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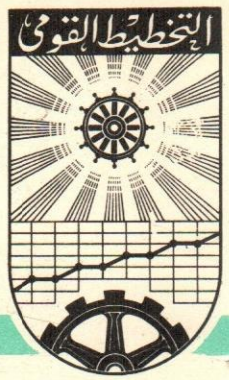

Memo. No. 760

METHODOLOGICAL REVIEW OF MAJOR AGRICULTURAL SUPPLY STUDIES

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April, 1967

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OBJECTIVES OF STUDY:

The purpose of this study is to present to researchers in the fields of agricultural economics, agricultural planning, and to econometricians a brief review of some of the major studies that have been done in U.S.A. to estimate and study agricultural supply functions. This review will be from the methodology point of view. That is to present the major procedures and techniques which American economists used in analyzing, studying, and dealing with agricultural supply studies. Beside describing the techniques used, this review, will try to present the steps the researchers have taken to overcome some of the problems they faced in their analyses.

It is also haped that a study of this nature may be helpful to those who are involved in research dealing with analyzing, estimating, and predicting supply for agricultural, industrial, and consumption commodities.

AGRICULTURAL COMMODITY SUPPLY FUNCTIONS

Graphical Methods

This technique, developed by Bean [1] in 1929, is based entirely on the use of graphs. Successive curves for data that represent the relationship between the dependent variable and the independent variables are drawn. By studying these curves researcher can know which one of the independent variables has the greatest effect upon the dependent variable.

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1) L.H. Bean, "Applications of a Simplified Method of Graphic Curvilinear Correlation," Journal of American Statistical Association, 1929, 24: 386 - 397.

Smith used this technique to study the factors affecting the price of cotton. His dependent variable was the percentage increases or decreases in the harvested cotton acreage of the United States. He used four independent variables. The first independent variable was the New York average price of cotton for delivery in March as quoted during December of the calender Year Preceding the year of harvest divided by the Bureau of Labor Statistical Index of farm product prices at wholesale for the same December.

The second independent variable was the New York average price of cotton taken for one year earlier. The third independent variable was the percentage change that took place in acreage during the year preceding the year of harvest. The fourth independent variable was taken as the last two digits of the year of harvest (period 1902-1926) to represent a trend. By drawing curves to represent the relation between the dependent variable and these independent variables, Smith found that the relative price one year before the the given year will produce more effect upon acreage harvested than the relative price of two years before and the greater the increase the change in the acreage in the preceding year the greater the reaction or decrease in the given year.

Smith pointed out

> To employ these relationship curves for the purpose of forecasting, it is necessary to obtain the values of the independents listed previously for the given year, read from the curves their effects upon acreage, and add together the resulting readings. The sum will represent the estimated or forecasted acreage change.1)

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1) B.B. Smith, "Factors Affecting the Price of Cotton," U.S. Department of Agriculture, Technical Bulletin 50, 1928, p. 23.

He added:

> If similar estimates are made for all years throughout the period and these estimated changes compared with the changes that actually took place, a very close agreement is observed.1)

The correlation between the estimated changes and actual changes was 0.95.

Bean[2] in 1929 published an article estimating farmer response to price. He used the same technique to analyze changes in the acreage of potatoes in New York, Michigan, Idaho and the United States as a whole, sweet potatoes, cabbage, strawherries, watermelons, rye and cotton in United States, and flax in North Dakota. The dependent variable in his analysis was the absolute increase or decrease in acreage harvested over that of the preceding year. The independent variables were prices received by producers adjusted for changes in the general level of farm prices during the first season and second season preceding the change in acreage. Some of the prices were deflated by the prices of competing crops. The period covered was from 1921-1928.

Bean found that there was a general type of production response to price in all the cases analyzed. The dominant factor in the change in production in any given year was the price received for the production of the preceding year. The price received during the season two years preceding was an important factor particularly if it was low. The nature of the response of production differed by regions and commodities. The range of the indexes of correlation for the twelve cases was from 0.967 to 0.997.

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1) Ibid., p. 24.
2) L.H.Bean, "The Farmer's Response to Price," Journal of Farm Economics, July, 1929, 11: 368 - 385.

This technique of graphical curvilinear correlation depends solely on plotting the original observations on corrdinate papers. A continuous smooth curve can then be drawn through them by eye in such a way to pass approximately through the center of the observations. This is a very simple method when nature of the relation is indicated closely by the original observations. In this case, it might yield a satisfactory expression of the relation. In other case, the observations may be more scattered, therefore, determining the relation will be more difficult and different persons may draw different curves.

