Chapter 4

DALE A. KNIGHT
Kansas State University

Evaluation of Time Series as Data for Estimating Supply Parameters

THE SUBJECT of this paper calls for appraisal of past regression work in light of: (1) the production structure for agriculture, including not only the interrelations within agriculture but also the relations between agriculture and other sectors of the economy; (2) the institutional, technological, and behavioral complex in which prices are determined and decisions are made; and (3) the effectiveness of the data selected and the methodological formulations employed in reflecting the operation of the above forces and thus, furthering our understanding of the system.

A demand function exists for the aggregate output of the agricultural industry. Some like to study the effects of the level or changes in the level of at least three types of demand. One type results from variations associated with the general level of employment and industrial activity (5). Others are short-run and long-run variations not associated with these measures. Long-run demand variability is related to consumer income, population changes, and consumer tastes. Variations associated with the general level of employment can be explained with National Income type of analysis.

An aggregate supply function for agricultural products also exists. If the function were not shifting, three supply schedules could be traced by plotting prices and quantities which would reflect responses of agriculture to the respective changes in demand described above. We know the shifts have taken place, and this type of analysis would be subject to the identification problem as discussed early by Working (51) and more recently by such writers as Koopmans (36). Causes of supply shifts are highly complex. Alternative hypotheses to explain these changes have been advanced. Various explanations include technology, investment in the human agent, more efficient combination of inputs, increased specialization, reduction of risk and uncertainty, "better" distribution of assets, and assets changing from fixed to variable. Such changes have implications upon the "length of run" as used in the traditional sense.

*Acknowledgment is made of Associate Professor Paul L. Kelley's suggestions for this paper, and of his help in advancing the author's thinking on supply analysis as a contemporary on a study employing another methodology. The assistance of Professor Walter D. Fisher is also appreciated.

Price is determined by the simultaneous interaction of supply and demand forces. In determining agricultural product prices, representations for these forces may not give a too erroneous solution, especially if corrections are made for institutional forces as government demands, controls, etc. As important, if not more so, the "length of run" or effects for elements that are fixed and that are varying must be included in the analysis.

Broad interrelationships can be stated, but the structure cannot be described so simply. Within and as a part of the interrelationship, agriculture is producing not one product but many and using not one resource but many. The structure can be disaggregated down to any level — such as from the industry to regions or to national type-of-farming regions or to states or to state economic areas or to counties on down to firms or even lower. Principles have been outlined which explain how resources are allocated to products in this situation of demands for each product, resource supplies, and prices, and possible substitution among products and resources in production. These apply to any level of aggregation. A full explanation can be made only after the effects of numerous "non-price" factors are included in the study. The family farm is one of the major institutional factors crucial in supply analysis.

Resources are held, changed both for combinations and total quantity, and allocated toward agricultural production by operators of a family farm. The unit consists of a firm and household, maximizing what we have called utility, and which has some, but not fully known, relation to and differences from income maximization (28). This decision-making unit allocates resources to the firm and household. While classical economic principles are guides, accompanying difficulties include imperfect information on prices, technical conditions, institutions and their effects, etc. Change per se involves cost, and these extend not only to decisions on input and output combinations but to levels of both, and to changes in technology. Predictions of supply involve predictions of responses to prices determined at the aggregative level (and possibly other specified changes) in the light of objectives, informational, institutional, and technical problems, costs of making changes, and quantity, quality, and combinations of resources held on these family farms.

With time-series data typically consisting of a number of very limited observations, the problem is to choose a set of representations large enough to realistically describe the real world but small enough to enable estimation of coefficients. With a limited number of observations and often nearly as many variables, the number of degrees of freedom left for error terms often is very limited.

Data available for aggregative time-series analysis are extensive. However, they are subject to inadequacies of a size that requires researchers to restrict their analysis in some cases and probably always to qualify their final results. With most of the data collected for administrative and further reasons other than for research, its inadequacies are not surprising. Excellent discussions of problems encountered in using crop acreage and production data and livestock and feed production data are given by Nerlove (41) and Hildreth and Jarrett (32), respectively.

Although such questions as the accuracy and length of particular series are often troublesome, the main difficulty is that the series are not relevant and logical representations for the effects of the "true" variables. Improperly constructed series may lead to errors or biases. Ladd (38) gives a theoretical discussion of problems of constructing production indexes, while Griliches (19) discusses problems associated with excluding variables and ignoring quality differences in inputs. Schultz (44) discusses the problems of measuring labor, including adjustments for quality, for leisure, for investments in the human agent, changing management, as well as problems of measuring land and capital. Heady (27) suggests the production function as a basis for classifying and aggregating land (and other resources as well). Bradford and Johnson (5) suggest the aggregation of inputs that are perfect substitutes or perfect complements, and that inputs substituting, but not at constant marginal rates, not be aggregated. Nerlove's work in relating "unobserved variables of a theory to variables which can actually be observed" is leading to a methodology which shows promise of providing more realistic representations for farmers' price anticipations (41).

Rules have been prescribed for the statistical analysis of data, e.g., the identification problem and counting excluded variables for a particular equation for simultaneous equations. The compliance with these rules, important as it is, is no guarantee of a meaningful analysis if a priori knowledge and experience are not properly built into the design.

THE INTERPRETATION OF INDIVIDUAL STUDIES

Aggregate General Supply Relations in Agriculture

Girshick and Haavelmo, and Tintner, mainly to introduce the method of simultaneous equations, illustrated their use in deriving simple linear aggregate agricultural demand and supply functions (18, 47). As part of their respective systems, such variables as farm prices and consumer income were interrelated.

Tintner related supply to current farm prices, national income, and a cost factor. His coefficients, derived by the variate difference method, were not statistically significant. He concluded that an index of lagged farm prices might have served better. Girshick and Haavelmo related aggregate farm production to farm prices (endogenous), to farm prices lagged one year (all on an index number basis), and to time. For data for 1922-41, they derived a positive coefficient for current farm prices and negative coefficients for lagged prices and time.

In spite of this beginning and also in spite of hypotheses in the literature, the number of more complex and realistic models constructed and tested have been very limited. Some are reviewed below:

Cromarty's Econometric Model for United States Agriculture

The hypothesized model for which empirical estimates were derived by Cromarty is the most comprehensive model attempted for the agricultural sector (12). While it is tied to the Klein-Goldberger model for the U.S. economy, it interrelates the supply, demand, and prices for 12 farm commodities. The short-run model largely abstracts from resource shifts between the agricultural and nonagricultural sectors, but permits the tracing of short-run changes in either sector on variables related to commodities produced in agriculture. The model included 35 structural equations plus a number of identities (the sample period covered was 1929-53), and with very few exceptions, equations were linear in original values of the variables. Cromarty illustrated the usefulness of the model by tracing effects of a change in the price of feed grains on feed grain production, hog production and price, beef cattle production and price, and the demand for feed grains of commercial, inventory and government types (2).

Without pursuing the power of the interrelated structure further, we may examine Cromarty's representations for variables measuring supplies, demands, and prices, and for variables causally related to them.

The argument for representations of various types was made above. These can be classified into groups: (1) economic, including price expectations, (2) institutional, (3) technological, (4) weather, and (5) resource levels. It appears that the representations for "economic" variables were more reasonable substitutes for the true variables than for most of the other categories. A number of the empirical relations were what would be expected, e.g., the influence of lagged absolute wheat prices on wheat production, lagged wheat-feed grain price ratios on feed grain production, milk and feed grain prices on milk production, hog prices on hog production, lagged egg prices on egg production, lagged broiler prices on the production of poultry meat, lagged soybean-corn price ratios on soybean production, tobacco prices on production, and similarly for vegetables.

The hypotheses on the demand side were not too different from those stated by others, but the reasonableness of the coefficients (size, sign, and significance) was generally disappointing compared to those for the supply relations. Demand was expressed (where appropriate) by dividing total demand into commercial, inventory, and government types. The incorporation of variables such as marketing charges also makes the demand equations more complete.

Results from using such variables as acreage allotments, and government demand for wheat, cotton, feed grain, and tobacco (all representing institutional influences) were good. Variables such as the number of Dairy Herd Improvement Associations and the number of birds in the National Poultry Improvement Plan, included as exogenous variables in the milk production and egg production equations respectively, are presumably representations for the state of technology. The coefficients attached to these variables suggest that the use of representations of this type strengthened the structure. The fertilizer variables used in wheat and feed grain equations may have been intended to be this type of representation. Some would reason, however, that these variables more nearly represent the intensity of use of variable inputs rather than technology.

Nearly all the crop production equations were corrected for weather. The measure was constructed in an attempt to reflect the influence of weather on the production of the specific commodity. A measure of the level of resource use was used as a predetermined variable in many equations, especially those used to estimate the production of livestock products. Examples include the inventory numbers of steers and calves, dairy cows and heifers, sows and gilts, and hens and pullets. For crops, the acreage for the preceding year could be interpreted similarly, as could such measures as numbers of combines.

The inclusion of measures as these add to the meaningfulness of supply functions. With the short-run analyses, these measures allow corrections for fixed resource levels. Then schedules of supply against the set of commodity and variable input prices can be derived, and the structure will hold for various resource levels. Some may object to the linear algebraic form for this context. They might argue that output changes non-linearly relative to changes in the level of these resources. Others might feel that the short-run analysis is inadequate and that the level of these resources is really the crucial variable. They would like to see them as endogenous variables with their level explained, not as a given.

