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EMPIRICAL ANALYSIS OF AGRICULTURAL COMMODITY PRICES: A PRACTITIONER'S VIEWPOINT ON STRUCTURAL MODELS

Dean T. Chen*

> "Before accepting such counsel of despair, would it be advisable to ... turn away from the grossly aggregative approach ... and begin to analyze the admittedly very complex economic system in more realistic, more detailed terms?" (W. Leontief, 1993, p. 4.)

Modeling agriculture for forecasting and policy analysis has been the focus of my professional career and devotion for more than two decades. My early experience was marked by the agricultural model boom in the 1970s -- a drive for "Econometric Forecasting Moves to the Farm" (Business Week, 1976) and the launch of a first generation on-line and ongoing large-scale Wharton Agriculture Model for real-world forecasting operations (Chen, 1976; Chen, 1981; and Chen, 1982). Since the mid 1980's, I have had another intensive period of model-building and application, emphasizing ongoing policy analyses and impact simulations (Chen, 1987; Chen and Bessler, 1990; Chen and Dharmaratne, 1990; Chen and Anderson, 1991; Chen and Ito, 1992; Chen, August 1992; Chen and Penson, 1993; Chiou, Chen and Capps, 1993; and Chen and Anderson, 1994).

From this rare privilege of real-world modeling experience, I have learned some of the important values and limitations of the structural model in empirical agricultural price analysis. However, I have always found it difficult to provide a purely objective evaluation of the successes and failures of models because of a competing set of performance criteria and a persistent gap between the theoretical and empirical efforts in this field of scientific endeavor.

Recent literature clearly demonstrates such a dilemma. Tomek and Myers (1993), in a review article on empirical agricultural price analysis, suggest that "the cumulative effect" of structural model research "is somewhat disappointing," and that "the optimism of the past must be tempered by the reality of the present." Fair (1993) on the other hand, indicates that structural models generally do better than vector autoregressive (VAR) and autoregressive components (AC) models in complete model testing. Chen and Bessler (1990) also demonstrate the superior performance of a structural model compared to VAR in forecasting monthly cotton prices under policy shocks.

In Tomek and Myers' article, a total of 54 studies are cited, of which 13 are concerned with the general methodological issues of price determination, 22 with supply

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analysis and 19 with demand analysis. Their discussion of price determination focuses upon the recursive, block recursive and disequilibrium models, with reference to the international trade, multi-product partial equilibrium and Computable General Equilibrium models. Many of the referenced studies are not specifically involved with structural modeling work. Few of these research studies give explicit accounts of price determination equations, especially the process by which farm commodity prices are determined in the model.

Much needs to be learned from the past modeling experience. From the theoretical (applied econometrics) perspective, there has been a mixed record of success and retreat. From the practical viewpoint, there has been significant advancement in every aspect of modeling operations: the information, the accuracy of predictions, and the reliability and sensitivity of models. A balanced view on the state of the arts is needed in order that an objective and realistic re-appraisal of applied econometric models be made. Perhaps a methodological re-orientation as suggested by Leontief (p. 4) needs to be considered by agricultural economists, to help analyze the very complex economic system of agriculture in a more realistic and more detailed fashion.

This paper first provides a brief discussion of three new dimensions of modeling requirements, and then summarize from a practitioner's viewpoint the past success and retreat of applied econometrics for on-line and ongoing modeling operations. Next, three important methodological issues involved with the construction and use of structural models for agricultural price analysis are explored: equilibrium and price determination, dynamics and market expectations, and non-linear simultaneous system solutions. The final section of the paper contains concluding remarks regarding future model research and development.

New Dimensions of Modeling Requirement

> "Clearly, the amount of information which this measurement procedure yields is very large -- if only it works! ... But it may be the only way in which new and useful theory can be developed, and this, after all, is the primary purpose of quantitative research." (G. M. Kuznets, p. 1397)

Quality and Efficiency of Information

Model-builders have long been preoccupied with the task of searching for an economic structure as a close approximation to reality, while demonstrating a high degree of negligence toward a key modeling requirement -- the quality and efficiency of information useful for optimal choice of public policy and competitive market decisions in an uncertain environment. Econometric models can be considered as information processing tools, using the existing information to generate new information that potential model users do not yet possess. The implication is that much relevant information and large bodies of microdata are needed to describe the complexities and interdependencies of the agriculture system.