By taking Smith's and Bean's curves as representatives of this technique, we find that no one of them can be regarded as very accurate, because they fitted complex free-hand curve to a small number of observations. Even though this method is a simple one and takes less time to find the relation between the dependent and independent variables, it will be too difficult to use in finding the true relationship, if it is used for many observations. In this case it is not easy to indicate the curve which fit the data best. Moreover, there will be many successive approximations in handling these many observations.

In their analysis, Smith and Bean used central market prices rather than farm prices. The latter is the price to which response of production takes place. The quantity supplied does not depend solely on prices and change in acreage harvested in preceding seasons but also on many other variables which they assumed to be constant or did not mention. For these reasons one cannot place a great deal of confidence in their results. Moreover, this method cannot be used in predicting or describing the relationship between price and production in the future because all of the results obtained from it depend on the circumstances that prevailed in the period covered.

By looking back to the time in which they published their work, it is found that they did attempt to find and determine the relationship between production and prices. They used central market prices because they were the only available prices which could be obtained for a long series of years. By relating changes in acreage to absolute levels of prices, they introduced a dynamic element in their analysis.

Some of the economists now use this technique primarily to give some idea about the relationship between quantitites supplied and changes in prices.

Time Series Analyses - Single Equations

Simple and Multiple Regressions. Moore in 1917 wrote a book in which he introduced a method to estimate the response of cotton production to prices. He believed that price ought to have something to do with production. He wrote,

> There should .... in normal times, be some relation between the percentage change in the price of cotton last year over the preceding year and the percentage change in the acreage of cotton this year over last year.1)

Using the simple linear regression technique he related the logarithmic first differences of cotton acreage with the lagged logarithmic first differences of cotton prices. His analysis covered the period 1890-1913. He found that the simple correlation between the percentage change in the acreage of cotton and the percentage change in the price per pound of cotton lint for the year before was equal to 0.532.

1) H.L.Moore, Forecasting the Yield and Price of Cotton, New York The Macmillan Company, 1917, p. 87.

Moore's work can be criticized on some points. The cotton acreage does not by any means represent the quantity supplied of cotton and hence the response to price changes. Quantity supplied is the product of acreage harvested times the average per acre and not all cultivated acres are harvested. But it seems that this was the best available data to Moore at that time. Response of farmers likely will not only be to change in prices of cotton of the preceding year but also to other previous changes and to changes in the prices of other products.

Moore was, in fact, the first economist who introduced this method of relating quantities to previous prices. His work can be considered as the first study ever made of actual supply response in agriculture. Many of the American economists following him used his technique of relating quantities supplied to prices prevailing at some earlier period throughout all the work they have done.

Smith in 1925 published an article in which he related absolute changes in cotton acreage to prices during the November, December, January, February and March preceding planting. Each price was the mean of the average of the daily spot prices in the New York and New Orleans markets and was deflated by the wholesale price index of agricultural commodities for the same month.

He stated that

> Since prediction of future conditions must be based upon analysis of present conditions, the price of cotton during the planting period might conceivably be a prime factor in the formation of the producer's opinion as to future price and hence of his decision with reference to acreage.1)

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1) B.B. Smith, Forecasting the Acreage of Cotton, Jornal of American Statistic Association, New Series, March 1925, 20; 31 - 47, p. 32.

Smith followed Moore in using the first differences rather than the original values to obviate the necessity of computing trends and to transform the nonlinear relations which are usually associated with the phenomena of diminishing returns into linear relations. The period covered in his analysis was 1907-1923. At first he drew a series of correlation charts between the dependent variable and the respective independent varibales. He found that the relationships were almost perfectly linear. Smith found that the coefficient of correlation = .9502 and that the series of December, January and February were the most important. Secondly, he used another regression in which the independent variables were the three price series and the production and yield-value series per harvested acre lagged one year. The coefficient of correlation was 0.93. This indicates that prices have more to do with determining the producer's mind with reference to acreage than do production and yield-value per harvested acre.