Fox, in estimating the coefficients of what was for this study the parent Klein-Goldberger model, obtained reasonably similar results by the use of least squares regression as were originally obtained by limited information (16). It would be instructive here to gather empirical evidence on the necessity of using simultaneous equations by a further comparison of results from the two methods.

Other Studies of the Feed-Livestock Economy

Hildreth and Jarrett studied the feed-livestock economy where prices, feeds, production, and other data were considered for all classes of livestock as an aggregate (32). Five equations were fitted for data from 1920-49. The length of run again was essentially short, with roughage supplies and beginning inventory of livestock predetermined, but prices and quantities fed of feed grain and protein endogenous. However, the expression of the demand for livestock products equation on a per capita basis made some correction for long-run changes in demand. Other equations fitted were a production relation and three farm decision relations (farmer demand for feed grain and protein feed, and supply of livestock products), all linear in logarithms, in contrast to linear in values of variables as by Cromarty. The separation of the technological and behavioristic equations also distinguished the two analyses.

Their quest for a representation for anticipated prices did not uncover a variable in which the authors could place much confidence. In explaining livestock sales by current livestock prices, they derived a negative elasticity. They also found that livestock sales were positively related to the amount of livestock produced, the price of feed grain, farm wages, and beginning inventory numbers, and negatively related to the price of protein as well as the current price of livestock.

They were unable to find a variable to use to reflect the effects of changing technology in the industry although they made an empirical trial subsidiary to the main analysis. Less attention was shown for fixed assets such as equipment inventory. These differences, with the difficulties with price anticipations, describe the principal dissimilarities in handling difficulties with price anticipations and in handling different representations in the two studies. Feed grain production was determined in the Cromarty model, while in the Hildreth-Jarrett study, the equation was not complete because some variables could not be specified.

Their formulation does not give easily interpretable supply relations. The discussion of steps in building models, of problems inherent in the data, in the statistical procedures used, and the consequent interpretation given the final results, are all outstanding.

Foote's study is further analysis of the feed-livestock economy, where feed and livestock were likewise aggregated (15). Variables used, with data for 1922-42, were:

C = Price received by farmers for corn, cents per bushel.

S = Supply of all feed concentrates, in million tons.

A = Number of grain consuming animal units fed annually, in millions.

L = Price received by farmers for livestock and livestock products, index.

Q = Production of livestock and livestock products for sale and home consumption, index.

I = Personal disposable income, in billion dollars.

Using first differences of logarithms, coefficients were derived by least squares as follows:[1]

[1] Numbers in parentheses below coefficients on this and succeeding pages are standard errors for the regression coefficients.

(1) $$\Delta C = .00373 - \underset{(.24)}{2.36\Delta S} + \underset{(.57)}{1.94\Delta A} + \underset{(.18)}{1.13\Delta L}$$

(2) $$\Delta A = -.092 + \underset{(.040)}{.214\Delta S} - \underset{(.032)}{.185\Delta C} + \underset{(.036)}{.207\Delta L}$$

(3) $$\Delta Q = .00369 + \underset{(.090)}{.562\Delta A}$$

(4) $$\Delta L = .00578 - \underset{(.25)}{2.08\Delta Q} + \underset{(.08)}{1.45\Delta I}$$

In equation 2, the interpretation of the coefficient of ΔL is that for a 1 per cent change in L, A changes in the same direction by .207 per cent. In equation 3, a 1 per cent change in A results in a change of .562 per cent in Q. The effect of a 1 per cent change in price on sale of livestock equals (.207) x (.562 or .116 per cent), the supply price elasticity.

Although the author recognized the influence of technology on Q (and illustrates the influence on a flow diagram), the influence of this variable was not imposed on equation 3.

Hogs

Dean and Heady estimated a set of elasticities for the United States and north central region for 1924-37 and 1938-56 (13).

The authors concluded that most of the elasticity in hog production came from changes in the number of litters. They described changes in the industry that led them to hypothesize that the supply-price elasticity increased between time periods, especially for the north-central region. The hypothesis was not rejected for both the study of number of farrowings and weight of animals marketed.

Cromarty derived a short-run elasticity estimate of .130 (12). For the length of run implied by his equation, his estimate and those of Dean and Heady are not inconsistent. Where liveweight slaughter was related to hog prices and production of feed grains (year t + 1) (both endogenous variables in his model) and to the available supply of feed grains and January 1 inventory of sows and gilts (both predetermined), his model is more short-run than Dean and Heady's model explaining the number of spring farrowings but is less short-run than their within marketing period analysis. It is not clear how fall-farrowed pigs sold within the year will enter the Cromarty model. They too could be in a January 1 inventory measure. Likewise, another group will be farrowed within year t but will not be sold until year t + 1. The treatment of feed grain production, year t + 1 as endogenous, seems to be a realistic representation for an industry in which the production of hogs and corn is simultaneously determined. That is, the production of hogs is a function of, among other factors, corn supplies and prices.

	United States		North Central Region	
	1924-37	1938-56[2]	1924-37	1938-56[2]
Spring farrowings				
Expected price model	.46	.65	.53	.73
Equations 1 to 4	.50	.60	.58	.69
Fall farrowings[3]				
Equations 5 to 8	.28	.30	.41	.35
Within marketing period				
Aug. 1 - Feb. 1	.04	.08	---	---
Feb. 1 - Aug. 1	.05	.07	---	---

For equations 1 to 4, first differences in number of spring farrowings (December, year t-1 — May, year t) were explained by hog-corn price ratio, October-December, year t-1, by first differences of oats, barley, and grain sorghum production as a percentage of corn production, ratio of stocker and feeder cattle to hog price, October to December, year t-1 (for early period) and deflated margin between price of feeder cattle and slaughter cattle, October to December, year t-1 (for later period).[4]

For equations 5 to 8, number of fall farrowings were explained by the number of spring farrowings, hog-corn ratio, October to December, year t-1, ratio of price of slaughter steers to price of corn, March to June, year t, production of oats, barley, and grain sorghum (for later period) and by change in corn production from year t-1 to year t (for the earlier period). For the expected price model, the number of spring litters was explained by lagged hog-corn and beef-hog price ratios and lagged number of spring farrowings.

For the within marketing period equations, total liveweight of hogs slaughtered was determined from a supply and demand set of simultaneous equations. The supply equation, Q, (slaughter) was related to the price of hogs (August 1 to February 1 for spring farrowed pigs and February 1 to August 1 for fall farrowed pigs) and a set of predetermined variables affecting hog supply. For the demand equations, prices were related to slaughter and per capita, deflated, disposable personal income.

Similarly, corn production is a function, among other factors, of prospective profits from the hog enterprise.

In explaining total hog production, with a logarithmic function for data for 1924-51, Williams and Sherman achieved somewhat different results (50). For independent variables, all predetermined, they used:

X_1 = spring pig crop previous year.

X_2 = fall pig crop previous year.

X_3 = breeders intention regarding current spring pig crop.

[2]Omitted war years.

[3]Periods 1924-36 and 1937-56.

[4]The theoretical model conformed to the cobweb theorem.

X_4 = corn supply previous year.

X_5 = hog-corn price ratio previous September-December.

They derived estimates of coefficients as follows:

$$Y = 9.331X_1^{.1741} X_2^{.3886} X_3^{.2334} X_4^{.0592} X_5^{.0162},$$

where the standard errors for regression coefficients were .1230, .0674, .0921, .0729, and .0586, respectively.

For their set of independent variables they found total production explained by the fall crop of the previous year and breeder's intention regarding the current spring pig crop, while such variables as corn supply and the hog-corn price ratio did not influence production significantly. The influence of corn supply and hog-price ratios on the spring pig crop, as determined by Dean and Heady, necessarily implies an intercorrelation between X_4 and X_5 with X_3 and a consequent difficulty in detecting separate effects for the variables. It is likely that the influence of X_4 and X_5 was carried by X_3.

Cochrane's informal estimate of the short-run supply elasticity was .8 to 1.0 (9), which is fairly close to the measures derived by Dean and Heady (.46 to .73) for the number of spring farrowings. Cochrane (10) also derived an elasticity of .309 for farmers' intentions to produce spring pigs (data for 1921-56) where the number of sows farrowing, December, year t-1 to June, year t, was explained by hog prices, July through November, year t-1 and by corn prices, September through November, year t-1. Respective coefficients were positive and negative in sign, as would be hypothesized.

Beef

Research workers have probably had more difficulty deriving meaningful and realistic supply-price elasticities for beef than for any of the other commodities. The main difficulty, discussed by Hildreth and Jarrett (32, p. 104) and by Ladd (37) for livestock as an aggregate and by Wallace and Judge (48) for beef, seems to be that as prices increase (decrease), farmers hold back (dispose of more rapidly than normal) animals for breeding purposes, which causes further price movement in the same direction, and in which considerable time elapses before the real supply response, to the original price, reaches the market.

Wallace and Judge derive formulations which they call "supply of beef at the farm" and "supply of beef at retail." The authors explain the amount of farm production of beef as a function of time, number of cattle on feed, number of beef cattle and calves not on feed plus the number of dairy cows, and the production of corn for livestock. For a function linear in logarithms (data for 1925-55), coefficients derived by least squares were all positive.

