation for broilers, an equation for broiler slaughter and an equation for chick placement in the feeding flock. Assuming that the number of chicks in the feeding flock predetermines broiler slaughter, Model 1 may be summarized as follows:

Broiler demand:

$$BRSL_t = a_{11} + a_{12}\, PBR_t + a_{13}\, PPK_t + a_{14}\, PBF_t + a_{15}\, DPI_t + \sum_{i=2}^{4} f_i\, Q_{it} + u_{1t} \qquad (3.1)$$

Broiler slaughter:

$$BRSL_t = a_{21} + a_{22}\, PFF_t + \sum_{i=2}^{4} g_i\, Q_{it} + u_{2t} \qquad (3.2)$$

Chick placement in the feeding flock:

$$PFF_t = a_{31} + a_{32}\, PBR*_t + a_{33}\, HATCH_{t-1} + a_{34}\, PCF_t + \sum_{i=2}^{4} h_i\, Q_{it} + u_{3t} \quad . \qquad (3.3)$$

Recognizing that X(t) is the same as X_t for any variable X, the variables in Model 1 are defined as follows:

PBR(t) = real wholesale price of broilers in period t,

PCF(t) = real price of broiler chicken feed,

PBF(t) = real retail price of beef,

PPK(t) = real retail price of pork,

DPI(t) = real per capita disposable personal income,

BRSL(t) = broiler slaughter under federal inspection,

PFF(t) = chick placement in the feeding flocks,

PBR*(t) = broiler price expected to prevail in the selling period t,

HATCH(t-1) = chicks hatched in period t-1 and

Q(i) = quarterly dummy variables, i=2, 3, 4.

Model 1 assumes that firms vertically integrate PFF(t) and subsequent activities, while taking the chick hatching activity as given.

Model 2

Model 2 assumes that firms vertically integrate the performance of chick hatching, HATCH(t), and all subsequent activities, taking chick placement in the hatchery supply flock as externally determined. With the planning horizon now one period ahead, i.e., t+1, Model 2 consists of Equations (3.1), (3.2) and the following two equations:

Chick placement in the feeding flocks:

$$PFF_t = b_{31} + b_{32}\ HATCH_{t-1} + b_{33}\ PCF_t + \sum_{i=2}^{4} h_i\ Q_{it} + v_{3t} \qquad (3.4)$$

Chick hatching:

$$HATCH_t = b_{41} + b_{42}\ PBR^*_{t+1} + b_{43}\ HSF_{t-2} + b_{44}\ PCF_t + \sum_{i=2}^{4} m_i\ Q_{it} + v_{4t} \qquad (3.5)$$

where

HSF(t-2) = number of chicks placed in the hatchery supply flocks in period t-2, presumably by other fully integrated firms and

PBR*(t+1) = broiler price expected to prevail t+1 periods ahead.

It is noted here that the a_{ij} coefficients in Eqs. (3.1) and (3.2) need to be changed to b_{ij} to make the specification compatible with Eqs. (3.4) and (3.5). The same is true for the structural disturbance terms in Eqs. (3.1) and (3.2).

Model 3

Model 3, which assumes that firms are fully vertically integrated in the performance of all broiler production activities, consists of Eqs. (3.1), (3.2), (3.4) and the following two equations:

Chick hatching:

$$HATCH_t = c_{41} + c_{42}\, HSF_{t-2} + c_{43}\, PCF_t + \sum_{i=2}^{4} m_i\, Q_{it} + e_{4t} \qquad (3.6)$$

Chick placement in the hatchery supply flocks:

$$HSF_t = c_{51} + c_{52}\, PBR*_{t+3} + c_{53}\, HSF_{t-4} + c_{54}\, PCF_t + \sum_{i=2}^{4} n_i\, Q_{it} + e_{5t} \qquad (3.7)$$

where PBR*(t+3) is the broiler price expected to prevail t+3 periods ahead. Once again, it is required that the notation for the parameters and the structural disturbance terms in Eqs. (3.1), (3.2) and (3.4) be altered to match those in Eqs. (3.6) and (3.7), respectively,

Econometric Implications of Rationality Hypothesis

This section presents the estimating equations obtained by imposing the rationality restrictions in the three alternative structural models. As indicated earlier, the sets of solutions below were derived within a market equilibrium context. Most of the theoretical underpinnings of the results have been presented in Chapter II and are, therefore, largely omitted in the present section. Also, because of the intermediate calculations involved, only key results are presented.

Beginning with Model 1 and utilizing the assumptions stated earlier in Chapter II, the rational predictor of the current period broiler price is given by

$$PBR^*_t = (a_{12}-a_{22}a_{32})^{-1}\,[a_{21} + a_{22}a_{31} - a_{11} + a_{22}a_{33}\,HATCH_{t-1} + a_{22}a_{34}\,\hat{PCF}_t + (a_{22}\sum_{i=2} h_i + \sum_{i=2} g_i - \sum_{i=2} f_i)Q_{it} - (a_{13}\,\hat{PPK}_t + a_{14}\,\hat{PBF}_t + a_{15}\,\hat{DPI}_t)] \quad . \tag{3.8}$$

With suitable projections for the current levels of the exogenous variables PPK, PBF, DPI and PCF (see Chapter II and the beginning of Chapter IV), Eq. (3.8) becomes an observable structure which can be substituted into Eq. (3.3) to obtain a non-linear expression in variable PFF(t). Substituting appropriately for PFF(t) in Eq. (3.2) and for BRSL(t) in Eq. (3.1), we obtain a system of nonlinear equations in variables PFF(t), BRSL(t) and PBR(t), all of which are linked by cross-equation restrictions.

The restricted form of Model 1 is thus given by the following system of equations:

Chick placement in the feeding flock:

$$PFF_t = (a_{12} - a_{22}a_{32})^{-1} [a_{31}a_{12} + a_{32}a_{21} - a_{32}a_{11} + a_{32}a_{12}\, HATCH_{t-1} + a_{32}a_{34}a_{22}\, \hat{PCF}_t + (a_{12} \sum_{i=2} h_i + a_{32} \sum_{i=2} g_i - a_{32} \sum_{i=2} f_i)Q_{it} - a_{32}\,(a_{13}\, \hat{PPK}_t + a_{14}\, \hat{PBF}_t + a_{15}\, \hat{DPI}_t)] + a_{34}\, PCF_t + u^*_{3t} \qquad (3.9)$$

Broiler slaughter:

$$BRSL_t = (a_{12} - a_{22}a_{32})^{-1} [a_{22}a_{31}a_{12} + a_{21}a_{12} - a_{22}a_{32}a_{11} + a_{22}a_{33}a_{12}\, HATCH_{t-1} + a_{22}\, a_{32}a_{34}\, \hat{PCF}_t + (a_{12}a_{22} \sum_{i=2} h_i + a_{12} \sum_{i=2} g_i - a_{22}a_{32} \sum_{i=2} f_i)Q_{it} - a_{22}a_{32}\,(a_{13}\, \hat{PPK}_t + a_{14}\, \hat{PBF}_t + a_{15}\, \hat{DPI}_t)] + a_{22}a_{34}\, PCF_t + u^*_{2t} \qquad (3.10)$$

Broiler price:

$$PBR_t = (a_{12} - a_{22}a_{32})^{-1} [a_{22}a_{31} + a_{21} - a_{11} + a_{22}a_{33}\ HATCH_{t-1}$$

$$+ (a_{22} \sum_{i=2} h_i + \sum_{i=2} g_i - \sum_{i=2} f_i)Q_{it}$$

$$+ (a_{22}a_{32}/a_{12})(a_{22}a_{34}\ \hat{PCF}_t - a_{13}\ \hat{PPK}_t - a_{14}\ \hat{PBF}_t$$

$$- a_{15}\ \hat{DPI}_t)] + (1/a_{12})(a_{22}a_{34}\ PCF_t - a_{13}\ PPK_t$$

$$- a_{14}\ PBF_t - a_{15}\ DPI_t) + u^*_{1t} \quad . \qquad (3.11)$$

Equations (3.9) through (3.11) have 20 structural parameters and 33 'free' parameters, making the total number of restricted parameters equal to 13. The generalized procedures of Chapter II also form the basis for deriving the restricted and unrestricted forms for Models 2 and 3. The only difference from Model 1 is that we are now concerned with planning horizons longer than the current period (t).

Using the assumption of market equilibrium, the assumptions on the structural disturbance terms and the assumption of weak consistency of expectations (Chapter II), the rational predictor for the price of broilers, one period ahead, is:

$$PBR*_{t+1} = (b_{12} - b_{22}b_{32}b_{42})^{-1} [b_{21} + b_{22}b_{31} + b_{22}b_{32}b_{41} - b_{11}$$

$$+ b_{22}b_{33}\,\hat{PCF}_{t+1} + b_{22}b_{32}b_{44}\,PCF_t + b_{22}b_{32}b_{42}\,HSF_{t-2}$$

$$- (b_{13}\,\hat{PPK}_{t+1} + b_{14}\,\hat{PBF}_{t+1} + b_{15}\,\hat{DPI}_{t+1})$$

$$+ (b_{22}\sum_{i=2} h_i + \sum_{i=2} g_i - \sum_{i=2} f_i)Q_{i,t+1}$$

$$+ b_{22}b_{32}\sum_{i=2} m_i\,Q_{it}] \quad . \tag{3.12}$$

A complication arises in Eq. (3.12). The presence of both Q_{it} and $Q_{i,t+1}$, i=2, 3, 4 in the same equation leads to a 'dummy variable trap' since at least one of the columns in matrix $\underset{\sim}{Q}_t$ is repeated in matrix $\underset{\sim}{Q}_{t+1}$. This problem was avoided by making a further assumption that $Q_{i,t+j-s} = Q_{it}$ for all j in the neighborhood of s, i=2, 3, 4, s > 0. Then, by substituting the adjusted form of Eq. (3.12) into Eq. (3.5), a non-linear expression in HATCH(t) results. Eliminating HATCH(t-1) from Eq. (3.4), PFF(t) from Eq. (3.2) and BRSL(t) from Eq. (3.1), a system of equations in HATCH(t), PFF(t), BRSL(t) and PBR(t) is obtained which are linked together by cross-equation restrictions. The restricted form of Model 2 can be summarized as follows:

Chick hatching:

$$HATCH_t = (b_{12} - b_{22}b_{32}b_{42})^{-1} [b_{42}b_{22}b_{31} + b_{42}b_{21} + b_{41}b_{12}$$

$$- b_{42}b_{11} + b_{43}b_{12} HSF_{t-2} + b_{44}b_{12} PCF_t$$

$$+ b_{42}b_{22}b_{33} \hat{PCF}_{t+1} + (b_{12} \sum_{i=2} m_i + b_{42}b_{22} \sum_{i=2} h_i$$

$$+ b_{42} \sum_{i=2} g_i - b_{42} \sum_{i=2} f_i)Q_{it} - b_{42} (b_{13} \hat{PPK}_{t+1}$$

$$+ b_{14} \hat{PBF}_{t+1} + b_{15} \hat{DPI}_{t+1})] + v*_{4t} \qquad (3.13)$$

Chick placement in the feeding flock:

$$PFF_t = (b_{12} - b_{22}b_{32}b_{42})^{-1} [b_{32}b_{41}b_{12} + b_{32}b_{42}b_{21} + b_{31}b_{12}$$

$$- b_{32}b_{42}b_{11} + b_{12} (b_{33} PCF_t + b_{32}b_{43} HSF_{t-3}$$

$$+ b_{32}b_{44} PCF_{t-1}) + (b_{32}b_{12} \sum_{i=2} m_i + b_{32}b_{42} \sum_{i=2} g_i$$

$$+ b_{12} \sum_{i=2} h_i - b_{32}b_{42} \sum_{i=2} f_i)Q_{it} - b_{32}b_{42} (b_{13} PPK_t$$

$$+ b_{14} PBF_t + b_{15} DPI_t)] + v*_{3t} \qquad (3.14)$$

Broiler slaughter:

$$BRSL_t = (b_{12} - b_{22}b_{32}b_{42})^{-1} [b_{22}b_{32}b_{41}b_{12} + b_{22}b_{31}b_{12} + b_{21}b_{12} - b_{22}b_{32}b_{42}b_{11} + b_{22}b_{12} (b_{33}\, PCF_t + b_{32}b_{43}\, HSF_{t-3} + b_{32}b_{44}\, PCF_{t-1}) + (b_{22}b_{32}b_{12} \sum_{i=2} m_i + b_{22}b_{12} \sum_{i=2} h_i + b_{12} \sum_{i=2} g_i - b_{22}b_{32}b_{42} \sum_{i=2} f_i)Q_{it} - b_{22}b_{32}b_{42} (b_{13}\, PPK_t + b_{14}\, PBF_t + b_{15}\, DPI_t)] + v^*_{2t} \quad (3.15)$$

Broiler price:

$$PBR_t = (b_{12} - b_{22}b_{32}b_{42})^{-1} [b_{22}b_{32}b_{41} + b_{22}b_{31} + b_{21} - b_{11} + b_{22} (b_{33}\, PCF_t + b_{32}b_{43}\, HSF_{t-3} + b_{32}b_{44}\, PCF_{t-1}) + (b_{22}b_{32} \sum_{i=2} m_i + \sum_{i=2} g_i + b_{22} \sum_{i=2} h_i - \sum_{i=2} f_i)Q_{it} - (b_{13}\, PPK_t + b_{14}\, PBF_t + b_{15}\, DPI_t)] + v^*_{1t} \quad . \quad (3.16)$$

Each of the new disturbance terms, v^*_{jt}, j=1, 2, 3, 4, is some function of the disturbance terms in the structural Model 2. Also, Model 2 can be verified as containing 26 structural parameters and 40 'free' parameters, thus imposing a total of 14 restrictions on the model.

