Agricultural Economics Research

APRIL 1968 Vol. 20, No. 2

in this issue Page

UNITED STATES DEPARTMENT OF AGRICULTURE • Economic Research Service

CONTRIBUTORS

W. NEILL SCHALLER is Leader, Production and Response Group, Production Adjustments Branch, Farm Production Economics Division, ERS.

L. G. TWEETEN is Professor of Agricultural Economics, P. L. STRICKLAND is an Agricultural Economist with ERS, and J. S. PLAXICO is Professor and Head, Department of Agricultural Economics; all are at Oklahoma State University.

THOMAS A. MILLER is an Agricultural Economist with the Farm Production Economics Division, ERS, stationed at Colorado State University where he is Great Plains regional analyst for the Division's work on area and national analytical models.

HAROLD B. JONES is an Agricultural Economist with the Marketing Economics Division, ERS, stationed at the University of Georgia. JACK C. THOMPSON is Professor of Marketing, Department of Agricultural Economics, University of Georgia.

GEORGE R. KRUER is Assistant Chief, International Monetary and Trade Research Branch, Foreign Development and Trade Division, ERS.

WARREN R. BAILEY is Deputy Director, Farm Production Economics Division, ERS.

ROBERT G. DUNBAR, Montana State University, works with the Foreign Training Division, International Agricultural Development Service.

ANN MILLER, International Economist, and HANS G. HIRSCH, Agricultural Economist, are in the Trade Statistics and Analysis Branch, Foreign Development and Trade Division, ERS.

SHELDON TSU is in the Europe and Soviet Union Branch, Foreign Regional Analysis Division, ERS.

Agricultural Economics Research

A Journal of Economic and Statistical Research in the United States Department of Agriculture and Cooperating Agencies

April 1968 Vol. 20, No. 2

A National Model of Agricultural Production Response

By W. Neill Schaller[1]

THE NATIONAL ECONOMIC MODEL described in this paper was developed by the Farm Production Economics Division, Economic Research Service. Many agricultural economists know of this analytical endeavor as the "FPED national model." The research is outlined in only a few published papers--none widely circulated (10, 11, 12)[2]-- and so a more complete and accessible report is overdue.

The developmental research began in 1964. Although the resulting model is now operational, improvements are still being made. Therefore, what follows is an interim report on the methodology used so far, a discussion of tests completed and underway, and a summary of lessons learned from the research experience.

Background

THE PROBLEM

The specific research mission is that of providing short-term quantitative estimates of aggregate production and resource adjustments under alternative prices, costs, technologies, resource supplies, and Government programs. This kind of research might be called "impact analysis" or "what-if" research. One can think of many policy questions requiring this information: What would be the probable acreage of cotton next year if proposed changes are made in the cotton program? How would these changes affect soybean production? How much will a proposed feed grain program cost the Government? What will be the most likely effects of the program on aggregate farm income and resource use?

Answers to such questions have always been provided by area and commodity specialists based on the facts and figures at their disposal. The specialist normally uses what might be called informal methods of analysis. His ability to draw logical inferences from available data and research results, and to season these with informed judgment, is his trademark. The purpose of a formal model is to help the specialist by providing a systematic way of bringing to bear on a research problem more quantitative facts and relationships than the human mind alone can analyze.

It became apparent in the early 1960's that the Division's ability to apply formal research to specific policy issues needed to be amplified. The models then in operation were designed for longer term use and did not yield timely estimates of probable short-run response for the Nation as a whole or for major producing areas and farm types.

Existing research centered on two activities: Participation in regional adjustment studies and analyses of interregional competition. The regional studies, in cooperation with State universities, used linear programming to quantify optimum adjustments on farms of different types.[3]

[1] Credit for the research reported in this article goes to a team of researchers located in Washington and at a number of field stations.

[2] Underscored numbers in parentheses refer to items in the References, p. 45.

[3] These cooperative studies have titles such as "An Economic Appraisal of Farming Adjustment Opportunities in the __________ Region to Meet Changing Conditions." The different regional projects are known popularly as S-42, W-54, GP-5, the Northeast dairy adjustment study, and the Lake States dairy adjustment study. See (16) and (18) for examples of published research.

The Division's interregional competition research, in cooperation with Iowa State University, was concerned with the longer run question, How would production be allocated among regions under optimum economic adjustments?[4]

THE TASK FORCE

In 1963, a Division task force set out to determine what could be done to strengthen research in this area.[5] We first considered the possibilities of modifying the existing representative farm research program to meet our additional needs. This would have involved (1) modifying the linear programming farm models, or systematically adjusting the solutions, so that the resulting estimates would more nearly represent probable short-term response; and (2) aggregating the results.

One way to modify a linear programming model for shorter-run predictive purposes, discussed again later on, is to use current technical data and to add behavioral or flexibility restraints on enterprise levels. Mighell and Black applied this general approach in their pioneering study of interregional competition (8). The theory of flexibility restraints suggests that actual year-to-year changes in the past are logical data on which to base these upper and lower bounds (2, 5, 13). But because time series data are available for aggregates of farms rather than individual farms, this theory would be difficult to apply at the farm level. Similarly, there was no known way to systematically adjust optimum farm solutions to represent "probable" response.

The problem of obtaining aggregate estimates from representative farm analyses appeared equally difficult. As several hundred of these farms were involved in the regional work, the basic question was whether it is realistic to try to build up national aggregate estimates from the farm level (1, 11, 14).

In view of these difficulties, the task force turned to the possibilities of adapting existing interregional competition models. Here the problems of modifying the model and obtaining aggregate results were less severe because the models were national in scope and used geographic regions as units of analysis. But these models, by design, were concerned only with the longer run equilibrium adjustments between regions, whereas we needed also to provide estimates for farming situations within regions.

In summary, the nature of our existing research pointed definitely to the need for a new, complementary model with two essential characteristics. First, the model must be aggregate in perspective but still retain as much micro detail as possible within practical limits on cost, time, and research manageability. Second, the model must incorporate technical attributes that will give it a much stronger predictive property than is found in most linear programming models.

Other techniques examined by the task force included a number of conventional statistical models and simulation. As statistical models analyze data on actual economic behavior, the resulting estimates are considered more predictive than the solutions to an optimizing model. However, policy questions typically require analyses of effects of production environments that differ substantially from the "structure" observed in the past.

Simulation was thought to be especially promising for our purposes. As defined by most economists, it too involves use of data on actual behavior. Simulation is more versatile than other statistical methods for many policy problems. However, at the time of our evaluation, few agricultural economists had had sufficient experience with simulation.

So, we came back to programming as the method currently best suited to our needs. We did so with the idea that the model would be only a first step--that it would be gradually reshaped to incorporate more desirable properties and that other models would be developed over time to supplement or even replace it.