For a function involving number of cattle slaughtered as dependent, a positive coefficient was derived for lagged price of corn and a negative coefficient for the lagged price of beef. This, the authors agreed, seemed opposed to theory. More meaningful results with supply-price elasticity implications were derived by explaining the weight of cattle slaughtered by a lagged price of beef, the production of corn for livestock, and the lagged weight of cattle marketed. All coefficients were positive, and here the supply price elasticity was .043. Cromarty derived an elasticity of .037 (12). These estimates appear unreasonably low; in fact, Cochrane believed the true elasticity might be .6 to .8 (9).

Milk

For his milk production equation, Cromarty (12) derived coefficients as follows:

$$Y_{41} = 198.188 + \underset{(.212)}{.869Y_{42}} - \underset{(.028)}{.116Y_{22}} + \underset{(.285)}{.598Z_{43}} + \underset{(.708)}{1.969Z_{44}} + \underset{(.510)}{2.425Z_{45}}$$

where

Y_{41} = production of milk in million pounds.

Y_{42} = price of milk in cents per hundredweight.

Y_{22} = price of feed grains (1910-14 = 100).

Z_{43} = number of Dairy Herd Improvement Associations operating on January 1, x 10.

Z_{44} = pasture condition as per cent of normal.

Z_{45} = January 1 inventory of cows and heifers, two years old or over, in hundred thousand head.

The coefficients were derived by the limited information method, with the coefficients for the Y's mutually determined by the system, while the Z's were regarded as predetermined variables. All the coefficients are acceptable. An increase in milk production can be predicted from an increase in milk prices and/or a decrease in the price of feed grain, a relation expected on a priori grounds. These are short-run responses, with technology, roughage supplies, and dairy cow numbers represented by Z_{43}, Z_{44}, and Z_{45}, respectively. These would become variable in a longer run, but here they are regarded as fixed.

The assumption that the Z's are not affected by the other variables might be difficult to argue. For example, changes in the number of cows milked might be explained to some extent by the milking (or allowing to nurse calves) of dual purpose cows on the margin. A large number of cows may be milked when price relationships are favorable, but not under other circumstances. Those who feel that the number of cows is the crucial variable explaining milk production will be disappointed with the short-run model and will be more interested in the results from use of a longer-run model in which this variable is endogenous.

Halvorson (using data for 1931-54) in a short-run analysis with a correction for cow numbers, pasture condition, and hay production, found that a 1 per cent change in the milk-price feed ration was associated with changes in milk production per cow per day (United States data) of .029 per cent during summer months and .135 per cent during winter months (24). He also found some evidence that farmers adjust grain feeding more in response to price increases than decreases.

A later study, encouraged by Nerlove's developments (with data for 1927-57 and for 1941-57) related milk production to a deflated lagged milk price and time, and successively added the variables milk production the previous year, total hay supply, supply of total concentrates, beef price, and hog price (25). As the number of independent variables was increased, he studied not only the coefficients and standard errors, but R^2, the coefficient of adjustment, and the short- and long-run elasticity. For the 1927-57 data, the supply elasticities for the alternative regressions were roughly .16 and .40 (but with data for 1941-57) the short- and long-run elasticities were both considerably lower for formulations including beef and hog prices. For formulations excluding these prices, he believed he detected evidence that farmers were more price responsive in the late period (elasticities of .286 and .526), compared to .157 and .398, short- and long-run elasticities respectively for 1927-57, which compares with the .212 estimate of Cromarty (12). The role of the price of beef toward explaining milk production was considerably greater during 1941-57. To the extent that the findings are valid, this represents a considerable change in structure. In an analysis, by years of rising and declining milk prices, he obtained the surprising results that the supply elasticity was greater (although not significantly) for years of declining prices.

Although the analyses of both led to results from which elasticities could be calculated, there were important methodological differences between the two studies. In the Cromarty model, milk and feed prices were endogenous variables, while for Halvorson's (25) single equation model, the price of milk and supply of concentrates were independent. Cromarty used variables for cow numbers and technology (to the extent that Z_{43} represented it). Halvorson used lagged milk production and prices for competing products in farm production.

Cochrane believes that the short-run elasticity for whole milk lies between .3 and .4 (9), but with quarterly data (1947-56), he derived a price elasticity of .030 where milk production by quarters was dependent, while milk prices and dairy ration prices (average for current and preceding quarter), annual production, and quarterly cow numbers were independent (10).

It is believed that the variables representing the effects of federal order markets are important omissions in these formulations. Also, the industry has made substantial changes since much of the data used in the analysis above were obtained. Farmers are investing in bulk tanks, pipeline milkers, and walkthrough milking parlors. It is anticipated that these developments, along with increased specialization and larger herds, will lead to marked structural changes for this industry.

Eggs

Where Y_6 is an estimate of the log of the index of per capita supply of eggs (for data for 1921-50), Judge (35) derived coefficients for an egg supply equation where other variables endogenous (Y's) and exogenous (Z's) were:

Y_5 = log of the index of prices paid to farmers for eggs, deflated by the cost of living index.

Z_4 = same as Y_5, lagged one year.

Z_3 = time.

Y_7 = log of the index of prices paid to farmers for meat, deflated by cost of living index.

Z_5 = log of index of cost of the poultry ration.

Z_6 = same as Z_5, lagged one year.

The estimated equation (in logarithms) was

$$\begin{aligned} Y_6 &= 1.6727 + 1.1659Y_5 + .2298Z_4 + .0018Z_3 \\ &\quad + .5438Y_7 - .9748Z_5 - .7769Z_6, \end{aligned}$$

where, of course, the price elasticity of supply was 1.1659 for current prices and .2298 for lagged prices.[5]

Cromarty, relating egg production to the price of feed grain (endogenous) and to the number of birds in the National Poultry Improvement Plan (NPIP), January 1 inventory of hens and pullets, and the price of eggs December 15 of the previous year, all predetermined, derived an elasticity of .298 (12). These equations had elasticities about equal to and less than, respectively, the range of 1.0 to 1.2 presented by Cochrane. Both were determined by simultaneous equation methods, are an

[5] Estimates of coefficients, where a reduced form model was used, were:

$$\hat{Y}_6 = .3608\,Y_5 + .3033\,Z_4 - .0095\,Z_3 + .5375\,Y_7 - .4401\,Z_5 - .5397\,Z_6 + 1.6158$$

and by least squares,

$$\begin{aligned} \hat{Y}_6 = \underset{(.1674)}{.1924\,Y_5} + \underset{(.1441)}{.5295\,Z_4} + \underset{(.0287)}{.0743\,Z_3} + \underset{(.1280)}{.0149\,Y_7} + \underset{(.1523)}{.0067\,Z_5} - \underset{(.1538)}{.3956\,Z_6} + 1.3006. \end{aligned}$$

These alternative derivations are examples of instability of estimates relative to estimating procedures.

interesting contrast. Judge made a correction for long-run changes in demand by stating supply in per capita terms. He allowed for the influence of competing commodities in production with variable Y_7, although the sign of the coefficient is unexpected. He also allowed for the influence of the current price of eggs.

Cromarty, on the other hand, made some correction for changing technology, to the extent that the number of birds in the NPIP represents the change. He also corrected for the number of layers with his January 1 inventory of hens and pullets. This omission in the Judge model makes the interpretation of the length of run difficult.

An additional study of the demand, supply, and price structure for eggs was published by Gerra (17). On the supply side, annual egg production was established as the product of size of laying flock and output per layer. The size of laying flock was determined by the rate of mortality and January 1 inventory of hens and pullets on farms (predetermined), by the number of layers sold (determined by egg and feed prices), and by the number of pullets started from January to June (determined by egg and feed prices for the same period). Output per layer was also determined directly by the same variables, but rate of a lay during the January to June period was assumed independent of egg and feed prices during that period. The influence of these prices was hypothesized to influence only the number of replacement pullets raised.

Estimates of supply — egg price elasticity — were not possible from this study. Other estimates presented were supply elasticity with respect to (a) the price of poultry ration, less than -.05 and -.3, (b) supply elasticity of pullets raised with respect to the egg-feed ratio, January to June, .40 to .44, and (c) the supply elasticity of layers sold with respect to the egg-feed ratio, annual average, -.40 to -.67.

It is believed that the method of handling feed and egg prices, inventory numbers, and changes in hen numbers in this study is realistic and leads to short-run relations more readily interpretable than some other treatments. The results must be interpreted as short run. Effects of more long-run factors as changes in population, tastes, etc. on the demand side and changes in technology (although drawn on the flow chart) on the supply side are omitted.

A further econometric study of the poultry industry was contributed by Fisher (14). Both deflated and nondeflated values were used for the price variables for a sample period 1915-40. Fisher estimated parameters for both a farm supply of eggs and farm supply of chickens against these variables. His short-run elasticity estimates for eggs ranged from -.11 to .217 and for chickens from -.18 to .31. Relating current quantities to lagged quantities and lagged prices, he derived long-run elasticities with respect to own price of 2.17 for eggs and .26 for chickens.

Cromarty's estimate of poultry meat production, explained by the price of feed grain (endogenous), the inventory of hens and pullets, index of poultry equipment, and lagged price of broilers (all predetermined) yielded an elasticity of .678 (12).