Smith in his analysis used the deflated mean of the average of the daily prices in New York and New Orleans markets. Farmers usually respond not to changes in the prices of the terminal markets but to changes in the prices received by them. But it seems that when he did his work, series on prices received by farmers were not avaialable. He introduced a trend in his regression equation which has no analytical significance here since he used the first difference of acreage which as he mentioned will take care of the trend problem. In his regression he introduced two new variables, the absolute change in production lagged one year and the absolute change in yield-value per harvested acre lagged one year. It is well known now that the use of lagged prices in regression rather than other lagged variables is helpful in identifying the supply curve. He used the acreage of cotton as an approximation to planned output and this may not be a good procedure but it seems that this was the only feasible one at that time.

Walsh[1] in 1944 published an article in which he summarized the results of his study of supply of cotton and cottonseed. The period covered by his analysis was 1910-1933. He used the cotton acreage in cultivation July 1 as the dependent variable. The independent variable was successively the average prices received by growers in the preceding crop year for cotton, cottonseed and composite price of cotton and cottonseed in his regression series. All these prices were lagged one year and deflated by the index number of prices paid by farmers to represent changes in unit cost.

Walsh's work has a great value relative to the time at which it was done. He used in his analysis the prices received by the growers to which farmers actually respond. He introduced a new independent variable in his regressions i.e. the change in cost of production. This was done by deflating all prices used by the index number of prices paid by farmers. This index number consists of prices of all the commodities that the farmer's family used either in production or consumption and, therefore, does not represent accurately cost of production. But it seems that this was the only available index at that time. Using the prices lagged one year has a significant meaning since there is usually a considerable time lag between price changes and production changes.

In 1950 Kohls and Pearlberg published the results of their study of a large number of commodities. They used in their analyses simple and multiple linear regressions. They pointed out that

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1) R.M. Walsh, "Response to Price in Production of Cotton and Cottonseed," Journal of Farm Economics. May 1944, 26 : 359 - 372.

> This work reports the results of a study of the short time response of agricultural production to price and other factors. The short-run response considers only the year to year changes which are primarily under the control of the producer.1)

The percentage change in acreage from the preceding year was the dependent variable in their analyses. The independent variables were price lagged one, two or three years and other factors.

All prices were deflated by an index of prices received by farmers. They converted all data to percentages of the preceding years. They wrote

> This procedure has the advantage of eliminating all but the most severe trends. It also converts all variables to a common denominator which greatly facilitates later application.2)

Their results show that both low correlations and low elasticities were found. They used the percentage change of acreage as an approximation to the planned otuput. In their regression they used the lagged prices which can help in the identification of the supply curve from the given data. It seems that the reasons for deflating all the prices used by the index of all prices received were that most of these crops were grown over a wide area and the number of relevent alternatives to any of these crops was very large. Their work can be considered the most comprehensive study published to that date.

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1) R.L. Kohls and Don Paarlberg, The Short-Time Response of Agricultural Production to Price and Other Factors, Purdue University Agricultural Experiment Station Bulletion 555, October 1950, Lafayette, Indiana. P.3.

2) Ibid., Appendix.

Halvorson[1] used a time series multiple-regression analysis and correlation analysis for the period of 1934 - 1954 for the United States as well as regional data. The study focuses on the short time supply elasticity which works primarily through changes in production per cow. Farmer's response to price (milk-feed ratio) was measured by the changes in their rates of feeding as represented by the pounds of grain fed per pound of milk produced.

Bowlen in 1955 published an article using a simple regression model to study farmer's response to changes in the price of wheat. The period covered by his study was 1926 to 1952, omitting the controlled years 1938-1943 and 1950. First he used lagged adjusted price as the independent variable and acreage planted as the dependent variable for the United States as a whole. The regression coefficient was 1.05 and a standard error of (b) some three times as large. Then he used the first differences of planted acreage and first differences of adjusted price ratios for the preceding season. But the results were only slightly different.

He stated that,

> It would be incorrect to conclude that price was not an important consideration in farmer's decision making process, but rather the direction and extent to which farmers respond is influenced by a most diverse set of conditions among areas, among farms within an area and over time. 2)

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1) H.W. Halvorson, "The Supply Elasticity for Milk in the Short Run". Journal of Farm Economics. December 1955, 37: 1186-1197.

2) B.J. Bowlen, "The Wheat Supply Function," Journal of Farm Economics, December 1955, 37: 1177-1185, p. 1177.

Therefore, he subdivided the state of Kansas into three areas on the basis of climatic and other conditions, including possible substitution of other crops. By using a simple regression model, Bowlen found no significant relationships when be used lagged adjusted prices of wheat and acreage planted or when be used first differences of these two variables.