A crucial modeling requirement concerns the type of information, e.g., is it relevant or irrelevant, consistent or inconsistent, partial or total, and imprecise or precise? Information design is central to model design. By emphasizing information requirement and utilization of advanced computer technology, the advantage is evident that large-scale models tend to provide the most effective means for information gathering, processing and delivery. During the years of agricultural model boom, there was remarkable progress in the agricultural data -- in accuracy, timeliness, consistency, comprehensiveness, and sophistication -- a noble extension of the fine tradition of agricultural statistics.

In recent years, a unique new development has been the integrated data and information systems, incorporating data bases with analytical techniques for on-line and ongoing operations. A large-scale model (AGGIES: Agricultural Globally Integrated Econometric Systems) was used as an illustrative example of the integration of two application systems, DSS (Decision Support System) and EIS (Executive Information System), with the data base (Chen, August 1992). This technological frontier contributes significantly to the quality and efficiency of information, pointing to a potential for future model development.

Although the data and computer technology play a crucial role, the most important factor for the improvement of quality and efficiency of information remains the structure and specification of models. A requirement is to construct the model with sufficient points of contact to the existing data source and information flow that have significant influences in agricultural price movement. In essence, the model needs to have direct or indirect ties with the release of government statistics, most notably, pricing information and policy announcements, outlook and situation reports, world supply and demand estimates, weather and crop reports, export commitments and shipments, and macroeconomic and international policy and statistics.

Thus, the key words are information gain. It is important to choose accurate and relevant data as endogenous and exogenous variables, and simulation and policy instruments. By building the institutional reality into a prior formulation of economic relationships, the refinement of data and enhancement of behavioral relationships have proven to be the most effective means to improve model performance in forecasting and policy simulation. The payoff from these factors yields much greater gains in predictive accuracy in models than from more elaborate methods of statistical inference (Klein, 1960).

Predictive Accuracy

Predictive accuracy is the single most important performance criterion of econometric models. Confirmation and replication in empirical econometrics have been criticized as a problem in agricultural economic research (Tomek, 1993). An even more serious problem is the lack of genuine evaluation of the predictive performance of the econometric models. Published models often contain superior but unrealistic predictive results due to the pre-testing bias and a performance evaluation based on historical data within the sample period of observations.

Hildreth and Jarrett (1955) recognized this and were among the earlier researchers that tested the accuracy of future data outside the sample period used for estimation. Predictive evaluation is a multi-dimensional problem requiring a realistic set of performance criteria to confirm the practical usefulness of models. It is important to distinguish between superficial performance, which shows accuracy from ex-post, single-period static and within-sample period conditions, and realistic performance, which demonstrates accuracy from ex-ante, multi-period dynamic and outside-the-sample period conditions (Chen and Bessler).

Particularly praiseworthy, in this respect, is Just and Rausser's (1981) study of commodity price forecasting with large-scale models and the futures market on an ex-ante and multi-period basis. From their testing results presented at the 1979 American Agricultural Economic Association's Annual Meeting, a comparison of various sources of forecasts at the same point in time was tabulated. A ranking of the accuracy of seven commodity price forecasts (wheat, corn, cotton, soybeans, soybean meal, soybean oil, hogs, and cattle) for a horizon of 1 through 7 quarters indicates the following results (rankings are averages for all quarters for all commodities):

1) Wharton	(2.528)
2) Futures	(2.533)
3) Chase	(2.684)
4) DRI	(2.753)
5) Doane	(3.188)
6) USDA	(4.190)

Just and Rausser arrived at the rather pessimistic conclusion that model-based farm price forecasts were not significantly better than futures market quotations. While I raised some methodological issues regarding their testing procedures and the choice of performance standards, I particularly expressed doubts about the use of futures prices as forecasts and the hidden discrepancy in forecasting data (Chen, 1981).

Nevertheless, their testing results suggest that all three large structural models (Wharton, Chase and DRI) gave much better price forecasts than the government agency (USDA) and a leading commodity advisory service (Doane). Since it is commonly thought that the models are unlikely to achieve such a high degree of accuracy, it is a remarkable accomplishment that large-scale structural models were able to predict most, though not all, important price movements better than the government agency and commodity market experts. This superior model performance record seems to have been grossly overlooked by agricultural economists for over a decade.

Predictive accuracy (or inaccuracy) was misconstrued as a deterrent to the development of large-scale econometric models. If accuracy is the criteria for the selection of price forecasts, then it is obvious that all three models should continue to garner support. This, however, has not been the case. This is particularly disturbing for my work on the Wharton Agriculture Model, which outperformed all sources, including the Futures market.