Price Expectation Models

An objective of Nerlove's work has been to provide more suitable representations for expected prices (41). By relating planned output (acres in most of his studies) not only to lagged price (deflated by prices received) but to lagged production (acres in his formulations), and in some cases to time, he obtained results he believed superior to earlier estimates based upon static analysis, where lagged production was omitted.

In a statistical sense, he found increased values for R^2, no positive serial correlation of residuals, and a reduction of importance of the trend variable for his dynamic model relative to the traditional method of acreage on lagged price regression. The short-run supply price elasticities were generally larger and more reasonable, he claims, although others might view them as being too high.

His early work concentrated on the expected price representation; and, by not allowing for the effects of other variables and possible simultaneity, his equations have been necessarily incomplete. A full appraisal of his advancements cannot be determined until more realistic models are studied. Some of the crop production equations of Cromarty (lagged price and lagged acreage variables), models of Halvorson explaining milk output, models of Dean and Heady for hog supply, and of Griliches on fertilizer demand were other examples of studies using essentially this procedure.

The representation would also be strengthened by empirical evidence of use of models of that type by farmers. The work of the Interstate Managerial Study indicated that farmers use price expectation models of a broad economic nature more and statistical models less than many had believed. The method would be strengthened by further economic interpretation. Ladd (37) did not believe the model would be appropriate as a representation for livestock prices, Brandow (6) expressed concern over the omission of variables, and Halvorson's experience was cited (25). Knowledge of a system's structure would be increased if effects carried by the adjustment coefficient associated with lagged output could be tied with changes in variables with more structural meaning.

Corn and Feed Grains

Nerlove's elasticity estimates were .09 and .18 for corn (40), and Cochrane's informal estimate was between .2 and .3 (9). Cromarty's estimate for feed grains was .430 (12). It is improbable that the effects of technology (hybrid seed, machinery, etc.) have been removed, and it is unlikely that the elasticities represent pure responses to price.

Wheat

For the Cromarty (12) model, the wheat production equation, derived by least squares, was

$$Y_{11} = -105.181 + \underset{(3.161)}{5.467Z_{13}} - \underset{(.518)}{.370Z_{12}} + \underset{(1.076)}{3.711Z_{14}} + \underset{(.909)}{2.632[Y_{12}]_{-1}}$$

where

Y_{11} = wheat production, in million bushels.

Z_{13} = seeded acreage of wheat for the previous year, or announced allotments when in effect, in million acres.

Z_{12} = fertilizer applied in North Dakota and Kansas, in thousand tons.

Z_{14} = index of weather influence in wheat areas (1943 = 100).

$[Y_{12}]_{-1}$ = higher, of price of wheat for the previous year or current year support price, in cents per bushel.

This equation represents both behavioristic characteristics of producers and technological characteristics of the wheat producing areas. For this reason we do not learn as much about the structure of the underlying relations as we would like.

Using New Zealand data for 1920 to 1953, Candler (8) explained wheat acreage (X_a) with the following variables:

X_b = wheat price, lagged or announced price.

X_c = fat lamb price.

X_i = red clover acreage.

X_j = number of rainy days at wheat planting time.

X_k = last year's wheat acreage.

The equation derived was

$$X_a = 155.0 + \underset{(0.165)}{0.269X_b} - \underset{(0.032)}{0.108X_c} - \underset{(0.079)}{0.145X_i} - \underset{(2.334)}{3.246X_j} + \underset{(0.167)}{0.507X_k}$$

Competitive crops were believed to be lambs and red clover, and a large value of X_j was hypothesized to make seeding difficult and to result in a reduced wheat acreage. Candler encountered a high degree of intercorrelation among his independent variables and expressed difficulty in using the equation for prediction if their interrelationships change in the future. The coefficient for the wheat price variable was significant at only the 63 per cent probability level, and he indicated there was no relation between his wheat price variable and acreage for the period beyond 1924.

Estimates of short-run supply price elasticity for wheat vary from near zero to .93. Bowlen (3), with regressions of first differences of acreage on first differences of lagged wheat prices, found the elasticity near zero (not different from zero statistically) for nine western Kansas counties and .315 for 44 eastern Kansas counties.[6] Nerlove (40), using data for 1909-32, derived an elasticity of .47 for acres seeded against a lagged deflated price and .93 by adding lagged acres as a variable. Cromarty (12) derived .370, and Cochrane indicates that the figure might lie between .1 and .2 (9).

One could safely assume that the true elasticity lies between the extreme estimates. From past estimates, we probably cannot make very accurate statements about the wheat supply-price elasticity. It is not likely that effects of technology, weather, reduced risks, etc. have been separated from the price effects.

Important changes in technology have been adopted in the wheat producing areas. The adoption of summer fallowing, methods of lessening soil blowing, purchase of new machinery, etc., have been at a time when the price of wheat was higher. The measures are not only correlated, but there is some causation (adoption during and following high prices). It is reasoned that part of the production response is explained by price per se and partly by the attending related developments, and that the elasticity estimates are probably biased upward. A decline in wheat prices would, in all likelihood, not be accompanied by a reduced level of use for some of these inputs or a readoption of the old cultural practices; in that sense the equation would not be appropriate for the irreversible portion of the supply curve.

It is believed that the short-run models neglect some longer-run factors at work on both the supply and the demand side for such factors as population changes, although Cromarty used a time variable in some demand equations to allow for changes in tastes. It may be that no correction has been made for some of these influences and that the resulting structure is a hybrid, influenced both by variables that are part of the system and others that were not specified.

Tobacco

After analyses of both a statistical and graphical nature, Johnson generalized that United States underplantings of burley tobacco acreage tend to "decrease around one thousand acres for each one cent increase in the real price of burley" (lagged one year, deflated by an index of prices paid) (33). In his same work he analyzed the effects of penalties on overplanting and of change in allotments. This is not only an illustration of the inclusion of representations for the effects of institutional arrangements (here penalties and allotments) in the analysis, but is

[6] Data for 1926-52, omitting 1938-43 and 1950.

further an example in which attention is pointed to unexplained variations in the dependent variable and consequent implications toward interpreting the results.

In another formulation, he offered an explanation of yield changes for the years 1935-49, where Y_1, United States average yield, was related to exogenous variables.

X_2 = logarithm of the lagged season average price of burley.

X_3 = squared index of prices paid for production items.

X_4 = time.

X_5 = index of weather effect on yields, constructed from yields on experimental check plots where cultural practices were unchanged from year to year.

X_6 = current years United States burley acreage allotment less average acreage of burley harvested in preceding six years.

The attention given to the algebraic form of the equation is interesting, especially regarding X_2 and X_3. A farm operator was assumed operating in stage II (diminishing marginal returns) and the use of logarithmic and squared values of the variables built the diminishing marginal returns concept into the function.

He derived statistical estimates of the influence of each variable. The supply-price elasticity (from yield changes) was roughly .11. The statistical analysis was followed by an examination of residuals unexplained by the statistical analysis. The problem of ascertaining the separate effects of X_2, X_3, and X_4 (which all moved closely together during the period) was examined. It was concluded that a modified interpretation of the statistical estimates was necessary. Also, the influence of certain "non-price" factors, as biological improvements, fertilizing improvements, and of increased price stability were major factors explaining yield changes (although they could not be incorporated in the statistical analysis).

Cromarty (12) derived a short-run elasticity of .381 for burley tobacco production. Coefficients both positive and significant were derived for independent variables, which were the higher of announced support price or price the previous year, time, and the higher of acreage allotment or last year's harvested acreage of burley tobacco.

The importance of "time" as an explanatory variable, and the many and complex set of factors it carries, makes interpreting the results from this equation difficult. As argued by Johnson and as in the discussion of the wheat production equations, it seems unlikely that the period with announced support price can be described by the same structure as the earlier period.

Cotton

Estimates of the elasticity for cotton range from roughly .2 as derived by Walsh (49) (acreage related to deflated, lagged prices for cotton and/or cottonseed) for 1910-24 and 1925-33, to .20 (acres = f (lagged, deflated price, time) and .67 (acres = f (lagged deflated price, time, lagged acres) by Nerlove (40). Cromarty's estimate was .361 and Cochrane's judgment estimate was .2 to .3 (9). Where Cromarty used lagged price and lagged acres plus representations for other influences, as climatic factors and prices paid by cotton growers for inputs, and allowed for simultaneity of supply and demand influences, his estimates stand on a stronger methodological footing.

While his equations do not contain the representations of Cromarty's, Brennan (7) has shown that for crops in which the substitute crops in production vary from region to region, there may be some advantage to geographical disaggregation. Using data for 1905-32 for regions he calls the Southeast, Delta, and Southwest, with acreage as a function of the past two years' prices for cotton and other crops believed substitutes in production, he derived regional elasticities of .33, .31, and .37. He also showed (for the period 1942-48) cross elasticities of cotton acreage with respect to the prices of substitute crops by states, where important substitute crops were hay and peanuts. While the prices of substitute crops explained cotton acreage from 1942-48, he found little such relation during the preceding nine year period. To the extent that his findings are valid (and he had data for only a limited number of years), he has shown some indication of (a) a change in structure over time and (b) differing structure (unlike substitute crops, own price elasticities nearly equal) across regions.