Characteristics of the Model

With only minor changes, the national model blueprint drawn up in 1964 describes the current framework. The model is based on the cobweb principle that current production depends on

[4] This research project is titled "Economic Appraisal of Regional Adjustments in Agricultural Production and Resource Use to Meet Changing Demand and Technology." See (15) for an example of published results.

[5] Members of the task force were Walter R. Butcher, Chairman (now at Washington State University), Thomas F. Hady, John E. Lee, Jr., and the author.

past prices, while current prices depend upon current production (6, 20, 21).

In its simplest form, the principle is expressed by two equations:

(1) $Q_t = f(P_{t-1})$

(2) $P_t = f(Q_t)$

Empirical applications of the cobweb principle almost always involve use of regression analysis of aggregate time series data on prices and production. The national model, in contrast, is a more elaborate cobweb model that uses recursive linear programming to estimate production (5, 13). To date we have limited our development and testing of the model to the part of the system in which production for year t + 1 is estimated from prices and other data through year t (equation 1). However, the full system is outlined below under "operation of the model."

The current model is primarily a crop production model. The methodology is believed to be less suitable for estimating livestock response. However, livestock are included on a limited scale.

The units of analysis in the model are aggregate producing units. They consists of geographic areas, many of which are further divided into aggregate resource situations. The latter unit is simply an aggregate of farms--not necessarily contiguous farms--having similar production alternatives, resource combinations, and other characteristics. The purpose of this subdivision is to strengthen area estimates, by recognizing major differences among farms within the area, and to enable us to say something about production response on major types of farms.

More often than not, the firm is the unit of analysis in applications of linear programming. When an aggregate of firms is the unit, one is assuming that the firms are sufficiently similar that they will respond in a similar way to economic stimuli.[6] One is not assuming that decisions for each firm are made by a hypothetical master-planner. This distinction seems trivial, but if the latter assumption is made, an incorrect evaluation of results of the model may follow. The real issue is the extent to which the reliability of aggregate model results is reduced as the assumption of firm homogeneity becomes less tenable. This question is discussed under test results.

[6] From a programming standpoint, if the firms meet certain conditions of similarity, the same programming solution is obtained by summing the solutions to individually programmed firms and by solving one firm model with right-hand-side elements equal to the sum of firm right-hand-sides.

METHOD OF ANALYSIS

Each production year is treated by the model as a different decision problem for farmers. Hence a different programming problem with profit maximization as the objective is defined for each year. Of course, a different problem is also specified for each resource situation.

The farmer, when making plans for next year, knows that he cannot influence the prices he pays and receives, nor does he know what yields he will obtain. We assume that he formulates his expectations largely on the basis of recent experience. Accordingly, the price and yield data in the programming problem for each year--the data we assume to represent farmers' expectations--are based on data for the preceding year(s).

The recursive programming model assumes that farmers want to make as much money as possible, but only within realistic and often very restrictive limits. Herein lies an important methodological difference between the traditional use of programming (to determine how resources "ought to be" allocated to maximize profit) and its use in the national model.

As noted earlier, farmers are not likely to maximize profit even if they want to (except by chance) because many of the profit-determining variables are unknown to them when plans are made. Also, farmers seldom choose to respond exactly as the short-run economic "optimum" would dictate. They have interests in addition to immediate profit, such as longer run income considerations, a desire for leisure, and personal preferences for producing certain commodities.

As we want to estimate farmers' most likely production response, the model must take these other economic and noneconomic forces into account.[7] The technique used so far is to add flexibility restraints on the year-to-year change in the aggregate acreage of each production alternative specified in the model. These limits are expressed as percentage increases and decreases from the previous year's acreage. In programming notation, they are expressed as follows for a given resource situation:

Upper bound: $X_{jt} \leq (1 + \overline{\beta}_j) X_{j,\ t-1}$

Lower bound: $X_{jt} \geq (1 - \underline{\beta}_j) X_{j,\ t-1}$

where X_{jt} refers to the total solution acreage of crop j for year t; $X_{j,\ t-1}$ is the actual acreage in year t-1 (or our best estimate of that acreage); and $\overline{\beta}_j$ and $\underline{\beta}_j$ are the maximum allowable percentage increase and decrease, respectively (decimal form), from the acreage in the preceding year. For example, if the cotton acreage in year t-1 is 100,000 acres, and $\overline{\beta}$ and $\underline{\beta}$ equal 10 and 40 percent, respectively, the solution acreage of cotton is restrained to fall between 110,000 and 60,000 acres.

Empirically, $\overline{\beta}$ and $\underline{\beta}$ (called flexibility coefficients) can be estimated in many ways, ranging from use of the average percentage changes in the recent past to application of a more comprehensive regression analysis.[8] The basic principle followed in almost all cases is that acreage history measures indirectly the many forces that have kept the particular enterprise from increasing or declining at a faster rate. Often, however, it is desirable to adjust the results of the historical analysis to account for information about the current production environment (for example, a new technology, market competitor, or change in Government supply programs for the enterprise or its alternatives.)

Apart from the explicit treatment of time and the addition of flexibility restraints, the programming problem for each resource situation--the programming submodel--is quite like a conventional programming model applied to an aggregate unit. The "objective" of each submodel is to maximize total net returns over variable costs. The activities in the submodel are the production alternatives and other choices open to the unit. The restraints include cropland, other physical resource limitations, and institutional limits such as allotments.

OPERATION OF THE MODEL

The cobweb or recursive principle of economic behavior fits crop agriculture better than any other industry. This is because of the relatively large number of producing units and the biologically imposed time lag in the production of farm crops. Thus it is reasonable to assume that farmers will act independently when making production plans for the period ahead and that aggregate acreage and price information received during the production period will not affect actual production as much as it often does in other industries. Livestock response is more complex. Hence the current model, as mentioned earlier, is primarily a crop model.

The cobweb principle applied to crops permits us to analyze response sequentially--the way it occurs. To estimate national response 1 year ahead (1) almost any producing unit--from the single farm to a broad geographic area--can be analyzed as an independent part of the whole, and (2) we can say with relative confidence that the sum of independent plans will be a reasonable estimate of aggregate output.

When aggregate estimates are to be made for more than a year ahead (or if income next year is to be estimated), the price effects of aggregate output in the first year must be taken into account. But this can be done as a separate step in the analytical sequence.

Short-run analysis (1 year ahead): The 1-year analysis is illustrated schematically in figure 1. In the case of each crop, the unknown variable estimated by the model is "planned" acreage. As in most models of this type, no attempt is

---

[7] Admittedly, there are different interpretations of this problem. Tweeten writes that "...farmers need not maximize profit for the programming models to predict actual behavior--it is only necessary that farmers behave as if they were following the profit-maximizing norm subsumed in the programming models" (19, p. 95).