Although forecasting accuracy is the top criterion of an academic exercise, the real world environment actually departs substantially from this standard. An explanation is that commodity price forecasts often provide sensitive and value-laden signals, affecting the interests of special-interests groups and the choice of public policy. My experience in developing AGGIES for policy simulation provides further evidence of the superior predictive performance of models and lack of professional reward for accuracy in prediction.

Reliability and Sensitivity

Widespread skepticism has been placed against the structural model regarding its accuracy in price forecasts. It is not well understood, however, that model forecasts are conditional on specific assumptions on a wide spectrum of exogenous variables, for example from policy assumptions to weather conditions for which the forecaster must carefully assess along the predicted outcome. The accuracy can not be achieved by the model alone and must be simultaneously attained by the forecaster in the preparation of exogenous assumptions and other input into the model.

In fact, the most important function of the model is its role in evaluating alternative scenarios and policy options. The real test of a model is the reliability of baseline solutions and the sensitivity of the model towards the assessment of uncertain weather conditions and changes in policy actions. It is recognized that the reliability and sensitivity of the model depends crucially upon the price specification and the solution methods of the model. Price specification determines the behavioral response patterns of the model. The choice of model solution methods has important implications for ultimate solution outcome.

A critical ongoing concern has been the validity of models as scientific instruments and the objectivity of econometric analysis for policy analysis. Inaccurate baseline forecasts and misleading policy analyses sometimes play a dominant role in the market, influencing producers' production and marketing decisions and the government's farm commodity program implementation. This type of information has cost taxpayers from hundreds of millions to billions of dollars in program payments, causing uncertainty and instability in industry planning and severe financial stress to producers (Chen, March 1992).

Applied Econometrics: A Mixed Record of Success and Retreat

The foundation of structural modeling work has been solidly built in three major areas: 1) the Walras' (1926) general equilibrium framework, 2) the Marshallian (1946, 8th edition) laws of supply and demand, and 3) the Cowles' econometric methods on statistical inference and simultaneous equation estimations (for a historical review, see Epstein, 1987 and Christ, 1994). These three areas have not received equal attention, but each one has played a significant role in structural modeling work.

Walras' general equilibrium and Marshallian supply/demand have been readily adopted in building structural models for farm commodity sectors. These theoretical frameworks have been effectively utilized with little dispute in agricultural modeling work. A historical aberration was marked by the rise and fall of the recursive system and disequilibrium framework which sparked considerable interest in agricultural economists. Regardless of their attractive concept and ease in estimation, these approaches did not provide convincing empirical evidence and useful explanation of observed market behavior (Irwin and Thraen, p. 133).

Cowles econometric methods have had a dominant influence on applied econometric research in agriculture for more than five decades -- an intensive study on the structural modeling problems of identification, estimation, and statistical inference. The pioneering work of Elmer Working (1927) in estimating simultaneous supply and demand equations for the agricultural commodity market dates back even earlier than Cowles' revolution. Working contributed to the basic understanding of the problems of identification (if the supply curve alone shifts, then price-quantity data trace out the demand curve, and if the demand curve alone shifts, the data trace out the supply curve, but not if both curves shift) and simultaneity bias.

In resolving the identification problem, Cowles' contribution on rank and order conditions was naturally adopted by agricultural economists to determine the over-identified and just-identified equations for statistical estimation, and reject the under-identified equations from empirical consideration. The theoretical solution to the over-identification problem led modelers to consider either a priori restrictions on the linear structural parameters or arbitrary nonlinear restrictions on a nonlinear equation system. The over-identifying restrictions have been criticized by Liu (1960) and Sims (1980) on the ground that the simultaneous interactions of economic variables are so pervasive that most structural relationships are not identified (Christ, p. 51). From a practical viewpoint, the over-identifying restrictions may not be a critical obstacle to structural modeling work because of the ready use of unrestricted reduced forms and refined model specifications.

Recognition of the simultaneity bias and development of simultaneous equation estimators have been major intellectual achievements of the Cowles revolution. In the search for consistent and asymptotically unbiased estimators, the Cowles contribution includes a wide range of estimation procedures -- the indirect least squares estimators, the instrumental variable methods, and the maximum likelihood estimators (e.g., FIML, full information maximum likelihood estimator; LIML, limited information maximum likelihood estimator) (Christ pp. 42-44). Several other simultaneous equation estimators were developed in subsequent years, e.g., the two stage least squares (TSLS) by Theil (1953) and Basmann (1957) and three stage least squares (3SLS) by Zellner and Theil (1962).