Unharvested Crops

Analyses by Suits (45), and Suits and Koizumi (46) with supply implications were developed for watermelons and onions in two stages. In the first stage, a crop available for harvest estimate was derived, while in the second stage the portion of the crop harvested was explained. For the first stage, least squares estimates were obtained by relating the watermelon crop available for harvest to lagged prices of watermelons, cotton, and commercial truck and dummy variables representing government cotton policy and war, and the onion crop available for harvest to lagged onion prices, lagged costs, and time. Elasticity estimates against own price were .581 and .324 respectively.

For the second stage, the unharvested acreage was related to current own price, (endogenous-price simultaneously determined with demand equations), to the size of the available crop and to harvesting costs. For watermelons, the price elasticity for the harvested supply, given the available crop, was about .2. For onions, the corresponding elasticity was given as E (elasticity) = $1.71\frac{u}{x}$ ($\frac{u}{x}$ = portion of available crop unharvested to harvested), and it was concluded since $\frac{u}{x}$ is usually low, that the elasticity of market supply is low and usually considerably less than the elasticity of crop supply.

Nerlove's analysis of abandoned acreage of corn, oats, barley, and grain sorghums in Kansas where he correlated harvested yields and percent of the crop abandoned, was a similar type of analysis. His argument was that there is some yield, considering the price of wheat and harvesting costs, at which the crop will be just worth harvesting, and at lower yields the crop will be abandoned. The "critical" yield in some cases may be higher than this. If the crop in question has as an opportunity cost another crop that could be planted on the land, the old crop may be "torn up" to prepare the ground for the new crop even though it might have been worth harvesting.

For some crops, especially wheat, some knowledge of eventual yields is known at seeding time from soil moisture readings, previous rainfall, etc. A proper analysis of wheat supply starting with seeded acreage should include representations for variables of this type.

Potatoes

Working with the supply for late spring potatoes in Kern County, California, Mundlak and McCorkle (39) found no relation between lagged potato prices and yields, nor did they find a relation between change in price and change in yield. They found more response to price in their study of acres of potatoes for 1929-53. For a linear equation, for lagged prices for potatoes, cotton, and alfalfa, elasticities of .376, -.137, and .460 were derived for the three respective prices, while for an equation linear in logarithms, elasticities of .237, -.229, and .450 were derived. Other formulations, such as the use of lagged potato prices and a lagged gross return over a two year period gave elasticities of .101, .223, and .277 along with negative elasticities for lagged prices and gross returns for cotton and positive elasticities for alfalfa. For all formulations they found cotton a competing crop and alfalfa a complementary crop to potatoes as they had hypothesized. This is the only study reported where the geographical area for the statistical analysis is the county.

Using data for 1921-41 and 1950-56, Cochrane (10) derived an elasticity of .246, where

X_1 = acres planted in current year, as an indication of intentions to produce, 10,000 acres.

X_2 = potato prices deflated by index of prices received for all crops for years t-1 and t-2, weighted equally, cents per cwt.

X_3 = yield per acre in current year, cwt.

Coefficients derived were

$$X_1 = 378.791 + \underset{(.2402)}{.6308X_2} - \underset{(.1499)}{1.8351X_3}$$

The Dry Bean Industry in Michigan

Hatheway (26) analyzed planted acreage of beans against lagged price, abandonment the previous year, expected income from competing crops, and costs. He found the supply, calculated to be roughly .26, to be relatively inelastic. In his yield model, he related yields to acres in current year (endogenous) and lagged prices and a weather index for beans. He did not detect a relationship between price and yields (which checked with their experience of no response in yields to fertilizer application), but he found a clear tendency for yields to decline with increases in acreage.

Both equations here are further illustrations of care used in algebraic form. Values of specified independent variables were expressed as logarithms and squared values to force certain properties which enabled a more realistic representation for the effects of the variables.

The Supply and Demand for Technology — Hybrid Corn

The implications of technology upon supply analysis have been well-hypothesized, but effects due to changes in technology have at best been treated in supply studies as exogenous. Griliches (20) sought an explanation for the supply and demand for one form of technology, hybrid corn.

Although his analysis of supply was to some extent inconclusive, he was convinced that "market density" or "market potential," involving corn acreage and adaptability of hybrids, both on a land area basis, explained the variation in beginning dates for different areas. For this particular form of technology, once seed was developed for an area, the supply soon became very elastic.

On the demand side, he explained independently (a) the rate of acceptance, and (b) the equilibrium level of use, both essentially in terms of the change in profitability of hybrid corn, and both in a "long-run" framework. For data for states and crop reporting districts, he explained the rate of acceptance using as variables the average increase in yield over open pollinated varieties, the long-run average pre-hybrid yield of corn, and average acres of corn per farm. Corn prices were so similar among areas that no variable was added for price. For equilibrium level of use, (the long-run percentages of the corn acreage that will be planted to hybrid seed), the independent variables were average corn acres per farm, pre-hybrid yield (as profitability measures), and capital per farm. The latter explained variations in equilibrium levels between crop reporting districts but not between states.

Fertilizer Demand

Griliches (21, 22), and Heady and Yeh (29), employing somewhat unlike methodology, derived fertilizer demand functions. In Griliches' formulation, level of fertilizer use was assumed a function of the real price of fertilizer (fertilizer price deflated by index of prices received for crops) and changes in use proportional to the difference between the "desired" and actual level of use, all units in logarithms. Equivalently, fertilizer use was assumed a linear function (in logarithms) of the real price and fertilizer use (both lagged). In the Heady and Yeh model,

Y_1 = total tons of commercial fertilizer consumed was assumed a function of[7].

X_1 = fertilizer price index at planting time, deflated by wholesale price index.

X_2 = crop price index, lagged, deflated as X_1[8].

X_3 = cash receipts from farming (crops, livestock, and its products and government payments) lagged one year.

X_4 = cash receipts from crops and government payments lagged one year.

X_5 = total acreage of cropland.

X_6 = time.

Heady and Yeh derived coefficients for a number of algebraic forms, and results for the functions linear in logarithms were published (as well as for some other formulations, as first differences).

For both studies, coefficients were derived not only for demand at the national level but by regions. Although they did not divide the United States into the same regions, some comparisons are interesting. The coefficients for lagged prices in the two studies may be interpreted as measures of short-run elasticities. Elasticities were considerably greater in the Heady and Yeh study than in Griliches', but there was some consistency in the ranking of the different regions for the two works. The coefficient for X_6 (time) in the study by Heady and Yeh and the "b" value (adjustment coefficient) for the Griliches study likewise have more or less the same interpretation — an indication of a long-run adjustment. The values found by Griliches varied from .04 to .28, while Heady and Yeh derived estimates ranging from .002 to 1.074, and

[7] Functions were also derived for quantities of nutrients the dependent variable.

[8] For the different tests, X_2, X_3, and X_4 were not all employed in the same function.

they were generally more erratic than those of Griliches. Here the two studies indicate the fertilizer demand function shifting to the right, although the regional changes indicated by the two sets of results did not form a clear pattern.

For the formulation of Heady and Yeh, the coefficients for X_3 or X_4 were significant at the 1 per cent level for each region. These variables are presumably representations for farmers' capital position and ability to make purchases of this type. This study then, is an example of an analysis at the aggregative level with a representation for the firm-household complex.

Demand for Machinery

For a stock equation, where machinery stock was related to a "real" price of machinery, rate of interest and lagged stock, Griliches (23) derived short-run elasticities of -.25 and -1.2 with respect to real tractor prices and the rate of interest and long run estimates of -1.5 and -6.9. For an investment equation the elasticities were still more extreme.

Using a somewhat different approach, Cromarty (11) derived elasticities of -1.0 and -2.5 for demand at the wholesale and retail levels, respectively. He related the value of manufacturers' sales and the value of farm machinery shipments (deflated) to a number of variables, such as a real price for machinery, a price for a substitute item in production, a measure of assets held by farmers, a measure of farm income, and a quantitative measure of government programs. Estimates were also derived for tractors and trucks individually.

SUMMARY INTERPRETATION

Any analysis of aggregative relations must be interpreted as the result of a considerable amount of averaging. The analyst is forced to choose variables selectively, hoping he has chosen those which are crucial and those which the influence of the omitted variables will not be major, will not bias the results, and will not increase standard errors appreciably.

Of the many problems in using time-series data for supply analysis, it did not appear that the available statistical techniques (mainly multiple regression and simultaneous equations) were real limitations. The degree of simultaneity and hence the need for the latter method are not known exactly. Hildreth and Jarrett (32) obtained roughly similar results from the two methods, while Judge's (35) results by using the two methods for his egg supply equation were quite unlike. Although there are particular problems in which the degree of simultaneity can be deduced, one cannot generalize on the basis of either arguments or comparative empirical results on the necessity of using a method which handles simultaneous relations.

Those working with regression methods must experience uneasiness when there are more or less erratic changes in coefficients with changes in algebraic form and specification of variables, and where there are very few a priori grounds for one form and/or specification over another. This situation can be aside from problems of single equation versus simultaneous equations. If there is a problem as to the degree of simultaneity, the "uneasiness" is increased still further.

For studies where all (or a large proportion) or the results (and we don't know how many "poor" results have been withheld) have been published, it is possible to find different degrees of these "within study" fluctuations in values for coefficients. Examples of studies for which alternative results were published include Candler (8), Fisher (14), Gerra (17), Mundlak and McCorkle (39), and Wallace and Judge (48). One of the more interesting examples for this context is the model of Halvorson (25), where variables were successively added.