[8] In addition to using time series analysis of actual data to estimate bounds, an analysis of the discrepancies between optimum and actual response might also prove useful. One can see that with flexibility restraints derived from some kind of time series analysis, the model becomes a synthesis of what the profession calls "positive" and "normative" research.

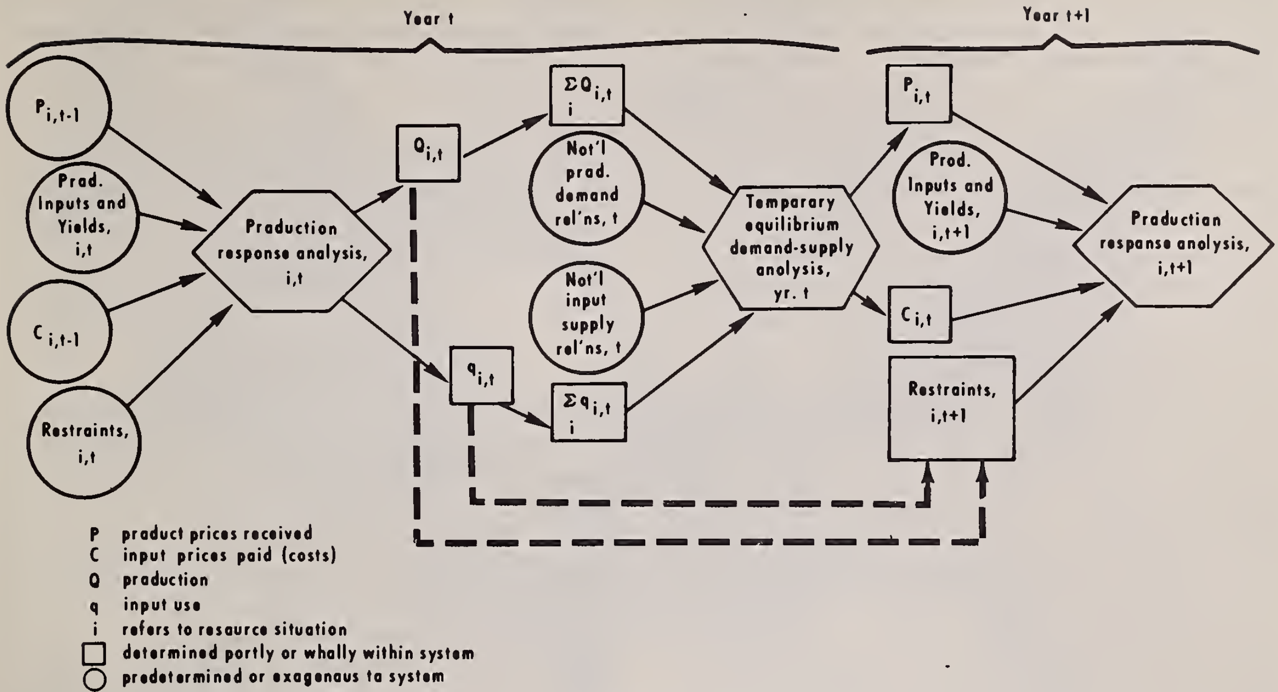

Figure 1

made to estimate "harvested" acreage within the model. That is, the analysis does not explain, or take into account, changes in post-planting practices or the effects of weather. Harvested acres are derived from planned (planted) acres using the average or expected differential between the two figures.

The programming solution also includes estimates of planned production, obtained by multiplying acreages times expected, normal, or assumed yields (whichever is appropriate to the policy problem at hand). The production so estimated for a given resource situation in year t is denoted by $Q_{i,t}$ in figure 1. This $Q_{i,t}$ includes a vector (or set) of production estimates, one for each commodity produced by the unit. The summation of these outputs across resource situations and areas (with the addition of production, if any, in areas excluded from the model) gives us a set of national estimates, or $\sum_i Q_{i,t}$. Similarly, on the input side, the quantities of inputs associated with the production estimated for a given resource situation are denoted by $q_{i,t}$, and the national quantities by $\sum_i q_{i,t}$.

Intermediate-run analysis (more than 1 year ahead): Having obtained estimates for next year, we can go on to subsequent years by introducing product demand and input supply relations. These are needed to determine the effects of aggregate output on the product and factor prices farmers will expect in the subsequent year. This can be done in a fairly simplified way using national relations, as illustrated in figure 1.

When the national estimate of production for a given commodity in year t is plugged into the demand function for that commodity, we obtain the market price that would be associated with that production.[9] This is done separately for each commodity. The resulting "temporary equilibrium" prices, as we call them, when fed back to each submodel--for example using historical price differentials--become or are used to derive the expected prices for year t+1.

[9] Stocks and other factors determining supply, in addition to production, will have to be taken into account beforehand. Also, the demand functions will have to show the effects of Government programs.

The same procedure applies in theory to the input side. Total inputs used in production for year t can be matched with input supply functions to determine "temporary equilibrium" input prices, which are then used to determine expected input prices for year t+1.

Theoretically, area product demand relations might be used instead of national relations. In this case, the programming results could be fed into transportation models (augmented to include relations instead of fixed demands). The results of the transportation model analysis would consist of area prices.

The feedback described above involves more than the derivation of expected prices for year t+1 based on the solutions for year t. Flexibility and other restraints for t+1 also depend on the estimates for year t, as suggested by the dashed line in figure 1.

The input and yield data and other components of the system determined outside the analysis are then updated to year t+1 and a new round of computations begins, this time to estimate production and resource use in t+1. Thus, the intermediate-run application of the model will generate a sequence of year-to-year estimates of planned acreage, production, and resource use. Also, given the product demand and input supply functions, and implied market prices, we obtain a rough measure of changes in farm income.[10]

Longer-run analysis: Certain policy questions will continue to require analysis of longer-run equilibrium adjustments in commercial agriculture. Public policy makers need such a frame of reference to measure the economic gains and losses associated with alternative courses of action and to establish policy goals. Thus the policy issue may require a comparison of equilibrium (how production would be allocated assuming all economic adjustments are made) and the most likely adjustment path. Rather than treat these two problems as entirely different research studies, a more meaningful comparison may be possible if the same basic model is used for both.

Although longer-run analyses are not in our immediate plans for the national model research, the model can also be used for such problems. This will probably involve the same general procedure outlined for the intermediate-run analysis, except that the variables will not be time-dated. Each round of computations will be interpreted as a "correction" for the effects of aggregate output on prices, and the sequence will be repeated until the prices we have at the end of one round are essentially the same as those we used at the start of that round.

A Historical Test

In most projects of this kind, where ex ante predictive estimates are the desired research product, one first converts the methodology into an empirical model and then tests that model against history. This procedure allows the analyst to evaluate the model's performance without waiting until model estimates can be compared with future outcomes.