With the exception that firms are assumed to be planning three periods ahead, the derivation of the restricted form of Model 3 follows identically the procedures used for Model 2. Thus only the rational predictor of broiler price, appropriate to Model 3, is presented, i.e.,

$$
\begin{aligned}
PBR^*_{t+3} = (c_{12} - c_{22}c_{32}c_{42}c_{52})^{-1} [&c_{22}c_{32}c_{42}c_{51} + c_{22}c_{32}c_{41} \\
&+ c_{22}c_{31} + c_{21} - c_{11} + c_{22}c_{32} (c_{42}c_{53}\, HSF_{t-4} \\
&+ c_{42}c_{54}\, PCF_t + c_{43}\, \hat{PCF}_{t+2}) + c_{22}c_{33}\, \hat{PCF}_{t+3} \\
&- (c_{13}\, \hat{PPK}_{t+3} + c_{14}\, \hat{PBF}_{t+3} + c_{15}\, \hat{DPI}_{t+3}) \\
&+ (\sum_{i=2} g_i + c_{22} \sum_{i=2} h_i + c_{22}c_{32} \sum_{i=2} m_i \\
&+ c_{22}c_{32}c_{42} \sum_{i=2} n_i - \sum_{i=2} f_i) Q_{it}] \, .
\end{aligned}
\tag{3.17}
$$

The above expressions have already been adjusted to avoid the dummy variable trap that would have resulted from the presence of matrices Q_t, Q_{t+2} and Q_{t+3} in the same equation. By substituting Eq. (3.17) into Eq. (3.7) and repeating the sequence of substitutions outlined for Model 2, a system of 5 equations in HSF(t), HATCH(t), PFF(t), BRSL(t) and PBR(t) can be derived which are linked by cross-equation restrictions. It can also be verified that Model 3 has 32 structural parameters and 55 'free' parameters, leaving the model with 23 restrictions. Finally, restricted and unrestricted forms of Models 1, 2 and 3 have been estimated. The results are presented and reviewed in Chapter IV.

CHAPTER IV. PRELIMINARY RESULTS AND DISCUSSION

This chapter presents the estimates of the alternative models formulated in Chapter III. Some of the conclusions reached in this chapter are preliminary in the sense that they would need further validation using alternative test procedures (see Chapter V). For each of the structural models presented earlier, the restricted form was estimated by maximum likelihood methods (for theoretical expositions of the non-linear algorithm, see Fomby et al., 1984; Maddala, 1977; Marquardt, 1963, Bard, 1974). The unrestricted form of each model was estimated by seemingly unrelated regression methods (Zellner, 1962), given the recursive structure of the models.

This chapter is arranged as follows. The ARIMA projections of the exogenous variables in the model are presented first. This approach is based on the earlier position that the information requirement for the econometric estimation of models incorporating rationality restrictions is crucial. The second section presents the estimates obtained for the restricted and unrestricted forms of each model, with emphasis on the signs and statistical significance of regression coefficients, and the sizes of economically relevant elasticity coefficients. The third section discusses the likelihood ratio tests of the rationality hypothesis for each model, followed by the evaluations of the results in the present chapter against those from other related studies.

Projections of the Exogenous Variables in the Models

Except for the slight differences in the length of forecasts required, all three models contain identical sets of exogenous variables. These are the retail prices of beef (PBF) and pork (PPK), per capita disposable personal income (DPI) and broiler feed cost (PCF). Each of these variables was forecast using the 3-step method suggested by Box and Jenkins (1976), namely, model identification, model estimation and diagnostic checking of estimated models. For each estimated ARIMA function, standard errors of coefficients are reported in parentheses below the corresponding AR and MA terms. Also presented are two diagnostic statistics, namely, the standard errors of residuals (S.E.R.) and the Box-Pierce's (1970) chi-square (Table 2).

For each estimated ARIMA function, it can be verified that the required stationarity and invertibility conditions are met for the AR and MA terms, respectively (e.g., see Pankratz, 1983 and Mabert, 1975). Also, the estimates for the diagnostic coefficients, namely, the Box-Pierce statistic and the standard error of residuals, are of acceptable magnitude for each process.

Results of the Estimated Structural Models

Results from estimating each model with and without the rationality restrictions are presented in this section. For each model (restricted and unrestricted), estimates of the standard errors are placed in parentheses, while the relevant elasticity values are placed in brackets below the corresponding regression coefficient.

Table 2. Estimated ARIMA functions for the exogenous variables

	PBR(t)	PPK(t)	DPI(t)	PCF(t)
Number of seasonal differencing	1	1	1	1
Number of regular differencing	1	1	1	1
Autoregressive (AR) terms				
1	.401 (.334)	1.342 (.097)	.282 (.092)	.269 (.049)
2	.377 (.343)	-.665 (.096)		
Moving average (MA) terms				
1	-.296 (.293)	-.975 (.059)	-.148 (.095)	-.006 (.005)
2	-.694 (.316)			
Box-Pierce $\chi^2_{(20)}$	14.71	38.74	35.20	23.11
S.E.R.	.058	.063	.017	.081

Model 1 - restricted form

Broiler demand:

$$\begin{aligned} BRSL(t) = {} & -1550700 - 36139\ PBR(t) + 3310\ PPK(t) \\ & (292850) \quad (4817) \qquad (1053) \\ & \qquad [-.60] \qquad [.17] \\ & + 4745.90\ PBF(t) + 984.10\ DPI(t) + 179230\ Q2(t) \\ & \quad (482.00) \qquad (28.05) \qquad (32490) \\ & \quad [.33] \qquad [1.69] \\ & + 162240\ Q3(t) - 53613\ Q4(t) \qquad (4.1) \\ & \quad (32500) \qquad (32828) \end{aligned}$$

Broiler slaughter:

$$\begin{aligned} BRSL(t) = {} & -810960 + 45.86\ PFF(t) + 32472\ Q2(t) \\ & (74660) \quad (1.49) \qquad (30398) \\ & + 314630\ Q3(t) - 53613\ Q4(t) \qquad (4.2) \\ & \quad (30220) \qquad (30162) \end{aligned}$$

Chick placement in the feeding flock:

$$\begin{aligned} PFF(t) = {} & 16012 + 320.55\ PBR*(t) + .149\ HATCH(t-1) \\ & (314) \quad (52.15) \qquad (.010) \\ & \qquad [.19] \\ & - 29.59\ PCF(t) + 2260.40\ Q2(t) - 12837\ Q3(t) \\ & \quad (9.32) \qquad (439.48) \qquad (603) \\ & \quad [-.04] \\ & - 8952\ Q4(t) \qquad (4.3) \\ & \quad (477) \end{aligned}$$

The estimated coefficients have the expected signs and are statistically significant. The estimated dummy variable coefficients in the demand equation have positive signs for summer quarters and negative signs for winter quarters (counting the intercept). This is consistent with the broiler consumption pattern described in Chapter III. The elasticities of broiler demand with respect to PPK, PBF, PBR and DPI are not only correctly signed, but are of significant sizes. The same interpretation goes for the elasticity of response of PFF(t) with respect to PBR*(t).

Model 1 - unrestricted form

Broiler price:

$$\begin{aligned} PBR(t) = {} & -15.28 - .0002\ HATCH(t-1) + 2.66\ Q2(t) \\ & (38.22) \quad (.00003) \qquad\quad (2.12) \\ & + 13.25\ Q3(t) + .88\ Q4(t) + .36\ \hat{PCF}(t) + .27\ \hat{PPK}(t) \\ & \quad (2.35) \qquad (2.29) \qquad (.59) \qquad (.16) \\ & - .02\ \hat{DPI}(t) - .07\ \hat{PBF}(t) + .04\ PPK(t) + .030\ DPI(t) \\ & \quad (.01) \qquad (.17) \qquad (.03) \qquad (.004) \\ & + .12\ PCF(t) + .11\ PBF(t) \qquad\qquad\qquad\qquad (4.4) \\ & \quad (.05) \qquad (.02) \end{aligned}$$

Broiler slaughter:

$$\begin{aligned} BRSL(t) = {} & 1245700 + 5.22\ HATCH(t-1) + 43026\ Q2(t) \\ & (646640)\ \ (.49)\qquad\qquad\ (36628) \\ & - 153420\ Q3(t) + 20145\ Q4(t) - 32302\ \hat{PCF}(t) \\ & \quad (36938)\qquad\ (40379)\qquad\ (10284) \\ & - 8699\ \hat{PPK}(t) + 727.40\ \hat{DPI}(t) + 8854.1\ \hat{PBF}(t) \\ & \quad (2730)\qquad\ (177.73)\qquad\ (2812.8) \\ & - 1391\ PCF(t) \\ & \quad (804) \\ & \quad [-.06] \end{aligned} \tag{4.5}$$

Chick placement in the feeding flock:

$$\begin{aligned} PFF(t) = {} & 67736 + .14\ HATCH(t-1) - 1507\ Q2(t) \\ & (26534)\ (.02)\qquad\qquad\ (1503) \\ & - 12796\ Q3(t) - 4965\ Q4(t) - 1223\ \hat{PCF}(t) \\ & \quad (1516)\qquad\ (1657)\qquad\ (422) \\ & - 98.03\ \hat{PPK}(t) + 27.35\ \hat{DPI}(t) + 2.01\ \hat{PBF}(t) \\ & \quad (112.01)\qquad\ (7.21)\qquad\ (115.42) \\ & - 68.89\ PCF(t) \\ & \quad (32.98) \\ & \quad [-.10] \end{aligned} \tag{4.6}$$

The first observation to make is that the broiler demand equation is price-dependent in the unrestricted form of Model 1. However, PBR(t) continues to be positively related to observed values of PPK(t), PBF(t), PCF(t) and DPI(t) as expected. Secondly, the presence

of demand-determining variables in the supply equations and vice versa is a consequence of the rationality restrictions imposed on the model (see Chapter II).