Intercorrelation, mentioned explicitly by some researchers (Johnson (33) and Candler (8) are examples), undoubtedly was a problem in many other studies. The correlation of independent variables makes difficult the detection and quantification of effects traceable to changes in values of specific variables. While predictions can still be made (and the predictions of the structural coefficients will be unbiased), the reliability of the coefficients will decrease and the real purpose of the analysis, deriving coefficients to enable an understanding of the system, may be defeated. It is doubtful if sufficient attention has been given either to the construction of variables or the application of such mathematical methods as the total derivative for this context.

The serial correlation of the residuals was tested for many of the equations, and was a problem in some but not in others. For an analysis of the residuals, see Johnson (33). Nerlove and Addison (43) indicate that serial correlation of the residuals is much less of a problem with price expectation models than with other models.

The choice of a particular algebraic form automatically builds certain properties into the structure. For studies with imaginative forms for equations and particular variables, see Johnson (33) and Hatheway (26). The Cobb-Douglas power function was used in more studies than any other form. The primary reason for its use is that it yields curves (in terms of original values for the variables) which approximate the "theoretical form." For supply analysis, for example, it permits diminishing returns for an input applied to a set of fixed resources, and non-constant (again original values of variables) marginal rates of substitution between inputs and between products. The linear form has also been used by many. Those using it believe linear relations approximate the "true" relations closely enough to justify their use. First differences were used by several, and more specialized forms as the logistic have been employed.

Representations for the effects of variables of various types are frequently necessary to determine a complete and realistic supply structure. Effects for "economic" variables, such as prices for products, variable inputs and substitutes in production and consumption have probably been best represented among the list of types of effects. Their use in these analyses is suggested by economic theory, and results reported by Boyne and Johnson (4) from the Interstate Managerial Study confirm that farmers operating farms respond to changes in these types of data. Many workers have been forced to use deflated prices, e.g., adjusting the price of a commodity whose supply was being studied by an index of prices received. For a commodity with substitutes differing by regions, this kind of construction of representations is probably about all that can be done at the broad aggregative level.

Trained as they are in explaining the determination of price and in determining the chain of effects from a change in price, economists have encountered difficulties in explanations through empirical analyses. These difficulties have come not so much from improper handling of "price" as from locating and incorporating in the analysis effects for changes in "non price" variables.

This generalization holds for those models in which price was endogenous, and where "non price" effects, particularly those changing over time, were not handled explicitly. Difficulties with "non price" variables have been no easier (relative to problems of using "price") in deriving coefficients for equations from which elasticities are derived. Even with the explanation of price determination and effects of price changes as an objective, researchers may not be able to achieve it unless proper "corrections" are made for "non-price" effects.[9]

The handling of fixed resources (also an "economic" variable, and its relevance was confirmed (4) in the IMS for both farmers organizing and operating farms who indicated that they responded to fixed resources) has been a major problem in constructing and interpreting supply functions. Johnson has argued that we do not know what resources are fixed and the conditions under which they become variable (34). Although a complete analysis would treat resources as endogenous, past supply studies haven't gone far in this direction. In the study of supply functions for particular crops, the acreage as in many studies cited above has been explained, while in the hog supply study by Dean and Heady, the number of sows farrowing were explained. The explanation of resource commitment as in these studies is about as far as we have gone in explaining use of resources in incorporating level of resource use within our supply analysis models. The more advanced work of this type has been in the area of farmer demand for fertilizer and machinery.

Not only has progress in explaining resource use been slow, but for many studies the level of resource use is not well-represented in the formulations. This makes difficult the interpretation of the "length of

---

[9] This is not to say that effects of other changes should not be studied. In fact, effects of some of these "non price" changes may be as deserving of study as are effects of changes for "price." For studies where effects of "non price" changes were explicit, see Cromarty's (12) handling of technology, and Johnson's (33) study of the effects of penalties and allotments on tobacco production.

run" as the term is traditionally used. Among studies specifying levels of resource use are Hildreth and Jarrett (32), and Cromarty (12).

There have been problems in constructing representations for farmers as profit maximizers, but those representing other considerations to which they respond have as a whole been less adequate in the formulations. The institutional, technological, and environmental (e.g. weather) situations to which farmers respond in production of commodities have not always been specified in the statistical designs. Recent farm income measures used in the farmer demand studies — by Heady and Yeh (29) for fertilizer, by Cromarty (11) for machinery and capital per farm, and by Griliches (20) for hybrid corn — are examples of representations pertaining to the institutional arrangement the family farm and the fact that farm production decisions are made at that level. Beyond these examples (where in reality farmers are maximizing utility, are acquiring assets, are reluctant more or less to make changes, etc.), we have been unable in our aggregative supply analyses to more than use representations which imply that the farmer is maximizing profits over some time period. In this context the past studies must be interpreted as "averaging out" considerations of this type. It is likely that we not only are unable at the present time to incorporate the effects of some of these factors in our aggregative analyses but do not know as much as we need even at the level of the firm.

Variables for other institutional effects have been less inadequately specified. There are a number of studies which have included specifications for effects of farm programs. Examples include penalties and allotments in Johnson's study of tabacco control programs (33), a dummy variable for government cotton policy in Suits' (45) watermelon supply study, a quantified measure of government price support programs in Cromarty's (11) study of farm machinery and in his econometric model (12) for United States agriculture, a number of measures for acreage allotments, announced support prices, and equations to ascertain government demands for certain commodities (feed grains, wheat, cotton, and tobacco products).

Realistic analyses of supply must be designed in the context of the technical conditions of production for the commodity. Most of the equations which have been fitted are behavioral or a combination of behavioral and production function. Equations more pure in the latter would enhance our knowledge of these technical conditions and basic structure of the system. Examples where the two types of formulations were more separately determined where Hildreth and Jarrett's (32) "farm decision relations" and "production relation" and Wallace and Judge's (48) "supply of beef at retail" and "supply of beef at the farm."

The relevance of technical conditions of production to decision making and to the design of the particular models was discussed as a part of many studies. In particular, the studies of Dean and Heady (13) on hogs, describing the length of gestation for sows and length of time necessary before fat hogs reach the market, and Candler (8) in his New Zealand wheat supply study, discussing substitute crops and difficulties in planting (caused by rains at seeding time), are examples of studies in which technical conditions influenced the statistical design.

The role of weather, neglected in most earlier studies, was explicit in studies by Candler (8), Johnson (33), Hatheway (26) (for dry beans), and in Cromarty's (12) crop supply equations. Its use, except by Candler and by Hatheway in his use of a variable for bean abandonment, was largely in a production function sense. It is believed that more use of it in behavioral equations, especially for resource commitment equations for crops grown in dry areas, where expected profitability of crops is a function of prior rainfall and of soil moisture at seeding time, would enable a more complete design for the decision-making situation.

Aside from the adjustment coefficients derived with the expected price models, and from some coefficients for "time" in some other formulations, the supply analyses were essentially derived within a short-run framework. The results primarily apply to a situation in which certain resources are fixed.

For crops, a typical set of formulations consisted of derivation of coefficients (a) for an equation explaining acreage seeded, and (b) for a second equation explaining yields, acreage given. The situation in (b) was necessarily a more short-run situation, and most of the results were as expected — greater supply elasticity for (a) than (b). Examples of studies obtaining results of this pattern were Mundlak and McCorkle (39) for potatoes, and Hatheway (26) for dry beans. Results of Suits (45) with equations for watermelon production and proportion of crop harvested, followed the same pattern. A number of studies stopped with an explanation of acreage, and Cromarty's (12) crop production equations must be interpreted as being a mixture of both (a) and (b).

For livestock, production commonly was studied with livestock numbers given, and hence is a shorter length of run than where numbers are endogenous. Dean and Heady (13), with their equations for number of farrowings and weight of hogs marketed, considered two lengths of run and obtained a higher elasticity, as expected, for the former relation compared to the more short run context.

The omission of the technology variable undoubtedly makes necessary a modified interpretation of many past studies. The data used in deriving most of the coefficients were generated essentially in the 1930's and 1940's, years in which time, price, production, level of resource use, more stable farm prices for some products, and technology have been correlated. As some have already pointed out, the use of technology and/or employment of more resources, especially those whose initial cost is high and whose disposal value is considerably less, are not unrelated to periods of high prices and production and hence high farm income. Until recently, these interrelations had been argued. For empirical relations, see the results of Heady and Yeh (29), and of Cromarty (11), and the relation of previous income to purchases of fertilizer and farm machinery. For further empirical verification, there was evidence (4) in the IMS that farmers are more responsive to product price increases (than decreases) and to input prices decreases (than increases). For contrary evidence, Halvorson found slightly higher elasticities for years of falling milk prices than for years of rising prices (25).

Further arguments are that when product prices fall, the technology and/or the resources that were first employed under high price situations will remain in employment. It is not likely that many of the formulations have provided for this "irreversible" portion of supply curves. The period over which our data were generated, its intercorrelations, and probable imperfections in statistical design may make some of the estimates not too reliable, especially for period of product price decreases. In Cochrane's terms, many formulations represent response relations in contrast to supply relations (9).