He thought that by dividing the state of Kansas into more homogeneous areas, he could get important results, but these, results were also unsatisfactory. This was a result of using a simple regression model with one independent variable. Wheat production is influenced even in small homogeneous areas by many other variables such as availability of other alternatives for resource use, weather conditions and farmer's income. It seems that using a multiple rather than a simple regression model would be more appropriate. His work can be considered as a guide for other economists to prevent them from over simplifying the problems which face them.

Nerlove in 1956 published an article estimating the elasticities of supply of cotton, wheat and corn for the period 1909-1932. In his regression model he used the expected price rather than last year's price. He stated that, "Farmers react, not to last year's price, but rather to the price they expect, and this expected price depends only to a limited extent on what last year's price was."[1] The expected prices of the past years could not be obtained. To estimate them he put the hypothesis that, "Each year farmers revise the price they expect to prevail in the coming year in proportion to the error they made in predicting price this period."[2] This hypothesis is equivalent to

1) Marc Nerlove, "Estimates of the Elasticities of Supply of Selected Agricultural Commodities," Journal of Farm Economics, May 1956, 38:496-509. p. 498.

2) Ibid., p. 500.

one in which expected price is represented as a weighted moving average of past prices. This can be expressed mathematically as follows:

$$P_t^* = \beta P_{t-1} + (1-\beta)\beta P_{t-2} + (1-\beta)^2 \beta P_{t-3} + \dots \quad 1$$

where P_t^* = the price expected in t years,

P_{t-1} = the actual price in t-1 year,

β = the coefficient of expectation.

By substituting this expected price equation in the acreage response function which is $X_t = a_o + a_1 P_t^* + u_t$, he found that there is a relationship between this year's acreage and last year's actual price and last year's acreage. He estimated the elasticities, multiple correlation coefficients and the trend for the three crops assuming that $\beta = 1$ which he called a special method. Then he compared his result with estimates that have been obtained by other workers in the field of supply response with the unrestricted β which he called the general method. He found that the coefficients of determination, and the elasticities of acreage to expected price are higher using the general method than they were by using the special method.

Nerlove in his paper inctoduced the concept that farmers react not to the last year's price but to the price they expect. But farmers, in fact, not only react to the expected price of the commodity they produce but also to the expected prices of competing products, the expected prices of factors of production, and to the alternative uses of their resources that will be available. He used in his regression deflated prices but it is not certain that farmers use this method at all and even if they do deflate their prices there is no evidence that they use the same deflator.

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1) Ibid., p. 501

Nerlove, however, by his paper contributed more understanding of the use of the econometric models in supply studies. His paper made an important advance in supply analysis.

Nerlove and Addison in 1958 published a paper presenting a method for deriving statistical estimates of long-run elasticities of supply and demand. On the assumption that farmers base their decisions on price lagged one year and by using the traditional approach that planted or harvested acreage represent planned output, they formulated the supply function as follows:

$$\bar{x}_t = a + bp_{t-1} + ct.^1 \qquad (1)$$

where $\bar{x}_t$ = the long-run equilibrium acreage,

p_{t-1} = the price of the commodity lagged one year,

t = trend variable.

But since the long-run equilibrium acreage could not be observed, then equation (1) could not be estimated directly. Therefore they supposed that the relation between the current acreage x_t and the equilibrium acreage $\bar{x}_t$ could be represented in the following equation.

$$x_t - x_{t-1} = \gamma (\bar{x}_t - x_{t-1}).^2 \qquad (11)$$

where γ the coefficient of adjustment. Substituting (11) in (1) they obtained the estimating equation:

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1) Marc Nerlove and William Addison, "Statistical Estimation of long-run Elasticities of Supply and Demand, "Journal of Farm Economics, November 1958, 40: 861 - 880, P. 865.

2) Loc. cit.

$$x_t = a\gamma + b\gamma P_{t-1} + c\gamma t + (1-\gamma) x_{t-1} + u_t.^{1} \qquad (111)$$

where u_t = a randomly distributed residual.

They used this equation to estimate short-run price elasticity over one production period and the long-run price elasticity for twenty vegetables produced for fresh market in the United States. Lagged prices, lagged acreages, and a linear trend were used in the analysis. The acreage and price data were obtained from published Agricultural Marketing Service sources. In describing their analyses, they stated that, "They are preliminary analyses and presented mainly for illustrative purposes."[2] They found that the price elasticties of supply for most vegetables were low over one production period and for many vegetables were in excess of one for the long-run.