In the early stage of development of simultaneous equation estimators, the new estimation methods were considered as logical replacements to the conventional ordinary least squares (OLS) method for estimating parameters in simultaneous equation systems, because of their consistency and unbiasedness properties. Simultaneous equation estimators have attracted much theoretical and empirical investigation over time.

Ladd's (1956) experimental study of the sample means and standard deviation of estimates of reduced form parameters of three methods (the least-squares estimates of structural parameters, LIML estimates of structural parameters, and OLS estimates) indicates that the LIML estimates have uniformly smaller variance. However, it was a frequent finding that although the OLS estimates are not consistent, they are quite close to consistent estimators. Many prominent economists questioned the wisdom of using simultaneous equation estimators as OLS estimators often yield similar results in practice.

Empirical evidence from the use of simultaneous equation estimators with Wharton agriculture models confirmed their unsatisfactory performance as compared with OLS. An experimental test of quarterly and monthly Wharton agriculture models was conducted for both sample period and outside the sample period of observations. The ex-ante and multi-period performance evaluation provided pair-wise comparisons of OLS results with Two Stage Least Squares Principal Component (TSLS-PC) and the time series model of Box-Jenkins. The testing results indicated that the OLS method had consistently outperformed the TSLS-PC and Box-Jenkins models.

The Wharton agricultural model experiment was found consistent with the results of a formal simulation study of the Wharton Annual (U.S. Macroeconomic) Model conducted by Preston (1972). On the theoretical ground, a clarification of the conflicting views about the efficiency of forecasts from unrestricted OLS reduced forms and solved reduced forms was given by McCarthy (1972), who demonstrated that the solved reduced form coefficients computed with 2SLS structural estimates do not possess finite variance when the structural equations are overidentified.

Largely due to unsatisfactory empirical results, a return to the conventional application of OLS has become inevitable -- a retreat from structure (Epstein, p. 110). However, a retreat from structural estimation did not trigger a retreat from structural modeling work. In the past two decades, there was a rapid expansion of modeling research and operations, with a brilliant record of success in every aspect of modeling efforts: theoretical knowledge, econometric techniques and systems operations.

Noticeable gains in theoretical knowledge came from several sources: the statistical information of small sample properties (Mariano), a prior knowledge of economic and institutional restrictions (Chen and Ito), the optimal choice of multi-hypotheses and alternative specifications (Chen and Dharmaratne, 1991), the process of market adjustment and equilibrium (Chen and Dharmaratne, 1990), and the dynamics of market expectations.

There were also important advancements in econometric techniques and information systems, in particular, the residual feedback mechanism for simultaneous solution, database, model and information systems integration, interactive simulation and policy analysis, multi-period and multi-frequency modeling methods, and the decomposition of simultaneous system errors. Overall, the simultaneous and equilibrium framework has proven to be the most effective means for modeling farm commodity sectors for practical application.

Three Methodological Issues

> "Alfred Marshall reminded us that both blades of the scissors do the cutting, and that neither supply analysis alone nor demand analysis alone will provide an adequate explanation of what is happening in the economy."
> (Klein, 1983, p. 1)

Past modeling experience suggests three major methodological issues are of utmost importance to the performance of structural models: 1) the market equilibrium hypothesis in describing the functioning of the farm commodity market, 2) the theoretical formulation of expectations with respect to the interaction of supply, demand, and price, and 3) the choice of solution methods for non-linear simultaneous models.

For discussion of these methodological issues, a standard linear simultaneous equations model with expectation variables is given as follows:

(1) $F\,(y_t\,,\; x_t\,,\; y^*_t\,;\; \theta) = \mu_t$

where F is a m x 1 vector of equations, y_t and y^*_t are m x 1 vectors of the actual values and the expected values of the m endogenous variables, respectively, at time t, x_t is a n x 1 vector of the values of the exogenous variables, θ is a matrix of the estimated parameters, and μ_t is an m x 1 vector of disturbances. Let y^*_t denote the forward looking expectations of y_t at time t. The expectation variables contain all relevant information up to and including time t for which a conditional expectation formulation of $y^*_t = E(y_t | \Omega_{t,t+k})$ defines the dynamic process of market expectation at time t given information for t+k periods ahead, and subject to revisions over time until actual realization. The disturbances, μ_t, follow the standard assumptions of distribution independent of the stochastic process generating x_t, a zero mean, a finite variance-covariance matrix, and serial independence.