It is not clear how much more knowledge of the basic structure a more disaggregated analysis would permit. The bulk of the analyses, conducted at the United States level of aggregation, necessarily yields results with a high degree of "averaging out." Brennan (7) found evidence that for cotton production, the substitute crops varied by region. Dean and Heady (13) determined a somewhat different structure for hog supply for the north central region than for the United States. Bowlen's (3) elasticity estimates for wheat acreage in eastern and western Kansas were different. Analyses of fertilizer demand indicated different functions by regions (22, 29).

At the aggregative level, regression analyses have been with time-series in contrast to cross-sectional data. The success of the many studies using inter-farm analysis on the many problems, including those with supply implications, to which they have been addressed suggests as potentially fruitful the extension of cross sectional analysis to aggregative data on the regional, state, or county, etc., level.

A further method of analysis, heretofore unused, and possibly a powerful method for future studies, is the method of analysis of covariance. This method enables the integrated analysis of time-series and cross-section data (for discussions of the method, see Hildreth [30, 31]). Although it builds degrees of freedom, it has even more important possibilities for examining effects due to years and to section as part of the over-all regression analysis.

While it is not clear how "far down" the analysis of disaggregative time-series should go, it likewise is not clear how "far up" farm-firm analyses such as budgeting and linear programming can be aggregated. The two methods are now being used for essentially the same purpose, e.g. deriving milk-supply functions for milksheds. The two methods can be used simultaneously for the same milkshed, for example, and yet be complementary (in contrast to competing) methods.

The understanding of the decision-making process and of factors to which farmers respond were necessary insights for designing realistic regression models. The studies at the level of the firm have been instrumental in the discovery of relevant variables and have been suggestive of appropriate forms for functions, and of directions in which static analysis needs modification to account for dynamic forces. It is unlikely that the processes of deduction and empirical testing of time-series data will alone ever lead to a sufficient amount of this knowledge, especially that associated with "non-price" elements.

The impact of farm-firm analyses, such as the IMS and the many linear programming studies, on analysis of aggregative time-series data has been to suggest needed representations for variables and the interrelations among them. The model of Cromarty (12), where the effects of changes in such variables as levels of resources, in technology, and acreage allotments, and government demands, was undoubtedly to some extent suggested by earlier studies at the farm-firm level.

The regression-linear programming work at the "regional" level contains potentialities for more integration than has been realized. The regression analysis could provide coefficients for spatial equilibrium studies; to date the regression work has not been on a disaggregated level. Unless the equilibrium model was for the United States level, this difficulty and the fact that coefficients for not many "clean" production function equations have been derived, have prevented the tieing of the methods thus far.

The applicability of the past estimates holds only until there has been a structural change in the system. The amount of such change for all the various product supplying segments is not known, but some changes have been argued and empirical evidence of changes in some sectors is available.

The role of high and stable prices and the adoption of technology in changing the structure in the wheat producing industry has been argued. Similarly, adoption of new technology in the dairy industry will lead, it is expected, to new relations. Johnson and Hatheway argued that, for tobacco and dry beans, announced support prices lead to a modified structure (26, 33). Brennan (7) found evidence of changes in the cotton industry for 1942-48 from 1933-41, as did Dean and Heady (13) for both sow farrowings and hog marketing weights between 1924-37 and 1938-56. Halvorson detected differences in the milk supply structure for 1941-57 over earlier years (25).

We have at hand estimates of parameters for supply equations and supply elasticities for most farm products, mostly at the United States aggregative level, subject to interpretations as set down. In the broadest sense, the product orientation of all but the most recent work on demand for factors has enlarged our knowledge of structural relations affecting that commodity and has enabled us to make better predictions. However, it has not yielded the more complete knowledge of the structure of the agricultural plant that would come by the use of models where resources were treated more explicitly and endogenously. The studies have been superimposed above a portion of the basic system — the resource base. Changes of a variety of types have been proceeding at that level — investment and disinvestment in land, reductions in labor, but increased investment in the human agent, increases in the quantity and quality of capital, etc. Here the institutions — the land, labor, and capital markets — probably serve most unsatisfactorily. And here, as was the experience of Heady and Yeh (29), and of Cromarty (11), representations for the effects of the family farm, as the locale of the decision-making process, can more easily be included in the formulations.

The work of Griliches (23) is illustrative of the derivation of product supply functions from derived demands for resources. Bachman and Nerlove have shown that cost, supply, and derived demand functions may be derived from production functions (1).

Hypotheses on the supply and demand for farm resources have not generally been tested, especially by regression analysis of time-series data. Approaching problems of supply through the product side has given some useful structural knowledge and more basis for making predictions of production in the immediate. It is believed it will be necessary to broaden the analysis to obtain knowledge of the ultimate structure.

REFERENCES

1. Bachman, Kenneth L., and Nerlove, Marc, "Memorandum on the analysis of changes in agricultural supply," USDA, ARS, Farm Econ. Div., 1959, (processed).
2. Bonnen, James T., and Cromarty, William A., "The structure of agriculture," in Agricultural Adjustment Problems in a Growing Economy,(E. O. Heady, et al., eds.),Iowa State Univ. Press, Ames, 1958, pp. 109-27.
3. Bowlen, B. J., "The wheat supply function," Jour. Farm Econ., 37:1177-85, 1955.
4. Boyne, David H., and Johnson, Glenn L., "A partial evaluation of static theory from results of the interstate managerial study," Jour. Farm Econ., 40:458-69, 1958.
5. Bradford, Lawrence A., and Johnson, Glenn L., Farm Management Analysis, John Wiley and Sons, Inc., New York, 1953.
6. Brandow, G. E., "A note on the Nerlove estimate of supply elasticity," Jour. Farm Econ., 40:719-22, 1958.
7. Brennan, Michael J., "Changes in cotton acreage in the Southeast — Implications for supply functions," Jour. Farm Econ., 40:835-44, 1958.
8. Candler, Wilfred, "An aggregate supply function for New Zealand wheat," Jour. Farm Econ., 39:1732-41, 1957.
9. Cochrane, Willard W., "Conceptualizing the supply relation in agriculture," Jour. Farm Econ., 37:1161-76, 1955.
10. _____, Farm Prices: Myth and Reality. Univ. of Minnesota Press, Minneapolis, 1958.
11. Cromarty, William A., "An econometric model for United States agriculture," Jour. Amer. Stat. Assoc., 54:556-74, 1959.
12. _____, "The farm demand for tractors, machinery, and trucks," Jour. Farm Econ., 41:323-31, 1959.
13. Dean, Gerald W., and Heady, Earl O., "Changes in supply response and elasticity for hogs," Jour. Farm Econ., 40:845-60, 1958.
14. Fisher, Malcolm R., "A sector model — The poultry industry of the U.S.A.," Econometrica, 16:37-66, 1958.
15. Foote, Richard J., "A four-equation model of the feed-livestock economy and its endogenous mechanism," Jour. Farm Econ., 35:44-61, 1953.

16. Fox, Karl A., "Econometric models of the United States," Jour. Polit. Econ., 64:128-42, 1956.
17. Gerra, Martin J., "An econometric model of the egg industry," Jour. Farm Econ., 41:284-301, 1959.
18. Girshick, M. A., and Haavelmo, Trygve, "Statistical analysis of the demand for food: Examples of simultaneous estimation of structural equations," in Studies in Econometric Method (W. C. Hood and T. C. Koopmans, eds.). John Wiley and Sons, Inc., New York, 1953, pp. 92-111.
19. Griliches, Zvi, "The demand for fertilizer: An economic interpretation of a technical change," Jour. Farm Econ., 41:591-606, 1958.
20. _____, "The demand for inputs in agriculture and a derived supply elasticity," Jour. Farm Econ., 41:309-22, 1959.
21. _____, "Distributed lags, disaggregation, and regional demand functions for fertilizer," Jour. Farm Econ., 41:90-102, 1959.
22. _____, "Hybrid corn: An exploration in the economics of technological change," Econometrica, 25:501-22, 1957.
23. _____, "Specification bias in estimates of production functions," Jour. Farm Econ., 39:8-20, 1957.
24. Halvorson, Harlow W., "Response of milk production to price," Jour. Farm Econ., 40:1101-13, 1958.
25. _____, "The supply elasticity for milk in the short run," Jour. Farm Econ., 37:1186-97, 1955.
26. Hatheway, Dale E., "The effects of the price support program in the dry bean industry in Michigan," Mich. Agr. Exp. Sta. Tech. Bul. 250, 1955.
27. Heady, Earl O., "Basic logic in farm and home planning in extension education," Jour. Farm Econ., 38:80-92, 1956.
28. _____, Economics of Agricultural Production and Resource Use, Prentice-Hall, Inc., New York, 1952.
29. _____, and Yeh, Martin H., "National and regional demand functions for fertilizer," Jour. Farm Econ., 41:332-48, 1958.
30. Hildreth, Clifford, "Combining cross section data and time series," Cowles Commission Discussion Paper: Statistics No. 347, May 15, 1950.
31. _____, "Preliminary considerations regarding time series and/or cross section studies," Cowles Commission Discussion Paper: Statistics No. 333, July 18, 1949.
32. _____, and Jarrett, F. G., A Statistical Study of Livestock Production and Marketing, John Wiley and Sons, Inc., New York, 1955.
33. Johnson, Glenn L., "Burley tobacco control programs," Ky. Agr. Exp. Sta. Bul. 580, 1952.
34. _____, "Supply function — Some facts and notions," in Agricultural Adjustment Problems in a Growing Economy, (E. O. Heady, et al., eds.), Iowa State Univ. Press, Ames, 1958, pp. 74-93.
35. Judge, George G., "Econometric analysis of the demand and supply relationships for eggs," Conn. Agr. Exp. Sta. Bul. 307, 1954.
36. Koopmans, Tjalling C., "Identification problems in economic model construction," in Studies in Econometric Method (W. C. Hood and T. C. Koopmans, eds.), John Wiley and Sons, Inc., New York, 1953, pp. 27-48.
37. Ladd, George W., "Biases in certain reproduction indexes," Jour. Farm Econ., 39:75-85, 1957.
38. _____, Review of Nerlove (41), Jour. Farm Econ., 41:452-55, 1959.
39. Mundlak, Yair, and McCorkie, Chester O., Jr., "Statistical analysis of supply response in late spring potatoes in California," Jour. Farm Econ., 38:553-69, 1956.
40. Nerlove, Marc, "Distributed lags and the estimation of long-run supply and demand elasticities," Jour. Farm Econ., 40:301-11, 1958.