Model 2 - restricted form

Broiler demand:

$$\begin{aligned} BRSL(t) = {} & \underset{(308900)}{-1415148} - \underset{(2735)}{\underset{[-.49]}{29386}}\ PBR(t) + \underset{(879)}{\underset{[.16]}{3043}}\ PPK(t) \\ & + \underset{(620)}{\underset{[.32]}{4596}}\ PBF(t) + \underset{(104.60)}{\underset{[1.56]}{900.84}}\ DPI(t) + \underset{(32539)}{180092}\ Q2(t) \\ & + \underset{(32013)}{167248}\ Q3(t) - \underset{(33188)}{56622}\ Q4(t) \end{aligned} \qquad (4.7)$$

Broiler slaughter:

$$\begin{aligned} BRSL(t) = {} & \underset{(74721)}{-798917} + \underset{(1.04)}{45.71}\ PFF(t) + \underset{(30143)}{33383}\ Q2(t) \\ & + \underset{(29585)}{311683}\ Q3(t) + \underset{(30613)}{251106}\ Q4(t) \end{aligned} \qquad (4.8)$$

Chick placement in the feeding flock:

$$\begin{aligned} PFF(t) = {} & \underset{(6867)}{9748} + \underset{(.01)}{.26}\ HATCH(t-1) - \underset{\substack{(40.32)\\[-.21]}}{144.88}\ PCF(t) \\ & - \underset{(923)}{7442}\ Q2(t) - \underset{(1154)}{6682}\ Q3(t) - \underset{(967)}{1250}\ Q4(t) \end{aligned} \qquad (4.9)$$

Chick-hatching:

$$\begin{aligned} HATCH(t) = {} & \underset{(25623)}{136464} + \underset{\substack{(182)\\[.39]}}{2864}\ PBR^{*}(t+1) + \underset{(4.26)}{34.86}\ HSF(t-2) \\ & - \underset{\substack{(132)\\[-.24]}}{733}\ PCF(t) + \underset{(3749)}{48022}\ Q2(t) + \underset{(3735)}{14949}\ Q3(t) \\ & - \underset{(4072)}{10060}\ Q4(t) \end{aligned} \qquad (4.10)$$

The planning horizon for Model 2 is t+1, where t is the period in which chick-hatching occurs. This explains why the broiler price expectations variable PBR*(t+1) is in the equation for HATCH(t). The estimated coefficients for PBR*(t+1), PCF(t) and other biologically and economically relevant variables in the model have the expected signs, most of which are statistically significant.

It is noteworthy that the elasticity of HATCH(t) with respect to expected broiler price PBR*(t+1), .39, is larger than the elasticity of PFF(t) with respect to PBR*(t), .19, earlier obtained in Model 1. Similar trends are suggested for the elasticities of HATCH(t) and PFF(t) with respect to feed cost PCF(t) whether one compares Models 1 and 2 or restricts attention only to Model 2. One possible explanation for this trend in the elasticities of broiler supply activities is that the total time available for adjusting to changes (or expected changes) in these economic variables tends to decrease as the firms operate closer and closer to the broiler

selling period. Actually, this was the reason for excluding these two variables from the structural equations describing broiler slaughter in the three models analyzed.

Model 2 - unrestricted form

Broiler price:

$$\begin{aligned} PBR(t) = {} & -41.57 - .010\ HSF(t-3) - 2.21\ Q2(t) \\ & (13.63)\quad (.002)\qquad\quad (1.31) \\ & - 1.02\ Q3(t) - 3.93\ Q4(t) + .24\ PCF(t) - .02\ PCF(t-1) \\ & (1.22)\qquad (1.14)\qquad (.08)\qquad (.08) \\ & + .04\ PPK(t) + .07\ PBF(t) + .020\ DPI(t) \\ & (.03)\qquad (.03)\qquad (.003) \end{aligned} \tag{4.11}$$

Broiler slaughter:

$$\begin{aligned} BRSL(t) = {} & -741350 + 158.36\ HSF(t-3) + 243500\ Q2(t) \\ & (350310)\quad (43.08)\qquad\quad (33564) \\ & + 199400\ Q3(t) + 26018\ Q4(t) - 5635\ PCF(t) \\ & (31348)\qquad (29267)\qquad (1930) \\ & \qquad\qquad\qquad\quad [-.23] \\ & - 417\ PCF(t-1) + 1035\ PPK(t) + 2169\ PBF(t) \\ & (1942)\qquad (854)\qquad (697) \\ & + 636.02\ DPI(t) \\ & (81.66) \end{aligned} \tag{4.12}$$

Chick placement in the feeding flock:

$$\begin{aligned} PFF(t) = {} & \underset{(7229)}{8292} + \underset{(.86)}{4.32}\, HSF(t-3) + \underset{(753)}{4969}\, Q2(t) \\ & - \underset{(717)}{2212}\, Q3(t) - \underset{(679)}{4856}\, Q4(t) - \underset{\substack{(39.14)\\ [-.20]}}{140.45}\, PCF(t) \\ & - \underset{(36.49)}{39.28}\, PCF(t-1) + \underset{(16.10)}{33.07}\, PPK(t) \\ & + \underset{(13.20)}{28.93}\, PBF(t) + \underset{(1.57)}{13.15}\, DPI(t) \end{aligned} \qquad (4.13)$$

Chick-hatching:

$$\begin{aligned} HATCH(t) = {} & \underset{(389720)}{21016} + \underset{(3.75)}{18.67}\, HSF(t-2) + \underset{(13661)}{45471}\, Q2(t) \\ & + \underset{(39659)}{9425}\, Q3(t) - \underset{(18946)}{15851}\, Q4(t) + \underset{(6086)}{1437}\, \hat{PCF}(t+1) \\ & - \underset{\substack{(141)\\ [-.23]}}{719}\, PCF(t) + \underset{(437)}{341}\, \hat{PPK}(t+1) + \underset{(429.67)}{26.93}\, \hat{PBF}(t+1) \\ & + \underset{(73.08)}{17.97}\, \hat{DPI}(t+1) \end{aligned} \qquad (4.14)$$

Of special interest are the signs and statistical significance of the feed cost variable PCF(t) and the lagged values of broiler production activities in the unrestricted form of Model 2. As evident from the results presented, these variables have plausible

signed and statistically significant coefficients. Also, the absolute value of the elasticity of HATCH(t) with respect to PCF(t) is noted to be larger than the corresponding value for activity PFF(t) which follows HATCH(t). This trend is consistent with earlier results from the restricted form of Model 2.

Model 3 - restricted form

Broiler demand:

$$\begin{aligned} BRSL(t) = {} & -1233000 - 29404\ PBR(t) + 2982\ PPK(t) \\ & (351930) \quad (2663) \qquad (874) \\ & + 4567\ PBF(t) + 862\ DPI(t) + 170761\ Q2(t) \\ & (634) \qquad (116) \qquad (31923) \\ & + 155431\ Q2(t) - 67651\ Q4(t) \\ & (32023) \qquad (32712) \end{aligned} \tag{4.15}$$

Broiler slaughter:

$$\begin{aligned} BRSL(t) = {} & -749579 + 45.15\ PFF(t) + 25368\ Q2(t) \\ & (78264) \quad (1.09) \qquad (30114) \\ & + 310208\ Q3(t) + 253651\ Q4(t) \\ & (30200) \qquad (30618) \end{aligned} \tag{4.16}$$

Chick placement in the feeding flock:

$$\begin{aligned} PFF(t) = {} & 8595 + .21\ HATCH(t-1) + 33.76\ PCF(t) \\ & (7215) \ (.01) \qquad (41.48) \\ & + 2007\ Q2(t) - 16259\ Q3(t) - 11169\ Q4(t) \\ & (943) \qquad (1227) \qquad (1008) \end{aligned} \tag{4.17}$$

Chick-hatching:

$$\underset{}{HATCH(t)} = \underset{(55266)}{362469} + \underset{(10.99)}{74.50}\ HSF(t-2) - \underset{(317)}{2622}\ PCF(t)$$

$$+ \underset{(9531)}{48183}\ Q2(t) + \underset{(9654)}{14881}\ Q3(t) - \underset{(10261)}{16383}\ Q4(t) \qquad (4.18)$$

Chick placement in the hatchery supply flock:

$$\underset{}{HSF(t)} = \underset{(940)}{922} + \underset{(6.23)}{27.06}\ PBR*(t+3) + \underset{(.01)}{.07}\ HSF(t-4)$$

$$+ \underset{(4.08)}{3.22}\ PCF(t) + \underset{(104)}{162}\ Q2(t) - \underset{(99)}{128}\ Q3(t)$$

$$+ \underset{(102.68)}{64.44}\ Q4(t) \qquad (4.19)$$

The assessment of the estimates of the restricted form of Model 3 is at best mixed. For example, the results of the likelihood ratio tests (presented later) suggest that the rationality restrictions imposed on Model 3 may not be valid. However, one of the surprises in the restricted form of the model is that the expected broiler price variable PBR*(t+3) is statistically significant with theoretically plausible sign in the equation for HSF(t). Also of interest are the coefficients on lagged values of the various broiler production activities, e.g., HSF(t-4), HSF(t-2), HATCH(t-1) and the current level of PFF(t). All contribute statistically to explaining the equations in which they are included. But, a further review of the results shows

that the restricted form of Model 3 was partly flawed because of the predicted response of firms to changes in the feed costs. For example, in the equations for PFF(t) and HSF(t), the estimates for the feed cost coefficients have positive signs, but are not significant. Only in the equation for HATCH(t) is variable PCF(t) correctly signed and statistically significant.

Turning to the demand equation, it is noted that the estimates of this equation have the expected signs and their levels of statistical significance comparable to those obtained for the restricted forms of Models 1 and 2. The overall picture, then, is that Model 3, in the restricted form, performs fairly well, but only on selective basis. However, since all the equations making up the restricted model were jointly estimated, it may not be accurate to take consolation in the theoretical correctness of only a subset of the estimates of the structural model. Also, because of the problems inherent in the results for the estimated form of Model 3, elasticity estimates are not reported for the relevant variables. The reliability of the elasticity estimates is doubtful since there is not econometric evidence to support the rationality restrictions imposed in the model.

Model 3 - unrestricted form

Broiler price:

$$\begin{aligned} PBR(t) = {} & -59.67 - .00003\ HSF(t-7) - .08\ PCF(t-3) \\ & (21.30)\quad (.002)\qquad\qquad (.06) \\ & + .09\ PCF(t-1) + .25\ PCF(t) + .09\ PPK(t) + .04\ PBF(t) \\ & \quad (.09)\qquad\quad (.09)\qquad\quad (.03)\qquad\quad (.03) \\ & + .01\ DPI(t) + .48\ Q2(t) + 1.25\ Q3(t) \\ & \quad (.004)\qquad\quad (.147)\qquad\quad (1.42) \\ & - 2.87\ Q4(t) \\ & \quad (1.31) \end{aligned} \tag{4.20}$$

Broiler slaughter:

$$\begin{aligned} BRSL(t) = {} & -1305400 + 124.06\ HSF(t-7) + 849.77\ PCF(t-3) \\ & \quad (512890)\quad\ (45.61)\qquad\qquad (1494.00) \\ & - 1810\ PCF(t-1) - 3915\ PCF(t) + 181.48\ PPK(t) \\ & \quad (2216)\qquad\quad (2059)\qquad\quad (731.58) \\ & \qquad\qquad\quad [-.15] \\ & + 2160\ PBF(t) + 793.14\ DPI(t) + 221330\ Q2(t) \\ & \quad (686)\qquad\quad (93.15)\qquad\quad (34999) \\ & + 180790\ Q3(t) + 11962\ Q4(t) \\ & \quad (33569)\qquad\quad (31026) \end{aligned} \tag{4.21}$$

Chick placement in the feeding flock:

$$\begin{aligned} PFF(t) = {} & 4607 + 2.59\ HSF(t-7) + 8.12\ PCF(t-3) \\ & (10618)\ (.91) \qquad\qquad (29.79) \\ & - 65.02\ PCF(t-1) - 133.83\ PCF(t) + 17.84\ PPK(t) \\ & (42.87) \qquad\quad (45.03) \qquad\quad (13.84) \\ & \qquad\qquad [-.19] \\ & + 23.97\ PBF(t) + 16.21\ DPI(t) + 4263\ Q2(t) \\ & (13.32) \qquad\quad (1.86) \qquad\quad (861) \\ & - 2551\ Q3(t) - 5290\ Q4(t) \\ & (839) \qquad\quad (795) \end{aligned} \tag{4.22}$$