Accordingly, we began in 1964 by developing an experimental model and testing it against a historical period of sufficient length to permit a meaningful interpretation of results. The period 1960-64 was chosen for this purpose. The 5-year test was limited to an evaluation of the model's performance looking only 1 year ahead (the short-run application).[11]

Forty-seven producing areas were delineated for the test (shown in white in figure 2). A total of 95 resource situations was defined. These represent differences in farm size, soil type, source and cost of irrigation water, and other characteristics.

The activities and restraints included in each submodel represented the alternatives available to producers during the period. Emphasis was placed on major field crops--cotton, wheat, feed grains, and soybeans. Other crop alternatives were included in areas where their production is interrelated with the production of major crops. Examples are flax, oats, extra long staple cotton, and sugarbeets. Livestock

[10] This intermediate-run operation is a simplified version of what Richard H. Day has called "dynamic coupling." See (3).

[11] The test was managed by four professionals in Washington, D.C. (W. Neill Schaller, project leader, Fred H. Abel, W. Herbert Brown, and John E. Lee, Jr.). About 20 members of the Division's field staff located at State universities spent an average of 2 to 3 months each constructing submodels and assembling data.

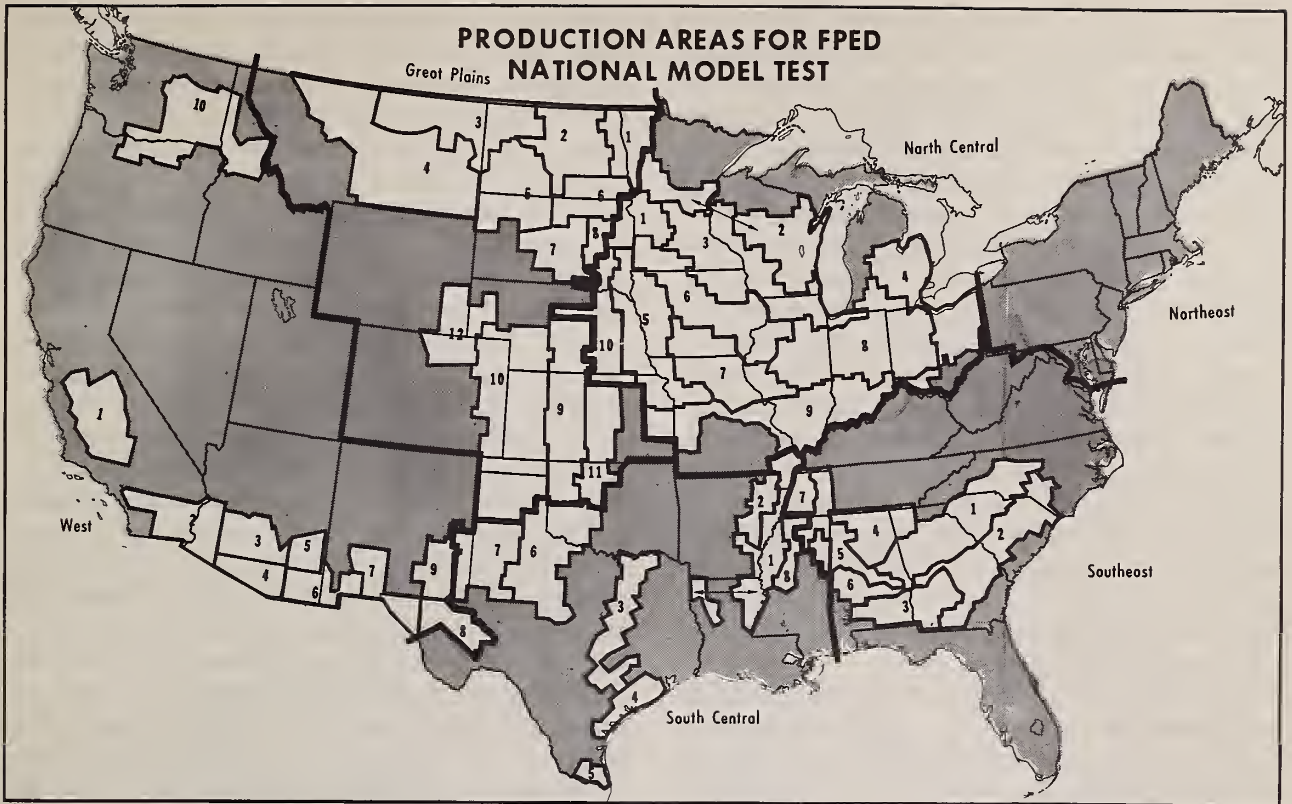

Figure 2

activities were included only in areas where it was believed that their inclusion would improve the model's ability to estimate crop acreages. Government programs for cotton, wheat, and feed grains were also built into each submodel.

The model areas shown in figure 2 accounted for the bulk of the 1960-64 U.S. acreage of most major crops: 85 to 90 percent of the upland cotton and soybeans; 80 to 85 percent of the corn, wheat, and grain sorghum; and 68 percent of the barley. As a rule, these areas accounted for somewhat higher proportions of U.S. production, as many of the omitted areas had lower yields.

The technical coefficients used in the test were based largely on the data developed for the regional adjustment studies discussed earlier. Other required data consisted of county acreage and yield estimates from USDA's Statistical Reporting Service, and county allotments, base acres, payments, and diversion data from Agricultural Stabilization and Conservation Service.

The 95 programming submodels varied in size and complexity from one area to the next. The average submodel for 1964, the last year of the test, had 39 rows, 28 real activities, and 309 matrix elements. The 95 submodels had a total of 3,700 rows, 2,630 columns, and 29,000 matrix elements.

SELECTED ACREAGE RESULTS

The results reported here are limited to the acreage estimates for six crops: upland cotton, wheat, corn, barley, grain sorghum, and soybeans. Also examined are the model estimates of acreage diverted under voluntary participation programs for feed grains, and wheat.

Table 1 shows the percentage deviation of model estimates from actual acreage for each of the six crops.[12] These results are summarized for the FPED field groups outlined in figure 2, as well as for the total model.

To interpret such a large and varied assortment of test results is a real challenge. Obviously the model estimates are relatively close to actual response for some commodities in some areas, but not for others. Unlike the results of regression analysis, the solutions to a programming (economic) model cannot be summarized by statistical measures of reliability. Nevertheless, a number of important observations can be made:

1. The deviations shown in table 1 tend to be smaller for the total model than for the FPED field groups. Though not shown in the table, the estimates for areas and resource situations within each field group tend to be less accurate than those for field groups.