The work of Nerlove and Addison can be considered the most important and comprehensive work that has been done in estimating long-run supply elasticities for agricultural products. It may be the changing point from static to dynamic understanding of supply phenomena. This may help economists to differentiate between short-run and long-run elasticities. It may also help applied workers in the future to obtain accurate results. Using the price expectation model in their anaylsis, they succeeded in demonstrating the concept that farmers react to expected prices rather than prices received. But using lagged time series may raise the problem of the lag correlation between the time series used. They found that the problem of serial correlation was much less than by using other models.

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1) Loc. cit.

2) Ibid., p. 871.

Barker [1] in 1960 realized that past work in aupply analysis has focused upon the individual farm unit or upon the United States as a whole, designed a study to bridge the gap between these extremes by providing regional estimates of supply response using regression technique. The hypotheses tested concerned differences in supply elasticities with respect to milk price for : 1- different geographical regions, 2- different time periods, and 3- different economic conditions. Variables used in addition to trend and the milk price were principally prices of competing products and costs of inputs, three basic forms of the single equations were employed : 1- a traditional model, 2- a distributed lag model, and 3- an ineversible model. In all three models milk production was the dependent variable.

Canonical Regressions. This method can be used in estimating the supply relation. Waugh wrote, "It appears to have obvious possibilities in reseach upon the elasticity of agricultural supplies."[2] This method is used to explain the relation between a group of products and their prices together. In the regression analysis an index may be built for the acreage of the whole group and another for the whole set of prices. This method helps in estimating the weights which will be used in building these indices.

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1) Randolf Barker, "The Response of Milk Production to Price; A Regional Analysis", Ph.D. Theseis, Iowa State University, 1960.

2) Frederick V. Waugh. Prospective Uses of Estimated Coefficients and Related Statistics. Agricultural Supply Functions, Edited by E. O. Heady, Iowa State University Press, Ames, Iowa, 1961.

Simultaneous Equations Systems

Hildreth and Jarret in 1955 published the results of their study of the relation between quantity and price of livestock in the United States. Their objective was " ..... to obtain quantitative approximations to some of the underlying relations determing quantity and price of livestock products produced and sold in the United States each year"(1). In their study, the individual products-cattle, calves, hogs, chickens, turkeys, sheep, milk and eggs-were included in the livestock products aggregate. The period covered by their study was 1920-1949. They formulated an economic model, by using the economic theory and previous knowledge to describe the relations among the variables. A statistical model was set-up to represent the relations of the economic model. This statistical model consisted of seven equations that were linear in the logarithms of the observed variables. These equations represented the production relation, demand for feed grain, demand for protein feed, supply of livestock products, demand for livestock products, supply of feed grain and supply of protein feeds. They solved these equations simultaneously to obtain the parameters and, found that there was a negative elasticity for livestock sales to current livestock prices. There was a positive relation between livestock sales and the amount of livestock produced, farm wages, beginning inventory numbers and the price of feed grains. In their analysis they did not take into account changing technology. The period covered was

(1) Clifford Hildreth and F. G. Jarret, A Statistical Study of Livestock Production and Marketing, John Wiley and Sons, Inc., New York, 1955, P.1.

relatively short for this kind of study. They did not introduce in their equations a variable to represent fixed assets.

Estimation of supply functions and response of output to changes in price by using time series regressions is a positive technique because it describes what does exist in a given time period. The above review shows that Moore was the first one to use the regression analysis to expalin farmer's response to price change and he was also the first to introduce the concept of using lagged prices. Most of the economicsts following Moore used the same principles with some modifications. Some have measured supply response in acreage planted or harvested, others in physical output. Some presented these acreages as absolute acreage, others as a percentage change from acreage of previous years. Prices were expressed either in absolute terms or based on prices of preceding years. Some deflated prices by the index number of prices paid by farmers to introduce cost of production. Others deflated prices by the index number of prices received to correct for changes in purchasing power. Some introduced prices of competing products, prices of inputs and yield per acre as independent variables.

All these attempts to estimate and analyze the relationship between quantities supplied and prices reflect only historic relationships. They describe something that happened over a previous period. Even though this approach was widely used, many problems still exist with the use of these techniques(1).