Chick-hatching:

$$\begin{aligned} HATCH(t) = {} & 1548500 - 1.11\ HSF(t-6) - 201.20\ PCF(t-2) \\ & (653460)\ (4.27) \qquad\quad (160.94) \\ & - 846\ PCF(t) - 16584\ \hat{PCF}(t+1) + 1665\ \hat{PPK}(t+1) \\ & (219) \qquad\quad (9917) \qquad\quad (537) \\ & [-.27] \\ & - 894\ \hat{PBF}(t+1) - 139.41\ \hat{DPI}(t+1) + 73349\ Q2(t) \\ & (593) \qquad\quad (113.39) \qquad\quad (20002) \\ & + 118800\ Q3(t) + 43105\ Q4(t) \\ & (63019) \qquad\quad (30569) \end{aligned} \tag{4.23}$$

Chick placement in the hatchery supply flock:

$$\begin{aligned} HSF(t) = {} & \underset{(21097)}{-53527} + \underset{(.09)}{.19}\, HSF(t-4) - \underset{\substack{(3.28)\\[-.20]}}{6.00}\, PCF(t) \\ & - \underset{(359.02)}{181.44}\, \hat{PCF}(t+2) + \underset{(280)}{969}\, \hat{PCF}(t+3) - \underset{(19.09)}{31.06}\, \hat{PPK}(t+3) \\ & + \underset{(18.32)}{54.50}\, \hat{PBF}(t+3) - \underset{(3.34)}{9.32}\, \hat{DPI}(t+3) + \underset{(1887)}{3871}\, Q2(t) \\ & + \underset{(1757)}{5963}\, Q3(t) + \underset{(1046)}{3802}\, Q4(t) \end{aligned} \qquad (4.24)$$

The estimates of the unrestricted form of Model 3 show more plausible results across all the equations. For example, at varying levels of statistical significance, the current-period feed cost variable PCF(t) exhibits a negative relationship with all the endogenous variables in the model. It is noted that the feed cost variable of interest for each estimated equation is PCF(t) since only the latter was specified in the structural models at the outset. The presence of other feed cost variables (lagged or forecasted) in the equations merely reflects the information requirements for testing the rationality restrictions imposed. A similar argument holds for the presence of demand-determining variables in the supply equations and vice versa. Thus, only the elasticities of the broiler supply activities with respect to PCF(t) are reported. With the exception of the equation for activity HSF(t), the elasticity

coefficients are once again seen to be decreasing in absolute values toward the broiler slaughter period. Also, lagged values of broiler supply activity HSF show positive and significant contributions to explaining the equations in which it is specified as a regressor. Only the equation for HATCH(t) was an exception to this tendency.

Likelihood Ratio Tests for Rationality

Following the procedures outlined in Chapter II, likelihood ratio tests were conducted for the rationality restrictions imposed on Models 1, 2 and 3. Results of the tests are summarized in Table 3. Using the log likelihood functions from the restricted and unrestricted forms of each model, that is, L(r) and L(u), the statistic -2 [L(r) - L(u)] was calculated for each test. This statistic lead to the acceptance of the rationality restrictions on Models 1 and 2, but Model 3 was rejected.

As pointed out by Maddock and Carter (1982), when the rationality restrictions are rejected, it is not immediately clear whether to blame the expectations generating mechanisms or the underlying structural model. For example, each of the models analyzed are under double restrictions - rationality and biological. Each of these restrictions independently imposes its own set of non-linearities on the structural parameters. Thus, as the structure of the model expands, such as for Model 3, the problems can only be expected to multiply, if not compound. This is probably the reason that Model 3 failed. Further validations of the foregoing conclusions

Table 3. Likelihood ratio tests for rationality

	Model 1	Model 2	Model 3
L(r)	-1449.38	-2097.81	-2470.08
L(u)	-1439.78	-2088.70	-2313.20
Number of restrictions (q)	13	14	23
$\chi^2_{.05,\,q}$	22.4	23.7	35.2
-2[L(r) - L(u)]	19.20	18.22	313.76
Restrictions on model	accepted	accepted	rejected

are provided by non-nested evaluations of the alternative broiler models in Chapter V.

Evaluation of Results

The estimates just presented are evaluated in this section against some estimates obtained from previous, but related studies. These studies are compared with reference to the statistical significance and elasticities coefficients of key economic variables and, when applicable, tests of rationality hypotheses.

Beginning with the elasticity values, it was noted earlier that the elasticities of the various broiler supply activities with respect to either the expected broiler price or feed costs tended to decrease in value as the slaughter date approached. For example, the elasticity of HATCH(t) with respect to PBR*(t+1) was found to be 0.39 in Model 2, while the elasticity of PFF(t) was .19 in Model 1. PFF(t) has been noted earlier to be closer to broiler slaughter period than HATCH(t). Comparable results on the elasticity of HSF(t) with respect to PBR*(t+3) are not available since the rationality restrictions imposed on Model 3 were rejected. However, results from earlier work by Chavas and Johnson (1982a) provide some indication. These authors obtained an elasticity of .60 for HSF(t) with respect to PBR(t-2) and .06 for BRSL(t) with respect to PBR(t-1), using quarterly data.

The elasticity value of .99 for broiler slaughter BRSL(t) with respect to PBR*(t), obtained by Goodwin and Sheffrin (1982), may have

overstated the response, possibly due to the neglect of previous activities involved in broiler production. The absolute values of the elasticities with respect to broiler feed costs were also noted to be decreasing nearer the slaughter period.

From the unrestricted form of Model 3, the elasticities were found to decline in absolute value from -.27 for HATCH(t) to -.15 for BRSL(t). From Model 2, the elasticities of response with respect to feed costs PCF(t) were similarly found to decrease, from -.24 (-.23) for HATCH(t) to (-.22) for BRSL(t). And, from Model 1, comparable trends were -.04 (-.10) for PFF(t) and (-.06) for BRSL(t). For Models 1 and 2, the elasticity values outside the parentheses are from the restricted models, while those enclosed in the parentheses are from the unrestricted models. These latter results generally agree with the trends noted for the unrestricted form of Model 3.

The study by Chavas and Johnson (1982b) showed the elasticity values to decrease from -.26 for HSF(t) with respect to PCF(t-2) to -.03 for BRSL(t) with respect to PCF(t-1). The study by Goodwin and Sheffrin (1982) obtained an elasticity of -.45 for BRSL(t) with respect to PCF(t-2), where t is measured in months. The latter value is larger than the values obtained in the present study even for the activity HSF(t), which leads once more to the suggestion that there may have been an overstatement of the response.

Results from the demand side of broiler models tend to compare favorably across different studies. For example, the studies by

Chavas (1978), Goodwin and Sheffrin (1982), Hein (1976) and the present study support the claim that pork and beef are substitute products for broilers. From Model 1, the elasticities of broiler demand were estimated to be -.60 with respect to broiler price PBR(t), .17 with respect to pork price PPK(t), .33 with respect to beef price PBF(t) and 1.69 with respect to per capita disposable personal income DPI(t). And, from Model 2, comparable broiler demand elasticities were obtained as -.49 with respect to PBR(t), .16 with respect to PPK(t), .32 with respect to PBF(t) and 1.56 with respect to DPI(t). The broiler price elasticities -.60 and -.49 are comparable to the values of -.53, -.57 and -.77 obtained by Hassan and Johnson (1976), Chavas (1978) and George and King (1971), respectively, for broilers. Also, the income elasticity values of 1.69 and 1.56 are comparable to the value of 1.22 obtained by Goodwin and Sheffrin (1982).

On the basis of likelihood ratio tests, the rationality restrictions for Models 1 and 2 were accepted, while the restrictions for Model 3 were rejected. The planning horizons for Models 1, 2 and 3 were t+0, t+1 and t+3, respectively. Using alternative test procedures, the monthly model by Goodwin and Sheffrin (1982) also accepted the rationality restrictions imposed on the broiler market model. The latter study is a form of Model 1. The study by Huntzinger (1979) did not allow for the test of the rationality restrictions because, as indicated earlier, the model was estimated by the two-stage instrumental variables approach. However, reported

t-values show that the broiler price expectations variable PBR*(t+8) contributed positively and significantly to chick placement in the feeding flock. Recall that Huntzinger's model was based on weekly data, explaining the use of a planning horizon of t+8.

CHAPTER V. NON-NESTED EVALUATION OF ALTERNATIVE BROILER MODELS

Frequently, comparisons between regression models with either non-overlapping variables or different functional forms are of interest. In these cases, the available data can be used to discriminate between the competing models. Two models are said to be nested if one is a special case of the other (Fomby et al., 1984). Conversely, two models are non-nested if neither of them can be formulated as a special case of the other.

This chapter is organized as follows. The non-nested model evaluation literature is first reviewed. This review is followed by an empirical application of the test procedures to the alternative specifications for the broiler model.

Non-nested Evaluations of Competing Models

A simple method of discriminating between two non-nested models is to choose the model with the lower residual variance estimate or, equivalently, the highest adjusted coefficient of multiple determination, R-square. However, it has been argued effectively that the R-square criterion may be of limited use if both models are incorrect. Specifically, this minimum variance criterion (e.g., see Thiel, 1957) has been superseded by the development of procedures for testing among families of distributions (Cox, 1961, 1962).

The Cox likelihood ratio test procedure is based on the so-called N-statistic, which has an asymptotic distribution was formally

derived by Pesaran (1974) and Pesaran and Deaton (1978). The N-statistic is such that a significantly negative (or an insignificant) value favors the null hypothesis. However, a significantly positive N-value favors the alternative specification. Cox's procedures have also been extended to discriminate between linear and log-linear models (Aneuryn-Evans and Deaton, 1980).

Relatively simpler tests, similar in concept, have been proposed by Davidson and Mackinnon (1981) and later extended by Davidson and Mackinnon (1983). These tests, each applicable in different situations, are called the C-test, the J-test and the P-test. Remarkably, the C-, J- and P-statistics are asymptotically equivalent to the Cox-Pesaran-Deaton N-statistic when the null hypothesis is true. This conclusion has been separately reached by all the protagonists of the alternative testing procedures. For example, Pesaran (1982) shows that in small samples the N-statistic tends to reject the true model too frequently. But, as the sample size and the number of non-overlapping variables increases, the power of Cox's test approaches the prediction from the asymptotic theory. White (1982) also shows that Cox's test, if properly implemented, yields one of the Davidson-Mackinnon test statistics directly. Empirical applications of Davidson-Mackinnon testing procedures include studies by Wisley and Johnson (1985) and Husted and Kollintzas (1984).

Since the various testing procedures are asymptotically equivalent under the null hypothesis, the present study applies only the C- and the J-tests. As a preliminary, the essentials of Davidson-Mackinnon

testing procedures are reviewed briefly. Suppose one is interested in testing the truth of the model given by

$$H_o : y_t = f_t (X_t, b) + u_t \quad , \tag{5.1}$$

where t = 1, 2, ..., n and u(t) is normally distributed with mean zero and variance σ_u^2. Let the alternative specification to Eq. (5.1) be of the form

$$H_1 : y_t = g_t (Z_t, d) + v_t \quad , \tag{5.2}$$

where t = 1, 2, ..., n and v(t) is normally distributed with mean zero and variance σ_v^2. Generally, f(.,.) and g(.,.) may be linear or non-linear. The C-test, which is the simplest of Davidson-Mackinnon tests, employs the weighted regression:

$$y_t = (1 - a) \hat{f}_t + a \hat{g}_t + e_t \quad . \tag{5.3}$$

The statistic for testing whether a = 0 is an asymptotic student's t-statistic.

While the C-test is conditional on first estimating parameters b and d, respectively, the J-test allows b to be estimated jointly with a, conditional on $\hat{d}$. Here, the appropriate regression for developing the test is:

$$y_t = (1 - a)\, f_t\,(X_t, b) + a\, g_t\,(Z_t, \hat{d}) + e_t\ , \qquad (5.4)$$

where the t-value corresponding to estimate $\hat{a}$ has been shown to have the asymptotic distribution N(0,1) under the null hypothesis. It is noted here that while f(.,.) may be linear, the regression implied by Eq. (5.4) need not be.