Based on formulation (1), the structural form of the model can be written as:

(2) $By_t + Cx_t + \Gamma y^*_t = \mu_t$

where B, C, and Γ are matrices of parameters, y_t , y^*_t , x_t , μ_t are actual and expected values of endogenous variables, exogenous variables, and disturbance term.

The equation system can be expressed explicitly as reduced forms, either analytically derived reduced forms using structural estimates, or unrestricted reduced forms as follows.

(3) $y_t = g\,(\mu_t\,,\, y^*_t\,,\, x_t\,;\theta)$

In general, this is a system of simultaneous equations that are nonlinear, stochastic and dynamic. Besides the applied econometric problems of identification and estimation, there are critical methodological issues of model specification and solution. Estimation and identification problems are traditional concerns of applied econometrics. Specification depends to a great degree on economic theory, and the perception of the behavioral process of price determination. Solution methods play an important role in forecasting and policy analysis. Following sections focus upon model specification and methods of solution.

Equilibrium hypotheses and price determination

Given the reduced forms formulation of (3), the basic structure of a farm commodity market model can be described by a system of four subsets of equations, including the key components of price, (4.1); demand, (4.2); supply, (4.3); inventory stocks, (4.4) as follows.

(4.1) $$P = f(Q_i ; X_i)$$

(4.2) $$Q_j = g_j(P; X_j)$$

(4.3) $$Q_s = Q_s(\Pi(P); X_s)$$

(4.4) $$Q_i = Q_s + X_k - (\Sigma_j Q_j)$$

where P denotes price, Q_i denotes inventory demand, Q_j denotes other demand components, and Q_s denotes quantity supply. X_i, X_j and X_s refer to relevant exogenous variables including the expectation endogenous variables in the model. Profit is denoted by $\Pi(P)$ as a function of price, and other exogenous components in the market clearance identity, such as beginning stocks, imports, etc., are denoted by X_k. The size of model can be substantially enlarged by disaggregation. The current AGGIES model, for example, contains nine major crop and livestock commodities and each commodity sector contains a system of 45 to 75 simultaneous equations, providing detailed information for each subset of equations.

Important deviations from the simultaneous and equilibrium framework can be found in the specification of farm commodity market models. Notable examples are the cobweb and recursive models. The model assumes some biological lags between decisions to produce and the realization of output, and that demand depends only on current price and supply depends only on lagged price. If disturbances in each equation are independent at time t, the model is a recursive system. The recursive model has the advantage that the problem of identification is solved and the estimation is straightforward.

The existence of biological lags in agricultural production, the sequential process of decision, the inelastic supply, and the simplicity in estimation are all appealing features of the recursive model. However, the model has failed to generate enough research interest because of its inherent weakness in several areas: the supply fails to reflect the dynamic nature of agricultural production adjustment, the changes in supply through inventory stock adjustment are not accounted for, and the significant influence of other demand components is not considered (Chen and Dharmaratne, 1990, p. 17). A clear implication is that the recursive model does not suffice for effective price analysis.

The disequilibrium framework provides another interesting example. The approach relies upon such assumptions that price responds to the difference between demand and supply (excess demand and excess supply), and that demand and supply do not stay in continuous balance through instantaneous price changes. Continuous clearing and instantaneous price adjustment are crucial economic assumptions of an efficient and competitive market. In simultaneous and competitive equilibrium conditions, inventory stocks are considered as a demand component and treated as endogenous variables in the model, responding to (actual and expected) price changes and playing a pivotal role in adjusting supply and demand.

The equilibrium framework clearly provides a better explanation of commodity market behavior than the disequilibrium hypothesis (Tomek, p. 12). Such a framework has been widely adopted in the specification of farm commodity market models based on the Walrasian concept of equilibrium. The model maintains a high degree of interdependence of supply, demand, and price relationships. The approach tracks farm price movement in a much more realistic fashion than the simplistic use of recursive or disequilibrium models.

A critical methodological issue that merits considerable research is the price determination specification. In applied modeling work, numerous price specifications have been developed. In general, there are two major types of specification: quantity-dependent demand and price-dependent demand models.