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(1) For details on problems of time series analysis see, "Techniques and Problems in Estimating Agricultural Supply Functions," by Mohamed G. Abou El Dahab, The Institute of National Planning, Memo.NO. 715, January, 1967.

OPERATING UNIT APPROACH

Budgeting Method

Black[1] in 1932 suggested this method in discussing methodology for research in interregional competition.

Allen and others published in 1940 a bulletin studying the long time supply schedule of milk. In describing their method they stated that

> By means of individual farm records and other data the past period is carefully examined farm by farm in a representative area. Net changes over the period are noted and explained. For the period ahead individual farm estimates are prepared for each of three price levels. The area summations of the individual estimates are further adjusted for certain factors which cannot be treated by individual farms. The final results can be presented as a long-time supply schedule for the area showing the probable output for each of the several levels of price for milk for a time some years ahead .(2)

They obtained from 109 farmers complete farm business records including all receipts and expenditures for 1936. After normalizing the data so that the comparison between different budget plans will be on the basis of normal conditions, they worked out three farm plans or budgets for 10 years ahead for each sample farm. These budgets are :

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(1) John D. Black, " Interregional Comptition in Agricultural Production, In Research, In Farm Management - Scope and Method..." Social Science Research Council Bul. 13.

(2) R.H. Allen, Erling Hale and R.L. Mighell, "Supply Response in Milk Production in the Cabot-Marshfield Area - Vermont, " U.S. Department of Agriculture Technical Bulletin 709, P.3.

a. the first in terms of present price relationship,

b. the second in terms of milk prices 15 percent higher relative to all other prices,

c. the third in terms of milk prices 15 percent lower relative to all other prices.

They pointed out :

> In general, the procedure followed in this study is to consider first a most profitable farm organization for each price situation as realistic terms as possible and then on the basis of personal acquaintance with the farmer and his past record performance to estimate the effect of subjective factors in causing him to fall short of the point arrived in the first approximation.(1)

They found that a 15 percent decline in milk prices would bring about a contraction in quantity sold considerably greater than the expansion that would result from a similar price increase.

The supply schedule which they obtained is associated only with the year 1946 and it could not be used in predicting the quantity of milk obtained as a result of an increase or decrease in the prices of milk for any of the years between 1936-1946 or even beyond 1946. It is a static or normal schedule which does not take into account whether the changes in the prevailing conditions in the normal year 1936, will exist in 1946 or not. Moreover, farmers in operating their farms usually do not attain the most profitable organization which Allen used in

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(1) Ibid., P. 31.

his analysis because not all production conditions are under their control. Therefore, the supply schedule obtained did not represent actual response to price change.

Schuch studied the supply of fluid milk in the Detroit milkshed using the budgeting technique to estimate a short-run supply curve. He used a mail survey of the producers in the area to determine the conditions under which fluid milk was produced. The results of this survey were his guide in selecting 10 typical herds representing production conditions in the Area. A marginal cost curve was estimated for each of these 10 herds, then the quantity of milk that each producer would supply at various prices was determined. The quantity at each price was multiplied by the number of producers represented by that typical herd. The results were summed to get an aggregate supply curve for all producers in the area. He found that "In the short-run, elasticity of supply in the Detroit milkshed varies around .426, depending on the level of production".(1)

Schuh, by introducing the aspect of the marginal cost in his analysis, did a very good job. But when he used the horizontal summation of the supply curves of individual producers to obtain the aggregate supply curve for the area, he was faced by the problem that the prices of variable inputs which tend to be the same to the individual farmer will vary to farmers as a whole.

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(1) George E. Schuch, " The Supply of Milk in the Detroit Milkshed as Affected by Cost of Production", Mich. Ag. Exp. Sta. T. Bul. 259, P. 45.

Linear Programming Technique

Knudtson and Cochrane published a paper to estimate the supply function for flax at the firm level. They stated that, "The purpose of this study was to explore the possibilities of using a linear programming technique to derive a commodity supply function at the firm level."[1)]

They formulated a model for a representative small grain farm in the northern Red River Valley of Minnesota. This representative farm was raising wheat, barley, oats and flax. The period 1940-1954 was selected as the basis for determining the average yields for the four crops. The prices of the period 1930-1937 were used as the base for determining average relative prices for the four grains. They used the Minneapolis wheat price as the basis for calculating the relative prices.

From the results obtained from the linear programming model, they constructed the flax supply function by varying the flax price and holding all other things constant.