This phenomenon, though not surprising, opens the question as to how one ought to interpret the more aggregative results, knowing that there are larger, offsetting errors in the estimates at lower levels of aggregation. The appropriate interpretation would seem to be that the model is not unlike a sampling procedure which gives the results for the aggregate greater validity than those for the parts. Of course this reasoning suggests that to provide estimates for areas and resource situations that are just as useful as those for the total model, either we need more realistic submodels or we must use other methods to obtain those estimates.

2. A second observation is that the model estimates for allotment crops, such as cotton and wheat, tend to be more accurate than those for nonallotment crops. This, too, is not surprising. Because the allotment crops are generally the most profitable alternatives, one expects them to go to their allotments in a programming solution.

3. The errors of estimation for a crop whose acreage fluctuates quite a bit are usually larger than for a crop with a relatively stable acreage path. There is also a tendency for the model to overestimate the acreages of the more profitable crops that are not restrained by allotments. This is due mainly to the use of a very simple technique to derive flexibility restraints. We used as flexibility coefficients (allowable rates of change) the average of actual percentage changes since 1957, plus a standard deviation. The same rule was applied throughout. Test results clearly suggest that different techniques of estimating flexibility coefficients should be used for different crops in different areas.

Flexibility coefficients are not the only source of error attributable to upper and lower bounds. The base acreage (X_{t-1}) may also be a culprit. Use of the preceding year's acreage as the base often produces unreasonable bounds when that acreage fails to represent the real intentions of farmers. For example, if poor weather at planting time in year t caused farmers to plant less than they had intended, flexibility restraints for year t+1, when set around that acreage, are likely to misrepresent the appropriate limits for t+1. This situation suggests that it may be better in some cases to use an average or trend acreage instead of X_{t-1}.

4. The 95 programming submodels yielded a total of 3,270 acreage estimates in the 5-year test. Two-thirds of these estimates were restrained by the crop's own upper or lower flexibility restraint. While this clearly indicates the importance of improving the upper and lower bounds,[13] it also reflects the absence of other restraints. If the model can be more fully specified on the restraint side, its dependence on flexibility restraints will be lessened. Unfortunately, it is more difficult to quantify restraints on physical inputs, such as cropland and labor, for an aggregate-predictive model than for a farm model.

[12] Percentage deviations provide a good summary but do not tell the whole story. One must take account of the absolute acreage levels to properly evaluate these results. In table 1, the deviations for the "total model" provide this information indirectly. For example, the 1962 wheat estimate for the Southeast is 105 percent in error, but the total model deviation is only 4 percent.

[13] It bears noting, however, that the "effectiveness" per se of flexibility restraints is not necessarily an indication of model weakness. Some have argued that it is--that if the bounds are effective consistently, one does not need to use programming. He can take the bounds as estimates of response. This argument ignores the fact that the analyst will not always know in advance which bounds will be effective or at what price and restraint conditions individual bounds would no longer be effective.

Table 1.--Percentage deviation of model acreage estimates from actual data for selected crops, 1960-1964[a]

Crop	1960	1961	1962	1963	1964	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Cotton, upland:						
Southeast.........	13	7	9	10	0	8
South Central.....	1	1	0	0	1	1
West..............	1	1	0	1	8	2
Total..........	2	2	2	2	1	1
Wheat:						
Southeast.........	63	15	105	7	2	38
South Central.....	2	10	5	5	21	9
West..............	1	0	7	1	4	3
Great Plains......	3	0	1	10	1	3
North Central.....	21	5	17	10	10	13
Total..........	7	1	4	9	0	4
Corn:						
Southeast.........	6	10	8	4	5	7
South Central.....	3	20	17	7	3	10
Great Plains......	8	15	10	4	6	9
North Central.....	12	26	18	9	17	16
Total..........	11	24	17	6	15	15
Barley:						
West..............	4	1	5	5	0	3
Great Plains......	7	14	1	2	0	5
North Central.....	26	22	3	35	21	21
Total..........	4	10	0	2	1	3
Grain sorghum:						
South Central.....	5	9	3	2	17	7
West..............	11	12	9	4	21	11
Great Plains......	22	26	3	9	37	19
North Central.....	13	116	19	10	29	37
Total..........	13	31	5	3	27	16
Soybeans:						
Southeast.........	2	0	17	10	11	8
South Central.....	6	1	1	2	2	2
Great Plains......	56	15	131	33	18	51
North Central.....	6	2	13	12	5	8
Total..........	7	1	12	10	4	7

[a] Deviations are without regard to sign.

298-263 O - 68 - 2

5. Errors in the model's estimates of crop diversion under voluntary Government programs (table 2) can be traced to a number of causes. The use of aggregates rather than individual farms is one. A linear programming model picks the most profitable alternatives open to the unit (subject to restraints). Therefore, the solution can be expected to include only one of the options offered in a voluntary program. This kind of solution makes sense for a single farm. It also makes sense for an aggregate model if the aggregate consists of homogeneous farms. In practice, the aggregate does not. We accounted for the expected range of individual farm responses in each resource situation by adding flexibility restraints on the aggregate diversion of each crop that were narrower than the limits specified in the program.

Historical data on actual diversion are far less useful for estimating such restraints than past crop acreages are for estimating crop bounds. This is because the history of diversion programs is limited and year-to-year changes in program provisions cast doubt on the validity of diversion bounds estimated from history. Consequently, our diversion bounds for the test--though reflecting history--had to be set somewhat arbitrarily. The extent to which these bounds were too wide, or too narrow, may explain part of the discrepancy between estimated and actual diversion.

One way to alleviate this difficulty is to use a larger number of resource situations per area, basing them on characteristics that influence farmers' decisions to go into or stay out of a voluntary program. Knowing what characteristics to define and having data to permit a breakout of new situations are the main problems involved in this approach.

The discrepancies shown in table 2 are too large to suggest that the model alone could provide reliable estimates of response to voluntary programs. Many factors affect farmers' response to such programs in addition to those quantified in the model (length of signup period, farmers' views on farm policy, their understanding of the program, and so on). But with the possibility of bringing more of these factors under control in the overall analysis, the outlook for the model is encouraging.

Table 2.--Percentage deviation of model diversion estimates from actual diversion, 1960-1964[a]

Crop	1960	1961	1962	1963	1964	Average
Feed grain diversion:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Southeast.........	(b)	(c)	7	28	9	15
South Central.....			28	1	25	18
West..............			10	9	9	9
Great Plains......			6	9	22	12
North Central.....			20	15	14	16
Total...........			9	9	16	11
Wheat diversion:						
Southeast.........	(b)	(b)	49	12	3	21
South Central.....			39	64	118	74
West..............			5	194	11	70
Great Plains......			27	49	15	30
North Central.....			24	142	130	99
Total...........	--	--	27	62	33	41

[a] Deviations are without regard to sign.
[b] Diversion program not in effect.
[c] Diversion program in effect, but data on actual diversion not available.