Since the J- and P-tests are equivalent when f(.,.) is linear, the P-test is illustrated with a simple non-linear example. Suppose f(.,.), under the null hypothesis, has the explicit form

$$H_o : f_t\,(X_t, b) = e^{b\,X(t) + u(t)}\ . \qquad (5.5)$$

Let the alternative specification have the simple linear form

$$H_1 : g_t\,(Z_t, d) = d\,Z_t + v_t\ . \qquad (5.6)$$

Davidson and Mackinnon suggest that f(.,.) be linearized about $\hat{b}$. The set-up for the required auxiliary regression facilitating the test is

$$y_t - \hat{f}_t = a(\hat{g}_t - \hat{f}_t) + r\,\hat{H}_t + w_t\ , \qquad (5.7)$$

where

$$\hat{g}_t = \hat{d}\,Z_t, \qquad \hat{f}_t = \exp\,(\hat{b}\,X_t) \quad \text{and}$$

$$\hat{H}_t = \hat{b} \cdot \exp\,(\hat{b}\,X_t)\ .$$

The statistic for testing whether a = 0 is a student's t-statistic which has an asymptotic distribution N(0,1) under the null hypothesis.

Davidson and Mackinnon (1981) add cautionary qualifications to the test procedure for the non-linear models. First, in equations such as Eq. (5.7), $\hat{H}$ may be an intractable matrix rather than the simple vector illustrated above. In this case, the authors suggest the use of the simple C-test. Second, the C-, J- and P-tests are not symmetric for testing H_0 vs H_1 and vice versa. Thus, the roles of H_0 and H_1 must be reversed and the tests repeated if one is to test H_1 against H_0 fully. Using this reversing of roles for H_1 and H_0, there is the possibility for either accepting or rejecting both hypotheses.

Application of Non-nested Test Procedures

In this section, the alternative reduced forms for the equations describing three broiler production activities are derived. The argument is that the biological restrictions on broiler supply and different vertical integration structures may lead to more than one plausible behavioral equation for the production activity. The C- and J-tests are utilized for pairwise evaluations of alternative equations describing broiler slaughter, chick placement in the feeding flock and chick-hatching (for placement in the feeding flock).

Except for slight modifications in notation in the parameter definitions, the following is a reproduction of the broiler supply equations for Models 1, 2 and 3, respectively. These modifications facilitate direct application of the two testing procedures.

Model 1

The supply response structure in Model 1 is the simplest. It includes:

Broiler slaughter:

$$BRSL_t = a_{21} + a_{22}\, PFF_t + \sum_{i=2} f_i\, Q_{it} + u_{it} \qquad (5.8)$$

Chick placement in the feeding flock:

$$PFF_t = a_{31} + a_{32}\, PBR*_t + a_{33}\, HATCH_{t-1} + a_{34}\, PCF_t + \sum_{i=2} g_i\, Q_{it} + u_{2t} \quad . \qquad (5.9)$$

Model 2

The behavioral equations constituting the broiler supply block in Model 2 are Eq. (5.8) and

Chick placement in the feeding flock:

$$PFF_t = a_{41} + a_{42}\, HATCH_{t-1} + a_{43}\, PCF_t + \sum_{i=2} g_i\, Q_{it} + u_{3t} \qquad (5.10)$$

Chick hatching:

$$HATCH_t = a_{51} + a_{52}\, PBR*_{t+1} + a_{53}\, HSF_{t-2} + a_{54}\, PCF_t + \sum_{i=2} h_i\, Q_{it} + u_{4t} \quad . \qquad (5.11)$$

Model 3

The set of equations describing the broiler production activities in Model 3 consists of Eq. (5.8), (5.10) and

Chick hatching:

$$HATCH_t = a_{61} + a_{62}\, HSF_{t-2} + a_{63}\, PCF_t + \sum_{i=2} h_i\, Q_{it} + u_{5t} \qquad (5.12)$$

Chick placement in the hatchery supply flock:

$$HSF_t = a_{71} + a_{72}\, PBR*_{t+3} + a_{73}\, HSF_{t-4} + a_{74}\, PCF_t + \sum_{i=2} m_i\, Q_{it} + u_{6t} \; . \qquad (5.13)$$

The variables in Eqs. (5.8) through (5.13) retain the definitions presented in Chapter III.

To facilitate the non-nested evaluation of the broiler supply structures in Models 1, 2 and 3, partial reduced form equations were derived for each competing specification. For example, Eq. (5.9) was substituted into Eq. (5.8) to obtain the reduced form for BRSL(t) implied by Model 1. Also, by substituting Eq. (5.11) into Eq. (5.10) and substituting the result into Eq. (5.8), the reduced form for BRSL(t), implied by Model 2, was obtained. This was the procedure followed for deriving the reduced forms for the remaining competing

equations in each model. The only notable exceptions are that (i) the linear Eq. (5.9) was simply taken to be the reduced form for PFF(t) in Model 1, (ii) the linear Eq. (5.11) was taken to be the reduced form for HATCH(t) in Model 2, (iii) Model 1 did not have a reduced form for HATCH(t) because the activity is exogenous and (iv) activity HSF(t) was excluded from analysis because the recursive nature of the models made it difficult to formulate a suitable alternative to Eq. (5.13).

Let $X_t(j)$ represent the reduced form for supply activity X as derived for model j, j=1, 2, 3. Then, the alternative reduced forms to be evaluated are

Broiler slaughter:

$$\begin{aligned} BRSL_t(1) = {} & (a_{21} + a_{22}a_{31}) + a_{22}\,(a_{34}\,PCF_t + a_{32}\,PBR^*_t \\ & + a_{33}\,HATCH_{t-1}) + (a_{22} \sum_{i=2} g_i \\ & + \sum_{i=2} f_i)Q_{it} + v_{1t} \end{aligned} \tag{5.14}$$

$$\begin{aligned} BRSL_t(2) = {} & a_{21} + a_{22}\,(a_{41} + a_{42}a_{51}) + a_{22}a_{43}\,PCF_t \\ & + a_{22}a_{42}\,(a_{54}\,PCF_{t-1} + a_{52}\,PBR^*_t + a_{53}\,HSF_{t-3}) \\ & + (a_{22} \sum_{i=2} g_i + a_{22}a_{42} \sum_{i=2} h_i + \sum_{i=2} f_i)Q_{it} \\ & + v_{2t} \end{aligned} \tag{5.15}$$

$$BRSL_t(3) = a_{21} + a_{22}a_{41} + a_{22}a_{42}\,(a_{61} + a_{62}a_{71})$$

$$+ a_{22}\,(a_{43}\,PCF_t + a_{42}a_{63}\,PCF_{t-1})$$

$$+ a_{22}a_{42}a_{62}\,(a_{72}\,PBR*_t + a_{73}\,HSF_{t-7}$$

$$+ a_{74}\,PCF_{t-3}) + (\sum_{i=2} f_i + a_{22} \sum_{i=2} g_i$$

$$+ a_{22}a_{42} \sum_{i=2} h_i + a_{22}a_{42}a_{62} \sum_{i=2} m_i)Q_{it} + v_{3t} \qquad (5.16)$$

Chick placement in the feeding flock:

$$PFF_t(2) = a_{41} + a_{42}a_{51} + a_{43}\,PCF_t + a_{42}\,(a_{54}\,PCF_{t-1}$$

$$+ a_{52}\,PBR*_t + a_{53}\,HSF_{t-3}) + (\sum_{i=2} g_i$$

$$+ a_{42} \sum_{i=2} h_i)Q_{it} + v_{4t} \qquad (5.17)$$

$$PFF_t(3) = a_{41} + a_{42}\,(a_{61} + a_{62}a_{71}) + a_{43}\,PCF_t$$

$$+ a_{42}a_{63}\,PCF_{t-1} + a_{42}a_{62}\,(a_{72}\,PBR*_t + a_{73}\,HSF_{t-7}$$

$$+ a_{74}\,PCF_{t-3}) + (\sum_{i=2} g_i + a_{42} \sum_{i=2} h_i$$

$$+ a_{42}a_{62} \sum_{i=2} m_i)Q_{it} + v_{5t} \qquad (5.18)$$

Chick-hatching:

$$\underset{t}{HATCH(3)} = a_{61} + a_{62}a_{71} + a_{63}\ PCF_t + a_{62}\ (a_{72}\ PBR^*_{t+1} + a_{73}\ HSF_{t-6} + a_{74}\ PCF_{t-2}) + (\sum_{i=2} h_i + a_{62} \sum_{i=2} m_i)Q_{it} + v_{6t} \quad . \tag{5.19}$$

As already indicated, $PFF_t(1)$ and $HATCH_t(2)$ are directly given, respectively, by the linear equations (5.8) and (5.11).

The alternative reduced form equations for the broiler supply activities were evaluated under two assumptions, namely, that (i) the expected broiler price was endogenously determined and (ii) the expected broiler price was exogenously determined. In this way, it was easier to isolate the effects of forecasting the relevant exogenous variables in the structural models on the estimates of the alternative reduced form supply equations. For example, consider the case of the broiler demand equation either misspecified or the exogenous variables describing broiler demand forecasted incorrectly. Then, under fully rational expectations of broiler price, problems inherent in the demand equation would be passed over to the supply block of the structural models.

The reduced form disturbance terms $v_t(j)$ are functions of the structural disturbances in the equations or systems from which the reduced form equations were derived. In practice, the reduced form

disturbances could contain useful information. While noted, investigation of this possibility and associated implications for the tests are left to future research.

Empirical Results with Endogenous Broiler Price Expectations

Results of the C- and J-tests for pairwise comparisons of the alternative derived reduced forms for supply activities BRSL(t), PFF(t) and HATCH(t) are presented in Table 4. The results in Table 4 are based on the sample period 1971:I - 1984:IV, subperiods 1971:I - 1977:IV and 1978:I - 1984:IV, respectively. First, for each of the pairwise tests, the equation listed first is the one assumed "true". For example, BRSL(1) vs BRSL(2) tests the reduced form of BRSL implied by Model 1 against the one derived for Model 2, and so on. Second, results for each pair of tests are presented in two rows, with the first row referring to the C-test and the second to the J-test. Third, the figures outside the parentheses are the estimates of the parameters a, while the figures inside the parentheses are the corresponding t-values.

Consider a cut-off value of 3.00 for the evaluation of the C- and J-statistics in Table 4. This critical value corresponds, approximately, to a standard normal probability level of .001. Beginning with sample period 1971:I - 1984:IV, it is observed that BRSL(1) and PFF(1) are readily accepted over their alternatives from Models 2 and 3. Both the C- and J-tests accept BRSL(2) over BRSL(3). However, these

Table 4. Results of pairwise non-nested evaluations of broiler supply models (endogenous broiler price expectations)[a]

Reduced forms tested	1971:I-1984:IV	1971:I-1977:IV	1978:I-1984:IV
Broiler slaughter:			
BRSL(1) vs BRSL(2)	.01 (.08) .03 (.33)	-.03 (-.30) -.16 (-.204)	-.02 (-.17) .26 (2.13)
BRSL(1) vs BRSL(3)	-.14 (-1.82) -.16 (-2.11)	-.23 (-3.00) -.21 (-2.93)	.05 (.31) .33 (1.73)
BRSL(2) vs BRSL(1)	1.01 (13.88) .99 (39.17)	.93 (9.12) 1.00 (34.82)	1.01 (8.09) 1.05 (22.95)
BRSL(2) vs BRSL(3)	.43 (2.91) .38 (2.99)	.21 (1.29) .42 (2.83)	.69 (2.94) .82 (17.48)
BRSL(3) vs BRSL(1)	1.13 (15.78) 1.14 (24.41)	1.13 (11.37) 1.01 (14.67)	.96 (6.55) .83 (6.89)
BRSL(3) vs BRSL(2)	.57 (4.19) .96 (85.03)	.38 (1.81) .96 (75.76)	.19 (.91) .92 (63.52)
Chick placement in the feeding flock:			
PFF(1) vs PFF(2)	.20 (1.85) .21 (1.95)	.01 (.10) .05 (.37)	.25 (1.84) .44 (2.31)
PFF(1) vs PFF(3)	.02 (.19) .02 (.19)	-.11 (-1.15) -.11 (-1.09)	.25 (1.43) .59 (2.41)
PFF(2) vs PFF(1)	.81 (7.61) .93 (20.85)	.91 (6.78) 1.00 (18.15)	.62 (3.57) .53 (3.78)
PFF(2) vs PFF(3)	-.01 (-.03) .71 (10.92)	-.19 (-.77) .50 (2.28)	.36 (1.52) .96 (25.62)
PFF(3) vs PFF(1)	.98 (10.95) .98 (13.25)	1.03 (9.08) 1.06 (21.79)	.67 (3.77) .47 (3.18)
PFF(3) vs PFF(2)	1.01 (5.84) 1.00 (18.53)	.99 (3.48) 1.00 (24.52)	.57 (2.17) .70 (5.51)

[a]First pair numbers is C-statistics; second pair is J-statistics.