41. _____, The Dynamics of Supply: Estimation of Farmers' Response to Price, The Johns Hopkins Press, Baltimore, 1958.
42. _____, "Estimates of the elasticities of supply of selected agricultural commodities," Jour. Farm Econ., 38:496-509, 1956.
43. _____, and Addison, William, "Statistical estimation of long-run elasticities of supply and demand," Jour. Farm Econ., 40:861-80, 1958.
44. Schultz, Theodore W., The Economic Organization of Agriculture, McGraw-Hill Book Co., Inc., New York, 1953.
45. Suits, Daniel B., "An econometric model of the watermelon market," Jour. Farm Econ., 37:237-51, 1955.
46. _____, and Koizumi, Susumu, "The dynamics of the onion market," Jour. Farm Econ., 38:475-84, 1956.
47. Tintner, Gerhard, "Scope and method of econometrics: Illustrated by applications to American agriculture," Statistical and Social Inquiry Society of Ireland, 18:161-75, 1958.
48. Wallace, Thomas D., and Judge, George G., "Econometric analysis of the beef and pork sectors of the economy," Okla. Agr. Exp. Sta. Tech. Bul. 75, 1958.
49. Walsh, Robert M., "Response to price in production of cotton and cottonseed," Jour. Farm Econ., 26:359-72, 1944.
50. Williams, H. C., and Sherman, R. W., "The demand for hogs," Ohio Agr. Exp. Sta. Res. Bul. 809, 1958.
51. Working, E. J., "What do statistical 'demand curves' show?" Quar. Jour. Econ., 41:212-35, 1927.

A. N. HALTER
University of Kentucky

Discussion

I HAVE NO PARTICULAR QUARREL with anything that Knight has said, but instead I would like to extend his criticism of past work. He says that the objective in studying supply elasticities is to understand the structure of agriculture. However, in the context laid out by Heady in his paper and at the Adjustment Conference the objective is clearly more than this. The objective is to derive empirical estimates which can form a basis for policy decisions at a level other than at the firm or household level, i.e., it is to determine the effects of changes in various variables brought about by policy makers.

Taking this later context, there are three questions I would like to raise concerning the interpretation of supply estimates. First, what is required of a model to be used for the stated purpose? Second, how can this requirement be met? Third, what is the major obstacle to carrying out this procedure?

REQUIREMENTS OF A MODEL USED FOR POLICY PURPOSES

The requirement of a model where someone is to manipulate one or more variables in order to cause an effect in another variable is best characterized by a scientist's experiment. Here certain causal variables are under the control of the experimenter who varies these at will to determine the effects upon the variables in which he has particular interest. Through the design and carrying out of the experiment he determines causal dependence. These causal dependencies are what the policy maker wants to know. He, like the scientist, is interested in variables he can control. Hence, in this context one of the important requirements of models which provide supply estimates is that they show causal dependencies between variables. This means that in the construction of the model, in addition to the effect variables, at least those variables should appear which the policy maker can and will manipulate. Whether or not the models Knight has drawn upon meet this requirement can be determined through answering the question of how can this requirement be met.

PROCEDURE OF MEETING THE REQUIREMENT

Most persons in the social sciences claim that experiments are impossible, and hence the requirement is impossible to meet. Therefore, policy based on empirical results are as good as those based upon ethical considerations only. Laboratory experiments on social phenomena to a scale that are useful for broad policy purposes are not feasible today. We must content ourselves with the real world and the ways in which variables are changing either by chance or as can be varied in smaller experiments. By smaller experiments I mean such piecemeal social engineering as currently is taking place in one of our more prominent Midwestern agricultural states. Whichever way the causal dependencies get tested, the important thing is that they be tested empirically. By testing empirically I mean that a specific event can be predicted which can be compared to the actual situation in order to ascertain the accuracy of the prediction.

Studies of time-series data provide an excellent opportunity for such testing by the predicting of events through time. The prediction can then be compared to the actual data and causal dependencies as specified in the model tested. Since Knight mentioned that such predictions had not been made and tested, I cannot accept the models as being useful to policy makers.

EXAMPLES OF PREDICTION — TESTING METHODOLOGY

In some of the work Karl Fox has done on spatial equilibrium models, some testing of predictions has been attempted.[1] He estimated

[1]Fox, K. A., Econometric Analysis for Public Policy. Iowa State Univ. Press, Ames, 1959, pp. 170-91.

coefficients from 1921-1942 data and then predicted regional price differentials for corn after specifying the value of certain initial conditions for a number of years beyond 1942. He says the degree of conformity of actual prices with the model based on the correlation coefficient is encouraging, but then recommends extensions before the model is used for policy decisions.

Another example of the procedure I would like to see carried out in supply studies is that used by Carl Christ in his "Test of an Econometric Model for the United States, 1921-1947."

Christ, upon modifying the Klein model, made predictions of variables for 1948 and then compared them with the actual observed variables. The accuracy of the predictions from the Klein model was compared with the accuracy obtained by using a simple naive model, such as last year's values. The Chirst study demonstrates the methodology of testing predictions I believe must be applied to the models described by Knight before policy makers can have confidence in the causal dependencies displayed by the equations.

The fact that I selected two studies in which hypotheses (models) were not only stated (estimated) but also refuted was intentional because I want to point out another feature of the prediction-testing methods. The results of testing can be the selection of hypotheses which have stood up to the test or the elimination of those hypotheses which have not stood up to them. At this stage of our empirical work, I would say it is the elimination of the false hypotheses which is most crucial. No doubt we could find many systems of equations, as pointed out by Knight, which adequately describe the data from which the coefficients are derived.[2] For many of the models discussed by Knight, the high correlation coefficients and small standard errors of estimated parameters are an inconclusive test for the adequacy of the models for explanatory purposes. As Friedman has pointed out in his discussion of Christ's work, the fact that the equations fit the data from which they were derived is primarily a test of the skill and patience of the analyst. Instead of praising, we must try to find fault with the theory and models. We must try to falsify them. Only if we cannot falsify them, in spite of our best efforts, can we say that they have stood up to severe tests. This is the reason why the discovery of instances which fit a model means very little if we have not tried, and failed, to discover refutations. If we are uncritical, we shall always find what we want. We shall look for and find confirmations, and we shall look away from and not see whatever might be dangerous to our pet theories. This is the foundation for my belief that the method of selection by elimination is more crucial and insures that only the fittest of models will survive.

Knight mentioned the reluctance to publish "poor" results from studies using regression and simultaneous equation techniques.

[2]This was also pointed out by V. I. West in discussing some published results of George G. Judge.

However, in the prediction-testing context the results to be published are the painstaking efforts at falsification of hypotheses. Likewise, in setting up social experiments the most noble of design is one destined to be "unsuccessful."

THE MAJOR OBSTACLE TO PREDICTION AND TESTING

In answering the third question regarding the main obstacle to carrying out the prediction-testing methodology described above, I wish to state that no obstacles exist in the short run. However, in the long run, the situation is different. Here, as Knight discussed, we have technological progress. From his discussion and others that he noted, I conclude that the majority of researchers believe that a technological variable can be specified so that shifts in the supply curve can be predicted. I would argue that such is impossible, because what we are asking for in a technological variable is a variable describing the evolution of knowledge. It is the accumulation of knowledge and its subsequent application to everyday affairs which gives rise to the observed technological change. However, the process of accumulation of knowledge is an unique historical process; and hence any hypothesis formulated to describe it cannot be tested. If it cannot be tested, then it can only enter in the deduction of shorter-run predictions as a constant for a particular historical period. Since we cannot predict by rational or scientific methods the future growth of our knowledge, we cannot predict the future course of technological progress, i.e., we cannot anticipate today what we shall know only tomorrow. I do not doubt that we can find trends within any historical period of application and adoption of new techniques, but this confines our models to a given technological period.

In my discussion of Knight's paper, I have tried to show that the interpretation of supply models depends upon the predictive power of the model. I have said that this power can be ascertained through empirical testing of the model beyond the series of data from which the parameters were estimated. The main obstacle to making long-run predictions is the impossibility of finding a law of technological evolution.