In quantity-dependent models, the conventional modeling approach, all supply, demand, and inventory stock relationships are expressed in quantity-dependent forms, with price on the right-hand side of equations. Price is implicitly determined by solving the simultaneous equation system, to achieve supply/demand balance. In linear models, price can be analytically derived in the form of equation (4.4). In non-linear models, the most common form of price specification, reduced form price equations can not be derived due to the difficulty in inverse of parameters matrix, therefore, numerical methods need to be used to solve for price in the implicit form.

The Solution algorithm in SAS (SAS/ETS, p.51) suggests that if price is to be implicitly determined by a specific equation, for example quantity-dependent stock demand, the demand function is given in price-implicit form as

$$P = P + Q_i\,(\,Q_i\,,\,P;\,X_i\,). \qquad (5)$$

When using numerical methods, price can be solved only with a specific demand function (e.g., stock demand) in the simultaneous system. To express the quantity-dependent model in price implicit form, Chen and Dharmaratne (1990) indicate that there are three major types of quantity-dependent (price-implicit) demand functions: domestic demand, export demand, and stock demand.

In price-dependent models, price as the left-hand side variable is considered the inverse demand function. This price specification represents an attempt to normalize a certain demand function for price determination (Adams and Behrman). Therefore, there are three major types of price-dependent (price-explicit) demand functions, depending upon which demand function is chosen for normalization, e.g., stock demand, export demand, and domestic demand. In these models, price is explicitly determined as in the reduced form equation of (4.4). This price specification has the advantage of direct estimation as unrestricted reduced form by OLS, and has been popularly used in applied modeling work.

Empirical results from using different price specifications, quantity-dependent or price-dependent, show substantially different price impacts in forecasting and policy simulation. In search for appropriate price specifications, Chen and Dharmaratne (1991) provide an analytical framework to explain the differential price impact of alternative price-dependent (inverse) specifications in response to a supply shock as follow.

$$(6) \qquad \Delta P = \frac{\Delta Q_s}{K\left(\frac{w_i}{\eta_i} + \sum_j \xi_j w_j\right)}$$

where P and ΔP are price and price impact, Q and ΔQ are quantity of supply and supply shock, ξ_j are price elasticities, and η_i are price flexibilities, w_i and w_j are demand shares, $w_i = Q_i/Q$ for inverse demand, $w_j = Q_j/Q$ for other demands, and $K=Q/P$.

There are two components in the denominator of (6): a term represents the single equation price impact of the model, and the other term represents the feedback effect generated by other demand functions. The single-equation price impact is determined by the inverse of the price flexibility weighted by the demand share of the inverse demand, and the feedback effect is generated by the price elasticities of other demand functions weighted by their respective demand shares. This relationship provides useful insights into the price determination behavior of structural models.

Price specification has received much theoretical and empirical investigation. In agricultural economics literature, a wide range of applications of both quantity-dependent and price-dependent models can be found. Notable examples of price-dependent models include the models by Fox (1957), Cromarty (1959), Houck and Subotnik (1969), Chen (1977), Meilke and Young (1979), Salathe, Price and Gadson (1982), and Westcott and Hull (1985).

Among recently constructed agricultural sector models (Taylor et. al.), FAPRI and AGSIM models are quantity-dependent models, and COMGEM/AGGIES and AGMOD models are price-dependent models. However, few of the listed studies provide a technical discussion of the price determination process, e.g., in price-dependent cases, the choice of a demand function to be normalized; and in quantity-dependent cases, the derivation of analytical reduced forms (linear model) or implicit price forms (non-linear model) used for model solution and the choice of solution methods.

Dynamic Process of Market expectations.

Of all the developments in price specification that led to improvement in model performance, none is more important than the formulation of market expectations. In recent years, numerous approaches have been advanced for modeling expectations in farm commodity market models. Traditional formulations of market expectations, e.g., the naive, extrapolative, adaptive expectations models have not been found useful in practical work. Johnson (1985) particularly expressed disappointment that most of the present modeling approaches utilize backward-looking expectations and suggested that forward-looking expectations be utilized in structural models.

Forward-looking expectations hold the promise of proving the supply and demand interaction and provide more realistic representation of the market equilibrium process for price determination. An important theoretical development in the use of forward-looking information is the rational expectations hypothesis (REH). Muth (1961, P. 316) argues rather convincingly that the dynamic economic models do not assume enough rationality. This provides a basic motivation to the development of REH and the subsequent rich collection of theoretical and empirical studies on this subject.