Table 4. Continued

Reduced forms tested	1971:I-1984:IV	1971:I-1977:IV	1978:I-1984:IV
Chick hatching:			
HATCH(2) vs HATCH(3)	-.03 (-.09) -.05 (-.22)	-.30 (-1.06) -.41 (-1.48)	.28 (1.22) .82 (3.75)
HATCH(3) vs HATCH(2)	1.03 (6.06) 1.03 (12.76)	1.12 (3.49) 1.00 (14.89)	.69 (2.89) .64 (3.00)

two test statistics give conflicting decisions for PFF(2) vs PFF(3). While the C-test accepts PFF(2) over PFF(3), the J-test strongly rejects PFF(2). Interestingly, however, both tests reject PFF(3) over PFF(2) in the test of PFF(3) vs PFF(2). In the evaluation of the chick-hatching equations, both tests accept HATCH(2) over HATCH(3) and both tests reject HATCH(3) as an alternative to HATCH(2).

Results of the tests applied to the subsamples are also presented in Table 4. Beginning once again with broiler slaughter activity, the tests BRSL(1) vs BRSL(2) and BRSL(1) vs BRSL(3) are seen to favor BRSL(1) in both subsamples. The only exception is provided by the C-test statistic for the test BRSL(1) vs BRSL(3) which is just equal to the cut-off value of 3.00. However, the test BRSL(3) vs BRSL(1) was strongly rejected against BRSL(3) by both test statistics for both subsamples. Also, in the test BRSL(2) vs BRSL(1), the null hypothesis BRSL(2) was rejected for both subsamples. The test BRSL(2) vs BRSL(3) produced mixed results. While the C-test and both tests accept BRSL(2) over BRSL(3), the J-test rejects BRSL(2). And, the null hypothesis BRSL(3) was rejected in three of four instances in the test BRSL(3) vs BRSL(2).

Turning to the equations for chick placement in the feeding flock, note that the tests PFF(1) vs PFF(2) and PFF(1) vs PFF(3) are both accepted in favor of PFF(1). The null hypothesis PFF(2) was rejected in all instances against PFF(1) in the test PFF(2) vs PFF(1). The same is true for PFF(3) in the test of PFF(3) vs PFF(1). From

Table 4, the results of the tests PFF(2) vs PFF(3) and PFF(3) vs PFF(2) continued to be mixed. However, the bulk of the evidence favors PFF(2).

In the tests for chick-hatching, the results are somewhat mixed, perhaps not unexpectedly, since these tests are only between Models 2 and 3. The C-test and the J-test both favored HATCH(2) in the test HATCH(2) vs HATCH(3), while the J-test accepted HATCH(3). In the test HATCH(3) vs HATCH(2), the C-test and J-test both rejected HATCH(3), while the J-test accepted the latter.

Empirical Results with Exogenous Broiler Price Expectations

The alternative reduced form equations, describing broiler supply activities, were reevaluated under the assumption that broiler price expectations were exogenously determined. The results are presented in Table 5, using the format of Table 4.

With the exception of the J-test in the subperiod 1971:I - 1977:IV, BRSL(1) was generally favored in the test BRSL(1) vs BRSL(2). As for the test BRSL(1) vs BRSL(3), the alternative specification BRSL(3) was slightly favored. However, in the tests BRSL(2) vs BRSL(1) and BRSL(3) vs BRSL(1), BRSL(2) and BRSL(3) were strongly rejected by both test statistics in favor of BRSL(1). As noted in Table 4, the results of the tests BRSL(2) vs BRSL(3) and BRSL(3) vs BRSL(2) continue to be mixed.

For chick placement in the feeding flock (PFF), the specification PFF(1) was accepted over both PFF(2) and PFF(3) in the tests

Table 5. Results of pairwise non-nested evaluations of broiler supply models (exogenous broiler price expectations)[a]

Reduced forms tested	1971:I-1984:IV	1971:I-1977:IV	1978:I-1984:IV
Broiler slaughter:			
BRSL(1) vs BRSL(2)	-.10 (-1.61) -.05 (-.53)	-.16 (-2.31) -.23 (-3.03)	.0001 (.001) .28 (2.60)
BRSL(1) vs BRSL(3)	-.21 (-3.16) -.21 (-2.76)	-.28 (-4.35) -.26 (-3.91)	.001 (.01) .63 (4.82)
BRSL(2) vs BRSL(1)	1.12 (16.50) 1.09 (18.18)	1.02 (9.61) 1.16 (12.77)	1.03 (8.23) 1.05 (23.81)
BRSL(2) vs BRSL(3)	.38 (1.89) .38 (2.28)	.16 (.79) .57 (6.42)	.59 (2.30) .92 (21.11)
BRSL(3) vs BRSL(1)	1.20 (18.92) 1.00 (104.99)	1.17 (11.95) 1.02 (101.10)	1.03 (7.48) .77 (5.41)
BRSL(3) vs BRSL(2)	.55 (3.04) .94 (73.17)	.11 (.53) .96 (79.39)	.34 (1.33) .92 (58.88)
Chick placement in the feeding flock:			
PFF(1) vs PFF(2)	.04 (.44) .16 (1.46)	-.14 (-1.29) -.01 (-.11)	.34 (1.71) .43 (2.32)
PFF(1) vs PFF(3)	-.07 (-.80) -.03 (-.31)	-.17 (-2.09) -.14 (-1.52)	.17 (.99) .74 (2.56)
PFF(2) vs PFF(1)	.97 (9.75) .93 (18.51)	1.07 (8.46) 1.07 (25.61)	.67 (3.91) .62 (5.55)
PFF(2) vs PFF(3)	-.22 (-.96) .72 (8.40)	-.40 (-1.22) .24 (1.65)	.23 (.89) .99 (56.89)
PFF(3) vs PFF(1)	1.07 (13.33) 1.06 (13.59)	1.11 (10.32) 1.08 (29.19)	.77 (4.46) .36 (2.80)
PFF(3) vs PFF(2)	1.17 (5.38) 1.16 (16.45)	1.01 (2.79) 1.00 (14.67)	.72 (2.39) .85 (11.69)

[a]First pair numbers is C-statistics; second pair is J-statistics.

Table 5. Continued

Reduced forms tested	1971:I-1984:IV	1971:I-1977:IV	1978:I-1984:IV
Chick hatching:			
HATCH(2) vs HATCH(3)	-.26 (-1.31) -.05 (-.23)	-.72 (-2.21) -.32 (-1.06)	.24 (1.04) .95 (3.89)
HATCH(3) vs HATCH(2)	1.22 (6.40) .99 (82.05)	1.46 (3.93) 1.00 (22.84)	.75 (3.06) .52 (2.35)

PFF(1) vs PFF(2) and PFF(1) vs PFF(3). Further, both PFF(2) and PFF(3) were strongly rejected in favor of PFF(1) in the tests PFF(2) vs PFF(1) and PFF(3) vs PFF(1). While the results are mixed in the tests PFF(2) vs PFF(3) and PFF(3) vs PFF(2), evidence favored the specification PFF(2) in all samples.

In the test HATCH(2) vs HATCH(3), HATCH(2) was accepted in all samples, except for the J-test in the subperiod 1978:I - 1984:IV. Also, except in the latter subperiod, HATCH(3) was rejected in favor of HATCH(2) in the test HATCH(3) vs HATCH(2).

The overall picture from the subsamples appeared in agreement with results from the entire sample. Except for isolated conflicts between the test statistics, the acceptability of the reduced form equations, which describe the various broiler production activities, increased from Model 3 to Model 1. This observation is generally consistent with the results of the rationality hypothesis tests for the alternative structural models (Chapter IV). Exogenizing broiler price expectations yielded test results (Table 5) which are not significantly different from when the price expectations variable was endogenously determined (Table 4). Thus, the results obtained possibly reflect the degree of specialization in the broiler industry rather than only price expectation formation pattern.

CHAPTER VI. AN EVALUATION OF STRUCTURAL CHANGE

This chapter examines composite forecasts of the price of broilers, PRB(t), and broiler slaughter, BRSL(t), the latter measuring marketed supply for purposes of studying structural change. These variables are common to the three alternative structural models of the broiler market. Thus, the two performance variables, PBR(t) and BRSL(t), embody the market structures implied by each of the models. The three models were formulated recognizing that firms in the broiler industry differ in terms of the broiler production activities they vertically integrate. These variations in activities performed imply differences in the information bases upon which the endogenous variables in each model reside. These alternative forecasts, which reside on different information bases, when combined result in an improved composite forecast. Different weights, through time, on the forecasts from alternative models can be interpreted as characterizing structural change in the broiler industry. The principal objective of this chapter is to develop and estimate these weights as a means of investigating structural change in the broiler industry.

Composite Forecasting with Time-varying Weights

If the underlying information sets are not completely dependent, it is always possible to generate a composite of individual forecasts that performs at least as well as any of the components. To illustrate this result, assume that each of the alternative forecasts

$\hat{y}_i$, i=1, 2, ..., n is unbiased. Then, the convex combination of the alternative forecasts is

$$y = \sum_{i=1}^{n} a_i \hat{y}_i \qquad (6.1)$$

where

$$\sum_{i=1}^{n} a_i = 1, \text{ and } 1 > a_i > 0 \quad .$$

Each a_i, i=1, 2, ..., n, is the "weight" assigned forecast i. Under the assumption that the n individual forecasts are unbiased and multivariate normal, the composite forecast is at least as efficient as any of the components, with a forecast error variance given by (e.g., see Johnson and Rausser, 1982):

$$\sigma_c^2 = \sum_{i=1}^{n} a_i^2 \sigma_i^2 + \sum_{i \neq j}^{n} \sum_{j}^{n} a_i a_j r_{ij} \sigma_i \sigma_j \quad , \qquad (6.2)$$

where r_{ij} is the correlation coefficient between the errors of forecasts i and j, and σ_i is the variance of forecast i. The optimal weights a^*_i, i=1, 2, ..., n can be obtained by minimizing Eq. (6.2), subject to the parameter restrictions accompanying Eq. (6.1).

The foregoing result (Eq. 6.2) is for the case when the composite forecast weights are constant for all observations. However, for structural change evaluations and even more flexible forecasting models, the composite forecast weights can be generated under a time-varying hypothesis. This varying weights hypothesis is important to the test

for structural change. Recall that Model 3 represents the case in which firms vertically integrate the performance of all broiler production activities. Thus, Model 3 is structurally more complete than Models 1 and 2. The proposition to be investigated is that if firms become more fully vertically integrated during the sample period, we expect the weights for the forecasts from Model 3 to increase relative to those for Models 1 and 2 over time.