In summary, the estimation errors revealed in the test fall into two general categories: Errors of aggregation, and errors of specification (9, 17). Aggregation errors, illustrated above for diversion results, are common to all research designed to yield aggregate estimates, regardless of the unit of analysis. The basic problem in the case of an aggregate model is that when firms are grouped together for analysis, as though they were homogeneous, the resulting estimates invariably differ from the estimates that would be obtained by analyzing each firm separately. Included under errors of specification are those due to the way the model simulates production alternatives, expected earnings, and restraints--as well as the decision-making process itself.

The errors in both categories are frequently due to scarcity and inferior quality of data. The structuring of an analysis is often guided by data availability, and the absence of certain data often forces the analyst to make compromises that may cause errors, although hopefully they will not be large ones.

The national model test was a test of the hypothesis that one can evaluate the effects of certain factors on farmers' aggregate production response using a profit-maximizing, recursive model with flexibility restraints. The results, though pointing to certain weaknesses in the model, support that hypothesis. Moreover, one must evaluate a model in terms of whether it can provide better information at reasonable cost than that obtainable from alternative methods.

An Ex Ante Test

The historical test taught us a great deal, but it did not answer several questions about the model's potential performance in a real world, or ex ante, application. For one thing, the test did not examine the model's true predictability because actual outcomes were known before the analysis was conducted. In fact, certain data on crop acreages and participation in Government programs for years through 1964 were used to derive restraints for each year of the test. This use of "advance information" was unavoidable when data for years prior to the test period were insufficient.

As explained earlier, the cobweb approach requires data for year t to estimate response in year t+1. Data for year t were available when the historical analysis was conducted. We realized that considerable data would not be available for ex ante applications. County acreages and yields for a given year are not reported until a year or so later. Hence, another unanswered question is, what do you substitute for these data? And what effect will this substitution have on the model results?

Finally, the test did not really answer the critical question, can a fairly comprehensive model be structured and updated during year t in time to provide estimates of response that are useful to those who have to make policy decisions for year t+1?

In view of these considerations, we decided early in 1967 to update the model and apply it to policy questions concerning response in the 1968 production year. The idea was to catch up with time--to begin to do before-the-fact analyses on an annual basis--all the while making improvements in the model and the data, and developing complementary models wherever appropriate.[14]

The initial step in the 1968 analysis was to update the historical model, incorporating a number of structural and data improvements, on a time schedule that would test the practicality of the model. A few changes were made in area boundaries and numbers of resource situations (the 1968 model includes 52 areas and 83 situations). Flexibility restraints were

[14] Early in 1967, 7 members of the Division's field staff were named regional analysts and given increased responsibility for the planning and conduct of the research: W. C. McArthur, Athens, Ga. (Southeast), Percy L. Strickland, Stillwater, Okla. (South Central), Walter W. Pawson, Tucson, Ariz. (Southwest), LeRoy C. Rude, Pullman, Wash. (Northwest), Thomas A. Miller, Ft. Collins, Colo. (Great Plains), Gaylord E. Worden, Ames, Iowa (North Central), and Earl J. Partenheimer, University Park, Pa. (Northeast). Glenn A. Zepp, Storrs, Conn., replaced Partenheimer as the Northeast Analyst during the year. Jerry A. Sharples shared with Worden the responsibilities of analyst for the North Central region until mid-1967 when Sharples transferred to Washington, D.C. for a temporary assignment with the Washington staff.

estimated in a number of ways considered appropriate for individual crops and areas.[15]

A benchmark policy situation was defined for 1968. It assumed that 1967 product prices would be those expected in 1968. Other assumptions included trend changes in inputs, yields, and costs, and a continuation of 1967 Government programs for cotton, wheat, and feed grains. Our plan was to complete the preparation of all benchmark data by July 1, 1967 (4 months after actually starting). Following the programming stage, we intended to analyze selected policy questions concerning proposed changes in Government programs.

As it turned out, preparation of the benchmark material was not completed until mid-September, and the benchmark programming was not finished until November. This "dry run" analysis proved that faster and more efficient procedures for collecting and processing data, and an earlier start, are needed if the national model is to make a timely contribution to policy questions. Most of the key decisions concerning 1968 program provisions were made before the analysis was complete. However, certain proposed changes in the 1968 cotton program were studied with the national model, mainly to gain further experience in policy application and to learn more about the model's capability. The results of the benchmark and cotton analyses are still being studied, but as in the case of the historical test, a few observations can be made:

1. We do indeed learn more by doing than by armchair reasoning. The 1968 experience suggested ways of reducing the time needed to update the model and complete the analysis. Current plans to update to 1969, and then to 1970, will include use of faster and more efficient data assembly and processing procedures.

Nevertheless, it is probably unrealistic at this stage of our experience to think of using the model to "field" a specific policy question requiring an answer in a matter of days, or even weeks. Considerable time is needed to study and evaluate the large quantity of results; this is often overlooked in the current age of electronic computation. A more reasonable approach is for the analysts--through good communication with policymakers--to anticipate the main policy issues early in the year and to develop a basic set of response estimates that can be used to shed light on specific questions that arise as the year progresses.

This discussion may suggest that the national model analyst is one who responds only to questions asked by others. On the contrary, the analyst not only can but should extend his role to that of studying policy alternatives which he believes to merit research, even though the public and policymakers have not posed any questions. Such a role also applies to the analysis of a question that has been asked. For example, if we are asked to analyze the effects on cotton production of a change in the diversion payment, we should also consider the effects on alternative crops. The results of this research may point out side effects of a program that had not been anticipated.

2. In the 1968 test, we came to grips with the problem of not having actual 1967 prices and acreages on hand when the analysis was conducted. The prices we used were based on 1967 projected U.S. prices developed by the Department, and individual crop acreages were derived from "March 1 planting intentions." The resulting input data are not as satisfying to us as their counterparts in the historical model, but by using them we learned more about their limitations--and possible alternatives--than if we had chosen the security of further historical testing.

Concluding Remarks

At a workshop on the national model in October 1967, Washington and field participants looked especially at where we had been and how we ought to proceed. It was agreed that the current national programming model should be viewed as a central activity, but by no means the only activity, in the Division's program of research on aggregate production adjustments. We need an integrated research program that includes an improved version of the current model plus other analytical means

[15] The paper by Thomas A. Miller in this issue of Agricultural Economics Research describes an approach used in the Great Plains to estimate flexibility restraints. Miller's regression model can also be used by itself without the additional programming step. The choice would seem to depend on the research problem.

of researching questions requiring more micro detail than is possible in the current model, as well as certain aggregate questions needing almost immediate answers.