There are two attractive features of the REH approach: 1) the inclusion of an additional vector of expected endogenous variables and its parameterization, and 2) the use of the model to define the expectations mechanism. Irwin and Thraen (1994, pp 136-37) demonstrate a pseudo-reduced form model to represent the basic REH formulation and its transformation of the problem of forming expectations of the endogenous variables to one of forming expectations of the exogenous and policy variables.

These assumptions provide theoretical appeal and empirical realism in agricultural modeling work. The inclusion of expected endogenous variables has been recognized as an important consideration in farm commodity market models. In the REH model, the expected endogenous variable y^*_t is assumed to be conditional on the set of market information available at time t. The expected forecast errors of y^*_t conditional on any subset of information available when the forecast was made are assumed to be zero.

In AGGIES modeling work, it was found useful to consider a dynamic process of expectations, covering the entire process of expectation formation, revision and realization. This theoretical framework is consistent with the "errors in variables" reformulation given by Muth (Lovell, P. 121-22), allowing the inclusion of additional random elements in the process by which market expectations are generated. It is assumed as in the equation (1) that a conditional expectation formulation is given as,

$$(7) \qquad y^*_t = E(y_t|\Omega_{t,t+k}).$$

denoting a dynamic process of market expectation at time t given information for t+k periods ahead as $\Omega_{t,t+k}$, and subject to revisions over time until actual realization. A novel feature of this formulation is its capability to provide multi-frequency and multi-period interactions of market expectations in practical operations. This approach allows the effective use of high-frequency (e.g, daily, weekly, monthly) market expectations as input into low-frequency (e.g., quarterly, annual) expectations, and single-period (static) market expectations as input into multi-period (dynamic) expectations. High-frequency data was found particularly useful for improving the predictive accuracy of low-frequency (quarterly macroeconomic) structural models and eliminating subjective judgements in economic forecasting. (Klein and Park, P. 307).

The introduction of expectations mechanisms into the model makes it possible to evaluate the implication of one set of expectation endogenous variables on another set of expectation endogenous variables. (The formulation differs from the REH approach which emphasizes the transformation of forming expectations of the endogenous variables to one of forming expectations of the exogenous and policy variables). The dynamic process of forming expectations and tracing their interactions generate useful information for agricultural forecast and policy analysis.

Two successful examples in the use of expectation mechanism in the AGGIES model can be cited: 1) the development of implicit revenue function for farm program analysis, and 2) the development of price-dependent stock demand function for price determination.

The implicit revenue function is a particularly useful mechanism to analyze the implication of changes of expectations of endogenous variables on the outcome of the expectation of other endogenous variables in the model, e.g., the effect of prospective planting survey of planted acreage on crop production and producer's net revenue projection. This expectation transmission mechanism provides a powerful tool for evaluating the supply response behavior and government program costs. This expectation mechanism provides a linkage between farm program instruments and commodity market equilibrium, allowing the use of expectations variables implicitly in the net revenue function and avoiding the multi-collinearity problems.

The dynamic expectation hypothesis provides theoretical foundation in specifying the price equation in the AGGIES model. Applied modeling experience suggests that the price-dependent inventory demand function is an effective choice of price determination specification. The model uses the actual stock-to-use variable (normalized inventory demand), expected and revised stock-to-use variables as key price determinants.

For time-disaggregated models, such as monthly, and for agricultural commodities such as crops, price expectations play an important role in the short term allocation of stocks from period to period. Additionally, price expectations may also have a substantial impact on the demand side since direct consumption would be an economic alternative to carrying stocks over into the next period.

Various ways have been used to model the formation of price expectations. A common practice is to use some distributed lag scheme on current and past values of cash prices or prices in an organized futures market, e.g., the quarterly econometric model for corn by Subotnik and Houck (1979).

There are additional available pieces of information upon which economic agents in the market, both suppliers and demanders, may base price expectations. In particular, one important source is the government outlook survey and official forecasts of crop production, consumption, trade flows data. Monthly or quarterly USDA data on world supply and demand estimates of agricultural commodities are found the most effective forward-looking market expectation data which have strong influence on short-term price movements (See for example, Sumner and Mueller, 1988; Bessler and Brandt, 1992).

Non-linear Model Solution Methods.