Time-varying coefficients have been widely studied in econometrics (e.g., Maddala, 1977; Singh et al., 1976). The use of time-varying weights in composite forecasting, for the present study, can be outlined as follows. Let $\hat{y}_{1t}$, $\hat{y}_{2t}$, $\hat{y}_{3t}$ represent the forecasts of variable y(t) from Models 1, 2 and 3, respectively, where y(t) is the endogenous variable of interest, e.g., PBR(t) or BRSL(t). The relevant linear combinations of the three forecasts, allowing for time-varying weights, are

$$y_t = a_{1t}\hat{y}_{1t} + a_{2t}\hat{y}_{2t} + a_{3t}\hat{y}_{3t} + e_t \qquad (6.3)$$

where

$$\sum_{i=1}^{3} a_{it} = 1 \text{ and } 0 < a_{it} < 1$$

and

$$a_{it} = b_{0i} + b_{1i}\, f_i(t) + v_{it} \quad . \qquad (6.4)$$

The random components e_t and v_{it} are assumed to be normally and

independently distributed. The b_{ji}s are the parameters determining weights a_{it}, j=0, 1, while f(t) is a suitable trend function. Two forms of f(t) were tested for the performance variables PBR(t) and BRSL(t). These were the linear and exponential functions

$$f(t) = t \tag{6.5}$$

$$f(t) = \exp(b_{2i} \cdot t),\ i=1, 2, 3\ . \tag{6.6}$$

By substituting the forms for f(t), Eqs. (6.5) and (6.6), into Eq. (6.4), it is possible to reparameterize Eq. (6.3) for the composite forecasts. The generalized estimating equation implied by Eqs. (6.3) and (6.4) can be written

$$y_t = \sum_{i=1}^{3} b_{0i}\, \hat{y}_{it} + \sum_{i=1}^{3} b_{1i}\, f_i(t)\, \hat{y}_{it} + \left[e_t + \sum_{i=1}^{3} v_{it}\, \hat{y}_{it}\right] \tag{6.7}$$

where the reduced form disturbance term is now heteroscedastic. Depending on the exact form of $f_i(t)$, suggested estimation methods for Eq. (6.7) include generalized least squares (GLS) and maximum likelihood (ML) procedures (Singh et al. 1976). While the restrictions on the parameters in Eq. (6.3) are plausible theoretically, they are often difficult to satisfy in practice. Thus, they are often ignored in the estimation of the reparameterized model (Johnson and

Rausser, 1982).

One further consideration is that there may be sufficient grounds to believe that $b_{1i} = 0$ in Eq. (6.4). Then, provided that each individual forecast y_{it} was non-stochastic, Eq. (6.3) may be simply estimated by ordinary least squares (OLS) to obtain the estimates of weights a_1, a_2 and a_3 appropriate to the sample period.

Composite Forecast Weights and Structural Change

As indicated earlier, broiler price and broiler supply variables are common to the three alternative structural broiler market models. Thus, these variables form the basis for evaluating the broiler sector for structural change over the sample period. The relevant individual forecasts of broiler price and broiler supply (restricted and unrestricted) were obtained from the preliminary estimates in Chapter IV. While the sample period for the study was 1969:I - 1984:IV, only the observations for period 1971:I - 1984:IV were simulated because earlier observations were used in lags.

Empirical forms of Eq. (6.7) were estimated using GLS and ML techniques for the linear and exponential forms of f(t), respectively. The results for the time-varying weights a_{it} are presented for the broiler price and broiler supply variables in Tables 6 and 7, respectively. For each estimated function specifying the variational weights, the values in parentheses are the standard errors. Tables 6 and 7 correspond, respectively, to the restricted and unrestricted forms of Models 1, 2 and 3.

Table 6. Estimates of the time-varying weight functions for broiler slaughter and broiler price (restricted models)[a]

	b_{0i}	b_{1i}	b_{2i}
Broiler price			
a_{1t}	-1.934 (1.401)	.039 (.043)	
	.647 (.702)	1.391 (9.684)	-.157 (.175)
a_{2t}	-4.606 (2.671)	.077 (.080)	
	1.969 (1.831)	-1.925 (10.781)	-.203 (.203)
a_{3t}	7.392 (2.711)	-.112 (.061)	
	-1.639 (1.573)	.696 (441.410)	-1.362 (74.813)
Broiler slaughter			
a_{1t}	.257 (.198)	-.004 (.005)	
	.100 (.069)	5314 (10951)	-899.21 (1849.50)
a_{2t}	-14.356 (3.516)	.300 (.092)	
	3333.1 (6889.6)	-3345.9 (6889.7)	-.0001 (.0002)
a_{3t}	14.998 (3.391)	-.293 (.089)	
	-3321.2 (6867)	3334.8 (6867)	-.0001 (.0002)

[a]First set of figures is estimates of parameters for the linear weight functions; second set is estimates of parameters for the exponential weight functions.

Table 7. Estimates of the time-varying weight functions for broiler slaughter and broiler price (unrestricted models)[a]

	b_{0i}	b_{1i}	b_{2i}
Broiler price			
a_{1t}	.266 (.242)	.0005 (.007)	
	.357 (.147)	-.202 (.205)	-.119 (.183)
a_{2t}	.251 (.429)	.0013 (.0011)	
	.182 (.186)	.0002 (.002)	.096 (.112)
a_{3t}	.370 (.363)	-.0029 (.012)	
	-.037 (1.199)	.498 (1.019)	-.012 (.058)
Broiler slaughter			
a_{1t}	1.277 (.261)	-.014 (.007)	
	-.771 (.074)	-98.958 (739.630)	-.825 (.878)
a_{2t}	-.730 (.663)	.019 (.014)	
	.287 (.199)	-.064 (.355)	-.048 (156)
a_{3t}	.439 (.545)	-.005 (.012)	
	-.053 (.192)	.159 (.449)	-.122 (.248)

[a]First set of figures is estimates of parameters for the linear weight functions; second set is estimates of parameters for the exponential weight functions.

The estimates of the parameters giving the time-varying weights were simulated for both linear and exponential forms of f(t) for each a_{it}, i = 1, 2, 3 and for the endogenous variables PBR(t) and BRSL(t). Simulated weights for the first and last two years in the series (i.e., 1971, 1972, 1983 and 1984) are presented for broiler price and broiler supply in Tables 8 through 11. It is recalled that a_{it} is interpreted as the time-varying weight for the forecast of either PBR(t) or BRSL(t) from Model 1, i=1, 2, 3. The estimated weights presented in Tables 8 and 9 correspond to the unrestricted models, while those in Tables 10 and 11 are for the restricted models.

Table 8 shows that for both the linear and exponential estimates of weight $\hat{a}_{2t}$, associated with $\hat{BRSL}_{2t}$, the values appreciated for the sample period 1971:I - 1984:IV. However, both linear and exponential estimates of the weight $\hat{a}_{3t}$, associated with $\hat{BRSL}_{3t}$, depreciated over the same period. The results for the weight $\hat{a}_{1t}$, associated with $\hat{BRSL}_{it}$, are less conclusive. While the linear weight function shows that $\hat{a}_{1t}$ increased over time, the exponential weight function suggests the opposite.

From Table 9, both linear and exponential estimates of the respective weights show that $\hat{a}_{3t}$, which is associated with $\hat{PBR}_{3t}$, declined in value over the sample period. However, both $\hat{a}_{1t}$ and $\hat{a}_{2t}$, associated with $\hat{PBR}_{1t}$ and $\hat{PBR}_{2t}$, respectively, appreciated in value during the same periods. Also, the weights appear to be evenly distributed between $\hat{a}_{1t}$ and $\hat{a}_{2t}$, while both dominated $\hat{a}_{3t}$, especially toward the end of the sample period.

Table 8. Simulated weights for combining broiler slaughter forecasts from Models 1, 2 and 3 (unrestricted)[a]

Year and quarter	Trend (t)	$\hat{a}_{1t}$	$\hat{a}_{2t}$	$\hat{a}_{3t}$
1971				
1	9	1.14 (.71)	-.56 (.25)	.39 (.00003)
2	10	1.13 (.75)	-.54 (.25)	.39 (-.01)
3	11	1.12 (.76)	-.52 (.25)	.38 (-.01)
4	12	1.10 (.77)	-.50 (.25)	.38 (-.02)
1972				
1	13	1.09 (.77)	-.48 (.25)	.37 (-.02)
2	14	1.07 (.77)	-.46 (.25)	.37 (-.02)
3	15	1.06 (.77)	-.44 (.26)	.36 (-.03)
4	16	1.05 (.77)	-.42 (.26)	.36 (-.03)
1983				
1	57	.47 (.77)	.36 (.28)	.14 (-.05)
2	58	.46 (.77)	.38 (.28)	.14 (-.05)
3	59	.44 (.77)	.40 (.28)	.13 (-.05)
4	60	.43 (.77)	.42 (.28)	.13 (-.05)
1984				
1	61	.42 (.77)	.44 (.28)	.12 (-.05)
2	62	.40 (.77)	.45 (.28)	.12 (-.05)
3	63	.39 (.77)	.47 (.28)	.11 (-.05)
4	64	.37 (.77)	.49 (.28)	.11 (-.05)

[a]Figures outside parentheses are linear weight estimates; figures inside parentheses are exponential weight estimates.

Table 9. Simulated weights for combining broiler price forecasts from Models 1, 2 and 3 (unrestricted)[a]

Year and quarter	Trend (t)	$\hat{a}_{1t}$	$\hat{a}_{2t}$	$\hat{a}_{3t}$
1971				
1	9	.27 (.29)	.26 (.18)	.34 (.41)
2	10	.27 (.30)	.26 (.18)	.34 (.40)
3	11	.27 (.30)	.27 (.18)	.34 (.40)
4	12	.27 (.31)	.27 (.18)	.34 (.39)
1972				
1	13	.27 (.31)	.27 (.18)	.33 (.39)
2	14	.27 (.31)	.27 (.18)	.33 (.38)
3	15	.27 (.32)	.27 (.18)	.33 (.38)
4	16	.27 (.33)	.27 (.18)	.32 (.37)
1983				
1	57	.29 (.36)	.33 (.23)	.20 (.21)
2	58	.30 (.36)	.33 (.23)	.20 (.21)
3	59	.30 (.36)	.33 (.24)	.20 (.21)
4	60	.30 (.36)	.33 (.25)	.20 (.21)
1984				
1	61	.30 (.36)	.33 (.25)	.19 (.20)
2	62	.30 (.36)	.33 (.26)	.19 (.20)
3	63	.30 (.36)	.33 (.27)	.19 (.20)
4	64	.30 (.36)	.33 (.28)	.18 (.19)

[a]Figures outside parentheses are linear weight estimates; figures inside parentheses are exponential weight estimates.

Table 10. Simulated weights for combining broiler slaughter forecasts from Models 1, 2 and 3 (restricted)[a]

Year and quarter	Trend (t)	$\hat{a}_{1t}$	$\hat{a}_{2t}$	$\hat{a}_{3t}$
1971				
1	9	.22 (.10)	-11.66 (-10.51)	12.36 (11.35)
2	10	.22 (.10)	-11.36 (-10.26)	12.07 (11.10)
3	11	.21 (.10)	-11.06 (-10.00)	11.78 (10.85)
4	12	.21 (.10)	-10.76 (- 9.75)	11.48 (10.60)
1972				
1	13	.21 (.10)	-10.46 (- 9.49)	11.19 (10.35)
2	14	.20 (.10)	-10.16 (- 9.24)	10.89 (10.10)
3	15	.20 (.10)	- 9.86 (- 8.99)	10.60 (9.85)
4	16	.19 (.10)	- 9.55 (- 8.73)	10.31 (9.60)
1983				
1	57	.03 (.10)	2.74 (1.66)	-1.70 (-.63)
2	58	.03 (.10)	3.04 (1.92)	-1.99 (-.87)
3	59	.02 (.10)	3.34 (2.17)	-2.29 (-1.12)
4	60	.02 (.10)	3.64 (2.42)	-2.58 (-1.37)
1984				
1	61	.01 (.10)	3.94 (2.68)	-2.88 (-1.62)
2	62	.01 (.10)	4.24 (2.93)	-3.17 (-1.87)
3	63	.005 (.10)	4.54 (3.18)	-3.46 (-2.12)
4	64	.001 (.10)	4.84 (3.43)	-3.75 (-2.37)

[a]Figures outside parentheses are linear weight estimates; figures inside parentheses are exponential weight estimates.