Several improvements in the model were planned. These include redelineation of area boundaries, better estimates of restraints, and collection of new data. Plans were also made to experiment with statistical models and to study the possibilities of using the results of individual farm analyses to provide better input data to the aggregate model or to adjust the estimates obtained from the latter.

A final point: The application of a formal model to policy research is often accompanied by skepticism on the part of some and by the belief on the part of others that what comes out of a computer is automatically right. Both reactions are incomplete. No formal model has yet predicted aggregate response with consistent accuracy. Neither has any informal model. But all too often, formal models are reported in the literature as though their purpose is to replace informal methods. A really effective tool kit must include both types.

References

(1) Barker, Randolph, and Bernard F. Stanton. "Estimation and aggregation of firm supply functions." Jour. Farm Econ., Vol. 47, No. 3, Aug. 1965, pp. 701-712.

(2) Day, Richard H. "An approach to production response." Agr. Econ. Res., Vol. 14, No. 4, Oct. 1962, pp. 134-148.

(3) ________ "Dynamic coupling, optimizing and regional interdependence." Jour. Farm Econ., Vol. 46, No. 2, May 1964, pp. 442-451.

(4) ________ "On aggregating linear programming models of production." Jour. Farm Econ., Vol. 45, No. 4, Nov. 1963, pp.,797-813.

(5) ________ Recursive Programming and Production Response. North Holland Publishing Co., Amsterdam, 1963.

(6) Ezekiel, Mordecai. "The cobweb theorem." Quart. Jour. Econ., Vol. 53, No. 2, Feb. 1938.

(7) Lee, John E., Jr., and W. Neill Schaller. "Aggregation, feedback, and dynamics in agricultural policy research." Price and Income Policies, Agr. Policy Insti., N.C. State Univ., Oct. 1965, pp. 103-114.

(8) Mighell, Ronald L., and John D. Black. Interregional Competition in Agriculture. Harvard Univ. Press, 1951.

(9) Miller, Thomas A. "Sufficient conditions for exact aggregation in linear programming models." Agr. Econ. Res., Vol. 18, No. 2, April 1966, pp. 52-57. Also, John E. Lee, Jr., "Exact aggregation--A discussion of Miller's theorem," pp. 58-61.

(10) Schaller, W. Neill. "Data requirements for new research models." Jour. Farm Econ., Vol. 46, No. 5, Dec. 1964, pp. 1391-1399.

(11) ________ "Estimating aggregate product supply relations with farm-level observations." Prod. Econ. in Agr. Res., Conf. Proc., Univ. Ill., AE-4108, Mar. 1966, pp. 97-117.

(12) ________ "New horizons in economic model use: An example from agriculture." Statis. Reporter, No. 67-12, June 1967, pp. 205-208.

(13) ________ and Gerald W. Dean. Predicting Regional Crop Production--An Application of Recursive Programming. U.S. Dept. Agr., Tech. Bul. 1329, April 1965.

(14) Sharples, Jerry A., Thomas A. Miller, and Lee M. Day. Evaluation of a Firm Model in Estimating Aggregate Supply Response. North Cent. Reg. Res. Pub. No. 179 (Agr. and Home Econ. Expt. Sta., Iowa State Univ. Res. Bul. 558). Jan. 1968.

(15) Skold, Melvin D., and Earl O. Heady. Regional Location of Production of Major Field Crops at Alternative Demand and Price Levels, 1975. U.S. Dept. Agr., Tech. Bul. 1354, April 1966.

(16) Southern Cooperative Series. Cotton: Supply, Demand, and Farm Resource Use. Bul. 110, Nov. 1966.

(17) Stovall, John G. "Sources of error in aggregate supply estimates." Viewpoint in Jour. Farm Econ., Vol. 48, No. 2, May 1966, pp. 477-479.

(18) Sundquist, W. B., J. T. Bonnen, D. E. McKee, C. B. Baker, and L. M. Day. Equilibrium Analysis of Income-improving Adjustments on Farms in the Lake States Dairy Region. Minn. Agr. Expt. Sta., Tech. Bul. 246, 1963.

(19) Tweeten, Luther G. "The farm firm in agricultural policy research." Price and Income Policies, Agr. Policy Inst., N.C. State Univ., Oct. 1965, pp. 93-102.

(20) Waugh, Frederick V. "Cobweb models." Jour. Farm Econ., Vol. 46, No. 4, Nov. 1964, pp. 732-750.

(21) Wold, Herman, and Lars Jureen. Demand Analysis. John Wiley and Sons, New York, 1953 (see esp. section 1.4).

Interregional Competition in Cotton Production

L. G. Tweeten, P. L. Strickland, and J. S. Plaxico[1]

GOVERNMENT programs to control cotton production and raise the price and income from the crop have not been free of criticism. One charge is that the allotment program has prevented the free movement of production to more efficient areas. It is argued that relaxing of Government programs would allow more cotton production to move profitably to irrigated sections of Texas and California. Such movement would be likely to affect the Southeast more than other areas.

The question of where cotton would be produced at various price levels in the absence of allotments is a problem of comparative advantage in interregional competition. The answer does not depend on absolute advantage, i.e., who can produce cotton at the lowest unit cost. The most extensive areas of low-cost cotton production are found in irrigated areas of Southern California and Southwest Arizona, the Texas and Oklahoma Plains, and the Mississippi Delta. Average direct cost per pound of producing cotton in these areas was approximately $0.19 in 1965 (4). In the same year, the average direct cost of producing cotton in the Southern Piedmont, Clay Hills, Black Belt, and Coastal Plains was about $0.25 per pound (4). These data, although useful for many purposes, do not tell us that the Southeast will discontinue cotton production if the price falls below $0.25 per pound.[2] The areas with an average cost of $0.19 per pound have an absolute advantage in cotton production over the areas with an average cost of $0.25 per pound. However, measuring absolute advantage with average cost data may be somewhat misleading because there are many local resource situations in each area which permit production at much lower cost.

Comparative advantage is reflected in the rate of return on scarce resources when farmers produce one commodity in preference to another. An area is said to have a comparative advantage in enterprises which yield the highest profit at specified or equilibrium market prices. The areas producing cotton at low cost may have alternative enterprises such as alfalfa, sorghum, wheat, etc., which are more profitable than cotton. These areas would continue to produce the most profitable crop even though their cost of producing other crops may also be lower than the cost in other areas. Conversely, in some areas with a high cost for producing cotton, cotton may still be the most profitable enterprise. These areas will continue to produce cotton as long as cotton holds this advantage.

Thus, answers to questions about the location of cotton production must consider not only the cost of producing cotton but also the alternative uses of scarce resources within the areas.