Kelley[2)] presented a paper at the Southwest Milk Marketing Conference to present a method for appraising the role of price in effecting output changes in Federal Order Milk Markets, and to estimate the elasticities of supply, output response and income with respect to price.

In his study, he used the linear programming technique. He programmed a sample of 49 farms of 1957 in the Topeka, Kansas Milkshed for three basic situations: (1) uses allresources, levels

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1) Arvid C. Knudtson and Willard W. Cochrane, "A Supply Function for Flax at the Firm Level," Journal of Farm Economics, February 1958, 40: 117-123, p. 117.

2) Paul L. Kelley, "Supply and Respense Relations for Milk," Contrinution No. 359, Department of Agricultural Economics, Kansas Agricultural Experiment Station.

of technology, levels of management, restrictions on crop and livestock activities, factor and product prices existing in 1957, (2) identical with situation I, except that base and blend milk were decreased 10 percent from 1957 levels, (3) identical with situation I, except that base and blend milk were increased 10 percent over 1957 levels.

Krenz[1] and others published a study to develop profit maximizing production plans for dairy farms in the Des Moines area, and to derive aggregate fluid milk supply schedules for the area based on these optimum plans. The dairy farms in the area were classified into 24 categories on the basis of average, soil type, tenure and dairy-building resources. Optimum plans were developed for an average farm in each category at two levels of production per cow. These plans were developed using linear programming techniques utilizing a variable price for fluid milk.

Fliud milk supply schedules for the optimum plans in each farm category are weighted by the estimated number of farms of each type in the area and aggregated overall categories.

Economists in using the linear programming technique have to specify some assumptions concerning the goals and actions of farmers, such as specific techniques of production, specific products, specific resource use and the attainment of maximum profits. Supply functions obtained are called normative supply functions. This means what farmers ought to do in their production operations in response to price changes under certain

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1) R.D. Krenz, E.O. Heady, and R.V. Banmann, " Profit Maximizing Plans and Static supply Schedules for Fluid Milk in the Des Moines Milkshed." Iowa Agr. and Home Econ. Expt. Station, Res. Bulletin 486, 1960.

assumptions. The results obtained by this method are optimum only in terms of the assumption used in the analysis.

Since this method depends upon certain assumptions, it has the advantage of allowing analysis of effects of new variables. Therefore, it is easy to include the effects of possible changes in technology in estimating supply functions.

AGGREGATE AGRICULTURAL SUPPLY FUNCTIONS

The previous part of this review has dealt with estimates and studies of supply functions for individual farm products. Knowledge of supply relations for individual farm products is useful and helpful in prediction and in formulating policies for individual farmers. It may be helpful to some extent to decision makers for public policies. But these micro-relations are not sufficient to be used to guide national policies directed towards changing the whole structure of the agricultural sector. Only supply relations on the macro level can be helpful in this latter case. It is through knowledge of aggregate supply functions of agriculture for a region or a nation, that agricultural problems can be solved.

Schultz wrote

> Tell me what the supply of farm products will be five or ten years from now, and I shall give you meaningful answers to the more important problems of agriculture. 1)

Heady in 1955 published a non-empirical paper studying supply functions of agricultural products under full employment. The steps which he recommended to be followed to obtain a good description of supply functions can be presented in the following steps.

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1) Theadore W.Schultz, " Reflections on Agricultural Production, Output and Supply, "Journal of Farm Economics, August 1956, 38: 748 - 762, p. 748.

> 1) Specification of the appropriate analytical modle, 2) measurement of the relevant observations, 3) prediction of the coefficients which make up the system of equations involved. [1)]

The only two periods of full employment which could be used were 1910-1929 and 1942-1954. The use of a simple least squares prediction of the regression, in the case of aggregate supply functions will not be helpful, since many different relations exist, between variables in the economy. He described the simple regression technique that " This procedure can only provide a mongrel relationship ...."[2)]. The supply elasticities, in this case, he said could be obtained only by a simultaneous equations system.

Cromarty in 1956 published a papaer studying the relationships within agriculture and between agriculture and other sectors of the economy on the national level. He wrote

> The object of this paper is to present some additional empirical results on the major macro-relationships existing within agriculture and between agriculture and the remainder of the economy.[3)]

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1) Earl O. Heady, "The Supply of U.S. Farm Products Under Conditions of Full Employment," Journal of American Economic Review, May 1955, 45: 228-238. P. 228.