Table 11. Simulated weights for combining broiler price forecasts from Models 1, 2 and 3 (restricted)[a]

Year and quarter	Trend (t)	$\hat{a}_{1t}$	$\hat{a}_{2t}$	$\hat{a}_{3t}$
1971				
1	9	-1.59 (.99)	-3.92 (1.66)	6.38 (-1.64)
2	10	-1.55 (.94)	-3.84 (1.72)	6.27 (-1.64)
3	11	-1.51 (.89)	-3.76 (1.76)	6.16 (-1.64)
4	12	-1.47 (.86)	-3.69 (1.80)	6.05 (-1.64)
1972				
1	13	-1.43 (.83)	-3.61 (1.83)	5.94 (-1.64)
2	14	-1.39 (.80)	-3.53 (1.86)	5.82 (-1.64)
3	15	-1.36 (.78)	-3.46 (1.88)	5.71 (-1.64)
4	16	-1.32 (.76)	-3.38 (1.89)	5.60 (-1.64)
1983				
1	57	.27 (.65)	-.23 (1.97)	1.01 (-1.64)
2	58	.30 (.65)	-.16 (1.97)	.89 (-1.64)
3	59	.34 (.65)	-.08 (1.97)	.78 (-1.64)
4	60	.38 (.65)	-.004 (1.97)	.67 (-1.64)
1984				
1	61	.42 (.65)	.07 (1.97)	.56 (-1.64)
2	62	.46 (.65)	.15 (1.97)	.45 (-1.64)
3	63	.50 (.65)	.23 (1.97)	.34 (-1.64)
4	64	.54 (.65)	.30 (1.97)	.22 (-1.64)

[a]Figures outside parentheses are linear weight estimates; figures inside parentheses are exponential weight estimates.

The results in Tables 10 and 11, corresponding to the weight estimates for the forecasts from the restricted models, bear some resemblance to those presented for the unrestricted models (Tables 8 and 9). For example, the linear estimates of $\hat{a}_{1t}$, associated with $\hat{BRSL}_{1t}$, decreased over time. However, the exponential estimate of the latter weight remained constant at its limiting value of .10 over the sample period.

Both the linear and exponential estimates of the weight $\hat{a}_{2t}$, associated with $\hat{BRSL}_{2t}$, suggest that $\hat{a}_{2t}$ increased in relative terms during the sample period. Conversely, the estimates of $\hat{a}_{3t}$, associated with $\hat{BRSL}_{3t}$, were predicted to decrease during the same period. The trend behavior of the weight estimates corresponding to the 'restricted' forecasts of broiler price (Table 11) are very similar to those observed for broiler slaughter in Table 10. The only notable exception was that $\hat{a}_{1t}$, associated with $\hat{PBR}_{1t}$, was predicted to have risen by the linear function, while the estimates implied by the exponential function declined over the same period.

Composite Forecasts

The time-varying weights were used to generate composite forecasts of variables PBR(t) and BRSL(t). Composite forecasts of PBR(t) and BRSL(t) were obtained as time-varying weighted averages of the individual forecasts of these variables from both restricted and unrestricted forms of Models 1, 2 and 3, respectively. For purposes of comparison, time-invariant weights were also obtained by applying

ordinary least squares (OLS) estimation to a simple linear combination of the alternative individual forecasts of PBR(t) and BRSL(t). The specification for this regression is illustrated by Eq. (6.1).

Summary statistics are used to compare the forecasts presented in Tables 12 through 15. These statistics include the mean error of forecasts (M.E.), root mean square errors (R.M.S.E.) and arithmetric means of the forecasts. Using y(t) to represent either PBR(t) or BRSL(t), the alternative forecasts (individual and composite) in Tables 12 through 15 are defined as follows:

$\hat{y}_t(i)$ = the individual forecasts of y_t from model i, i=1, 2, 3,

$\hat{y}_t(s)$ = the composite forecasts of y_t from simple linear combinations of $\hat{y}_t(i)$ using OLS. The weights a_i are time-invariant,

$\hat{y}_t(l)$ = the composite forecasts of y_t using estimated linear weights to combine $\hat{y}_t(i)$,

$\hat{y}_t(e)$ = the composite forecasts of y_t using estimated exponential weights to combine $\hat{y}_t(i)$ and

y_t = the observed vector of y.

The summary statistics in Tables 12 through 15 were based on the sample period 1971:I - 1984:IV, corresponding to 56 observations. Note that the mean error of forecasts (M.E.) is reported mainly to provide an indication on whether the relevant forecasts lie, on the average, above or below the corresponding observed values. This statistic provides only a general indication of forecast performance (Pindyck and Rubinfeld, 1981).

Table 12. Summary statistics for evaluating composite and individual forecasts of broiler slaughter (unrestricted models)[a]

Variable	Mean error	Root mean square error	Variable mean
$BRSL_t$			2513300
$\hat{BRSL}_t(1)$	-5472	48892	2518800
$\hat{BRSL}_t(2)$	-3282	80448	2516600
$\hat{BRSL}_t(3)$	-2387	79573	2515700
$\hat{BRSL}_t(s)$	-2409	44965	2515700
$\hat{BRSL}_t(L)$	61040	51828	2452300
$\hat{BRSL}_t(e)$	2128	43113	2511200

[a]Values are expressed in 1000 pounds.

Table 13. Summary statistics for evaluating composite and individual forecasts of broiler price (unrestricted models)[a]

Variable	Mean error	Root mean square error	Variable mean
PBR_t			42.39
$\hat{PBR}_t(1)$	-26.67	3.62	69.06
$\hat{PBR}_t(2)$	-10.17	3.36	52.56
$\hat{PBR}_t(3)$	14.91	3.55	27.48
$\hat{PBR}_t(s)$	-.095	2.93	42.49
$\hat{PBR}_t(L)$	-.145	2.92	42.54
$\hat{PBR}_t(e)$	.088	2.86	42.31

[a]Values are expressed in cents per pound.

Table 14. Summary statistics for evaluating composite and individual forecasts of broiler slaughter (restricted models)[a]

Variable	Mean error	Root mean square error	Variable mean
$BRSL_t$			2513300
$\hat{BRSL}_t(1)$	81554	58280	2431700
$\hat{BRSL}_t(2)$	4207	77776	2509100
$\hat{BRSL}_t(3)$	- 4694	77661	2518000
$\hat{BRSL}_t(s)$	2068	77566	2511200
$\hat{BRSL}_t(L)$	- 92911	87005	2606200
$\hat{BRSL}_t(e)$	-208880	142420	2722200

[a]Values are expressed in 1000 pounds.

Table 15. Summary statistics for evaluating composite and individual forecasts of broiler price (restricted models)[a]

Variable	Mean error	Root mean square error	Variable mean
PBR_t			42.39
$\hat{PBR}_t(1)$	-.09	3.45	42.48
$\hat{PBR}_t(2)$	-.21	3.51	42.60
$\hat{PBR}_t(3)$	.06	3.65	42.34
$\hat{PBR}_t(s)$	.002	3.41	42.40
$\hat{PBR}_t(L)$	.37	3.10	42.03
$\hat{PBR}_t(e)$	-.003	3.41	42.40

[a]Values are expressed in cents per pound.

The results in Tables 12 and 13 show that the exponential weight function provided the best composite forecast of broiler price PBR(t) and broiler supply BRSL(t). The simple composite forecast $\hat{y}_t(s)$ performed better than the composite forecasts using the linear weight estimates for broiler supply (slaughter). However, a clear choice between these two composite forecasts was not evident for broiler price (Table 13).

In Table 14, the simple composite forecast $y_t(s)$ performed best for broiler slaughter (supply). However, it was not evident from Table 15 which of the forecasts of broiler price (individual or composite) performed best. Note that the mean of all forecasts is only fractionally different from the observed mean of broiler price. However, if one was concerned with decimal accuracy, the composite forecasts of broiler price in Table 15 generally did better than the individual forecasts.

The conclusion from the foregoing is as follows. There is no evidence to indicate that vertical integration of all broiler production activities, as implied by Model 3, is a dominant organizational feature among firms in the U.S. broiler industry. What appears to happen is that firms combine varying numbers of the production activities. This phenomenon in essence suggests that firms in the broiler industry may have moved, over time, away from fully vertically integrated production arrangement toward more specialized ones. However, optimal forecasting of the relevant endogenous variables in the broiler market

must utilize all the different information matrices that are implied by the alternative organizations in the industry.

CHAPTER VII. SUMMARY AND CONCLUSIONS

The study estimated alternative quarterly econometric models of U.S. broiler market subject to two restrictions, biological supply response and rational expectations. While vertical integration prevails in the broiler industry, variations exist in the number of functions performed by individual firms in the industry. This was the basis for formulating three alternative models (designated throughout the study as Models 1, 2 and 3) designed to capture effects of the variations in the organizational structure.

Model 1 assumed that firms vertically integrate chick placement in the feeding flock, broiler slaughter and marketing. Model 2 assumed that firms vertically integrate chick hatching and the activities in Model 1. And, Model 3 assumed that firms vertically integrate chick placement in the hatchery supply flock and all the activities in Model 2. Thus, Model 3 is designated to represent a fully integrated industry. Each model was estimated and evaluated using the restricted and unrestricted reduced forms. Resulting estimates of the structural parameters were, in most cases, consistent with economic theory predictions and statistically significant. Also, lagged and current values of the biological variables in the models contributed positively and significantly to explaining supply response behavior.

Important trends were noted in the behavior of the elasticities of the broiler production activities with respect to feed cost and expected broiler price variables in the three models. There was a

tendency for the elasticity coefficients to decline in absolute values as the broiler slaughter period was approached. In a dynamic sense, this was interpreted to mean that less and less time is available for adjusting to changes in the economic variables as broiler slaughter and marketing period approached. Results from the demand components of the alternative models also suggested that broiler consumption was highly responsive to key economic determinants of broiler demand (e.g., broiler price, pork price, beef price and per capita disposable income).

The rationality hypotheses imposed in the alternative models were tested using likelihood ratio procedures. Based on the test statistics obtained, the rationality restrictions in Model 3 were rejected, while similar restrictions in Models 1 and 2 were accepted. In order to further validate the likelihood ratio results, the alternative equations describing the broiler production activities were evaluated using non-nested hypothesis testing procedures. The results obtained largely complemented the likelihood ratio decisions reported earlier. The relevant non-nested test statistics could not reject the reduced form equations describing broiler supply activities in Model 1 against their competing alternatives in Models 2 and 3. The tests of the reduced form equations in Model 2, against those in Model 3, yielded conflicting results in most instances. However, the evidence favored Model 2.

Finally, the estimated broiler models were used to evaluate potential structural change in the industry. This was done by generating composite forecasts of the two variables (broiler price and

broiler slaughter) believed to reflect alternative broiler market organizations. Composite forecasts of these two variables were obtained using time-varying weight functions (linear and exponential) and time-invariant weights. The composite forecasts of both variables were found to be generally more accurate than the individual forecasts. Also, while the weights associated with forecasts from Models 1 and 2 generally appreciated in value over time, those associated with forecasts from Model 3 decreased during the sample period.

On the basis of the results presented, the following conclusions are drawn. First, available econometric evidence did not indicate that firms in the U.S. broiler industry had a fully vertically integrated broiler production structure. What seemed to have prevailed was that firms combined varying numbers of broiler production activities. Perhaps for managerial and organizational efficiency, firms adopt the latter organization, which implies a diversity of firms carrying on the various functions. Stated differently, available evidence suggests that firms in the U.S. broiler industry may have evolved into more specialized production arrangements of units. However, while it is still not clear which organizational arrangement prevails, optimal forecasting of the relevant endogenous variables in the broiler market requires the use of all the information bases implied by the alternative arrangements in the industry.

Second, provided that the information requirements are met, rational expectations hypothesis offers a promising approach to the

modeling of agricultural commodity systems, even when the relevant planning (expectations) horizons are longer than the current period. Of course, there are no guarantees that the rationality restrictions will always hold. In such cases, simpler but plausible models may be more appropriate. However, with the rationality hypothesis empirically supported, the resulting estimates were at least as theoretically plausible as estimates from models in other studies of the broiler industry incorporating alternative expectational hypotheses.

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ABSTRACT

This work attempts to look at how organisations achieve marketing effectiveness through the marketing mix while focusing attention on PAN. In a dynamic business environment such as Nigeria marketing management must anticipate and adjust promptly to customers demand competitors actions and public expectations by evolving policies and marketing strategies that will make for corporate survival. The socio-economic changes in the society and at work place pose serious challenges to the organisation in general, and the marketing management in particular organisations must be alive to their social responsibilities (or responsiveness) and at the same time they must satisfy customers ever changing taste and that has to be at a profit in order to remain in business.

This research work is aimed at analysing Peugeot automobile of Nigeria (PAN) pricing policy, sales objective, the firms promotional effort in support of products. There is also an ray of the production and distribution policies. It shall also examined how far PAN had effectively applied the marketing mix