It is useful to note that specification and estimation sets a pre-condition for the choice of solution methods. For linear simultaneous equation models, estimated either by structural estimators or OLS, the model is easily solved by its analytical reduced forms. For non-linear models, the most commonly constructed models, there are many different ways in which the model is specified and estimated, and that there are many different choices of model solution methods.

For solving systems of nonlinear simultaneous equations, there are four major approaches most frequently used: 1) linear approximation to the non-linear model, 2) arbitrary use of "price adjustment mechanism" and "solution operators," 3) programming approaches to non-linear model solution, 4) numerical solution methods. Although the first three methods provide a convenient solution to the problem, they do not satisfy the rigorous requirement for a simultaneous system solution when prices are determined at market clearance. Therefore, the numerical analytical technique is the logical choice.

Drud's survey (1983) indicates that the numerical solution methods have been well developed for solving large-scale nonlinear simultaneous models. The Statistical Analysis System (SAS/ETS) provides three numerical solution programs, including Newton, Jacobi and Gauss methods. Newton has the restriction that the model is a differentiable function of endogenous variables. Jacobi and Gauss are derivative-free alternatives to Newton. By using an ordering procedure, Gauss has the advantage of computational efficiency. In applied modeling work, the Gauss-Seidel method (Heien, et. al) has been popularly used because of important advantages to the user than other numerical techniques.

Price specification remains the key factor towards the choice of the solution methods. In quantity-dependent models, all demand and supply functions are specified in quantity dependent forms, and price is implicitly determined in the model by supply and demand equilibrium. For solution purposes, a price-implicit form needs to be selected using a specific quantity dependent demand function, e.g. domestic demand, export demand and stock demand.

In price-dependent models, only one specific demand function, eg. stock demand, domestic demand and export demand is specified as an inverse demand function. This particular price-dependent demand equation is estimated and used for simultaneous equation solution by supply and demand equilibrium. As a result, there are six possible price determination specifications, three quantity-dependent (price-implicit) and three price-dependent (price-explicit) specifications for simultaneous solution.

Alternative specifications of price determination in a structural model show substantially different price response behavior in response to external shocks and policy actions. According to Chen and Dharmaratne's (1991) impact simulation study of six alternative price specifications to evaluate the effects of the 1988 drought on wheat price, price impacts were considerably higher for quantity-dependent models than for the price-dependent models. Testing results suggest that price-dependent stock demand specification generated more credible price outcome than other specifications.

Theoretical investigation of the price determination process and empirical testing of price response behavior to external shocks are needed in order to improve the structural model's capability for practical forecasting and policy analysis.

Concluding Remarks

This paper provides a practitioner's viewpoint of the recent development of structural models for online and ongoing agricultural forecast and policy analysis. The paper attempts to identify some positive experience from the past, explore areas of theoretical and empirical ad hocery, and suggests possible avenues for further modeling research and development.

A historical review of applied econometrics contributions to empirical agricultural price analysis shows a mixed record of success and retreat. There is a remarkable record of achievement in modeling efforts: theoretical knowledge, econometric techniques and practical performance. There is also a retreat in the use of simultaneous equation estimators. It is apparent that attention should be given to the refinement of model specification and operation (online, real-time and ongoing forecasting and policy analysis) rather than mere improvement of parameter estimation precision.

A critical review of the theoretical knowledge of structural models is needed to ascertain gains in several areas: the statistical information of small sample properties, a prior knowledge of economic and institutional restrictions, the optimal choice of multi-hypotheses and alternative specifications, the behavioral process of market adjustment and equilibrium, and the role and dynamic properties of market expectations. Important technical advancements also need to be recognized, especially the model operation, information system integration and performance evaluation.

Real-world modeling experience suggests that three major new dimensions of modeling requirement need to be stressed: the quality and efficiency of information useful for decision making under conditions of risk and uncertainty, the accuracy of prediction in terms of ex-ante, multi-period dynamic and outside-the-sample period conditions, and the reliability and sensitivity of the model in baseline projection and impact simulation of external shocks and policy options.

There is a crucial need to open the structural model black box in order to examine the validity of model as a scientific instrument and objectivity of econometric model for ongoing forecasting and policy analysis. Testing alternative price specifications is an important step in ensuring the validity and objectivity of models.

An unfortunate consequence of continued ignorance about the capability of structural econometric models is the loss of independent and objective models. Innovative and highly accurate models are in need of special sources of funding and support from the public sector to enhance their chance of survival and use for practical application.

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