2) Ibid., p. 233.

3) James T. Bonnen and William A. Cromarty, "The structure of Agriculture," Agricultural Adjustment Problems in a Growing Economy, Edited by E.O. Heady and others, Iowa State College press, Ames, Iowa, 1958, p. 110.

He studied only the most important commodities. He divided the commodities studies into twelve categories. The period covered was 1929-1953. He estimated the demand and supply relations for all these categories. He used a model of 35 structural equations. One hundred and ten variables were used. In estimating the supply relation for crops he attempted to explain the effects of price expectations as measured by lagged product prices, prices of alternative crops, costs of items used in production, wheather and technological advances as measured by physical units of equipment. In the case of non-crop products, he measured the effects of costs of items used in production, the level of fixed assets, price expectations as measured by lagged products prices and in some cases technological improvements.

The model used was relevant to a relatively short period. He stated that

> If the model is to be applied to longer time periods, then the flow of resources between the agricultural and non-agricultural sectors of the economy must be given more emphasis [1].

Brennan in 1958 published a paper studying the U.S. supply fuction for cotton. He wrote

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1) Ibid., pp. 155-116.

> The total U.S. supply could then be built up from several functions--one for each region containing the variables relevant to that region. Ideally each region would be defined in terms of homogeneity of crop substitutes, technology, climate, etc .... [1]

Therefore, he divided cotton acreage in the U.S. into three geographic categories, the Southeast, the Mississippi Delta and the Southwest. The period covered was 1905-1932. He represented the acreage-response function for each category by a linear equation. The independent variables were the expected prices of cotton, expected prices of selected substitutes such as corn, tobacoo, peanuts and wheat and trend.

Griliches in 1959 published a paper in which he estimated the aggregate supply elasticity of the United States farm products. He used in his estimate the elasticities of the demand for inputs in U.S. agriculture. He wrote

> .... agricultural inputs are responsive to changes in relative prices. But if inputs respond to rpice changes, so must also farm output. It can be shown that any supply elasticity can be expressed as a weighted average of all elasticities of demand for individual inputs with respect to price of the product. [2]

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1) Micheal J. Brennan, "changes in Cotton Acreage in the Southeast--Implications for Supply Functions," Journal of Farm Economics, November 1958, 40: 835, p. 842.

2) Zvi Griliches, "The Demand for Inputs in Agriculture and a Derived Supply Elasticity," Journal of Farm Economics, May 1959, 41: 309-322, p. 318.

He assumed that the input factors were paid the value of their marginal product, and therefore, he used the factor shares as weights.

His aggregate supply elasticity can be presented as follows:

$$eqp = \sum_i k_i \eta_{ip}$$

where eqp is the supply elasticity of output q with respect to its own price p, k_i is the share of factor i in total costs or revenue and η_{ip} is the elasticity of demand for factor i with respect to changes in the price of the product. He assumed also that factor prices are given and fixed.

Griliches in 1960 published a study of the aggregate supply function. He wrote.

> The purpose of this paper is then to present some estimates of the aggregate U.S. farm supply elasticity, using a relatively simple econometric model.[1]

In his study he used a simple distributed lag model and introduced Stalling's [2] weather index to take care of weather effects. The dependent variable was output measured by the ARS Index of Farm output. The independent variables were prices by the USDA Price Indexes, weather by Stalling's weather index, lagged farm output

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1) Zvi Griliches, "Estimates of the Aggregate U.S. Farm Supply Function, "Journal of Farm Economics, May 1960, 42: 282-293, p. 283.

2) James L. Stallings, "Weather Indexes, "Journal of Farm Economics, Febuary 1960, 42: 180-186.

and technological change by a trend variable. All variables except trend were expressed as logarithms of original values. He estimated also the elasticities of two sub-aggregates all crops and livestock and livestock products. The period covered was 1920-1957 for the aggregate farm output and 1911-1959 for the two sub-agregates.

By comparing the studies that have been done in micro level with that in the aggregate level, one can find that adequate work has not been done in estimating and studying the aggregate agricultural supply functions. Most of the work has described aggregate relations rather than estimating them. Even those who attempted to obtain aggregate supply functions by horizontal aggregating of supply functions in different regions or for different commodities were faced with many problems and limitations. These problems may be the result of complexity of the agricultural structure, data limitations and different alternatives available for factors of production.

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