What would be the location of cotton production at various prices in the absence of crop allotments? The answer to this question is the subject of this report. Data are from regional research project S-42, "An Economic Appraisal of Farming Adjustment Opportunities in the Southern Region to Meet Changing Conditions" (1). The project was a cooperative

[1] The authors have borrowed heavily from "Cotton: Supply, Demand and Farm Resource Use" (1), published in 1966. Numerous researchers in the Agricultural Experiment Stations and U.S. Department of Agriculture made the 1966 report possible, and must be considered coauthors of the material in the following pages. The contributors to the research project are listed in the report cited above (1). Underscored numbers in parenthesis refer to items in the References, p. 55.

[2] Neither, as the authors make clear, are they intended to do so.

Conditions" (1). The project was a cooperative effort of the U.S. Department of Agriculture and the State agricultural experiment stations.

Past Research

Traditionally, two approaches have been used to study the location of production. One approach has been to estimate the location of production by comparing production costs among areas from detailed crop budgets. A second approach has been to use data from the Census Bureau and other sources to find costs and returns, then to use a single aggregate linear programming model to compute the least-cost or profit-maximizing level of production of commodities by areas (cf. 2). The former approach is inadequate as stated before because it fails to account for the profitableness of cropping alternatives and the fixed rigidity of assets including farmland and family labor. The latter approach provides some interesting results, but has been hampered because the single research model has been unable to include the needed volume and diversity of information. Researchers constructing a single central model are unlikely to have adequate knowledge of current input-output data and resource restraints in each component area.

The research reported herein attempted to circumvent these problems by combining the advantages of the two traditional approaches. The most profitable combination of enterprises was determined by linear programming for individual resource situations by farm management research personnel located in each State and well informed on local conditions. The procedures were carefully specified in advance to permit aggregation of the data and to determine comparative advantage among cotton-producing areas.

Assumptions and Procedure

The assumptions and basic procedure of the S-42 project are specified in (1). The major assumptions are repeated here for clarity. It was assumed that all farms were owner operated and all farmers would adopt the enterprise combination that appeared to be most profitable. It was also assumed that acreage allotments and price support programs were not in effect. The assumption of no acreage allotments for cotton, peanuts, rice, tobacco, and wheat is not a forecast of what is likely to be in the future nor a recommendation of what should be in the future. Rather it is an assumption designed to permit unrestricted adjustments to maximize profits of the individual producer, subject to the relevant market restraints.

In appraising adjustments in enterprise combinations, the time period was assumed to be long enough for intermediate-term capital investments in items such as buildings, farm machinery, equipment, livestock, and pasture improvements to be considered as variable costs. In general, all costs except general overhead, land, operator labor, and management were considered variable. Land, operator labor, and management were considered fixed during the planning period; hence, they became restrictions for programming models for the individual resource situations.

An advanced level of technology was assumed when input-output coefficients and enterprise budgets were developed. This implies that the most profitable level or intensity of production practices (such as rate of seeding, fertilization, and irrigation) is employed based on the physical response expected under farm conditions when carried out by a good manager. In general, the advanced technology assumption implies that profitable practices now being followed by the better farmers will be the modal practices followed at the end of the planning period.[3]

The assumed national average prices received by farmers for selected commodities are summarized in table 1. These prices are below current prices, but were estimated to be consistent with the assumption of no allotment restriction. In the various geographic areas, product prices were adjusted for quality and locational differences. Prices received by farmers for commodities other than cotton were held constant at the level in table 1 while the price of cotton (U.S. average price) was varied over a range of $0.15 to $0.35 per

[3] The "end of the planning period," to which the estimates of representative farm size and demand projections were designed to apply, was 1975. However, recent trends indicate that the estimates are more nearly applicable to 1970.

Table 1.--Assumed U.S. average prices received by farmers[a]

Product	Unit	Price per unit
		Dollars
Corn (shelled)........	Bushel	1.10
Grain sorghum.........	Cwt.	1.77
Wheat.................	Bushel	1.25
Oats..................	Bushel	.65
Barley................	Bushel	.90
Soybeans..............	Bushel	2.00
Hay (average all kinds)..............	Ton	18.00
Cottonseed............	Ton	50.00
Beef cattle (average all kinds)..........	Cwt.	17.00
Calves (average all kinds)..............	Cwt.	18.00
Hogs..................	Cwt.	14.50
Peanuts...............	Pound	.08
Rice..................	Cwt.	3.85
Flue-cured tobacco....	Pound	.44

[a] Product prices vary between geographic areas. Prices received were developed for each area, based on quality and locational differences, in relation to the U.S. average price.

pound.[4] Cotton prices for specific geographic areas deviated from the U.S. average, depending on quality and location.

It was assumed that unlimited quantities of nonreal-estate capital were available at a 6 percent rate of interest. Interest was considered as an expense and was charged on an annual basis for all capital, regardless of whether the capital was owned or borrowed.

Seasonal labor was assumed to be available as needed and limited only by the wage rate. Operations such as tractor driving were performed only by the operator or skilled labor hired monthly or annually. With these limitations, the fixed supply of skilled labor during a critical period could become a restriction and an important determinant of the most profitable combination of enterprises.

[4] Situations were also programmed with prices of commodities other than cotton set at alternate levels to those in table 1, but the results are not shown in this paper.

Some enterprises were excluded from consideration in developing the most profitable plans for representative farms, and limitations were placed on other enterprises. For example, specialty crops such as fruits and vegetables (except in the Lower Rio Grande Valley), dairy, and poultry enterprises were not included as production alternatives to cotton in most programming models for representative farms. These exclusions were based on the assumption that the typical farms would not view these enterprises as relevant alternatives because of specialized management required and limited market opportunities.

The purchase of feeder pigs and hog feed, except for protein supplement, was not permitted. Beef cattle enterprises were limited to cow-calf herds, grazing of stockers, and feed-out operations for which only the protein supplement could be purchased.

Although no acreage allotments were assumed to be in effect, crops were limited in some areas by agronomic restrictions appropriate to the resource situation. For example, soil conservation practices and crop rotations associated with the control of diseases and insects were considered in the limitations imposed on the acreage of selected crops. Specific limitations such as availability of irrigation water restricted the acreage of crops in some areas. In resource situations where flue-cured tobacco was an alternative, tobacco was limited to the acreage planted in 1939, the most recent year in which acreage allotments were not in effect.

Geographic Areas and Resource Situations

Geographic areas were selected for detailed study on the basis of their homogeneity of resources, problems, and adjustment opportunities. In general, the areas corresponded to the 1959 U.S. Census of Agriculture Economic Subregions. In all of the subregions selected, cotton is an important enterprise and in most it is the most important enterprise. In 1962 these areas accounted for about 81 percent of all cotton produced in the United States. In reporting results pertaining to crop acreage and production and livestock numbers, the 25 geographic areas were combined into 17 areas (fig. 1).

298-263 O - 68 - 3

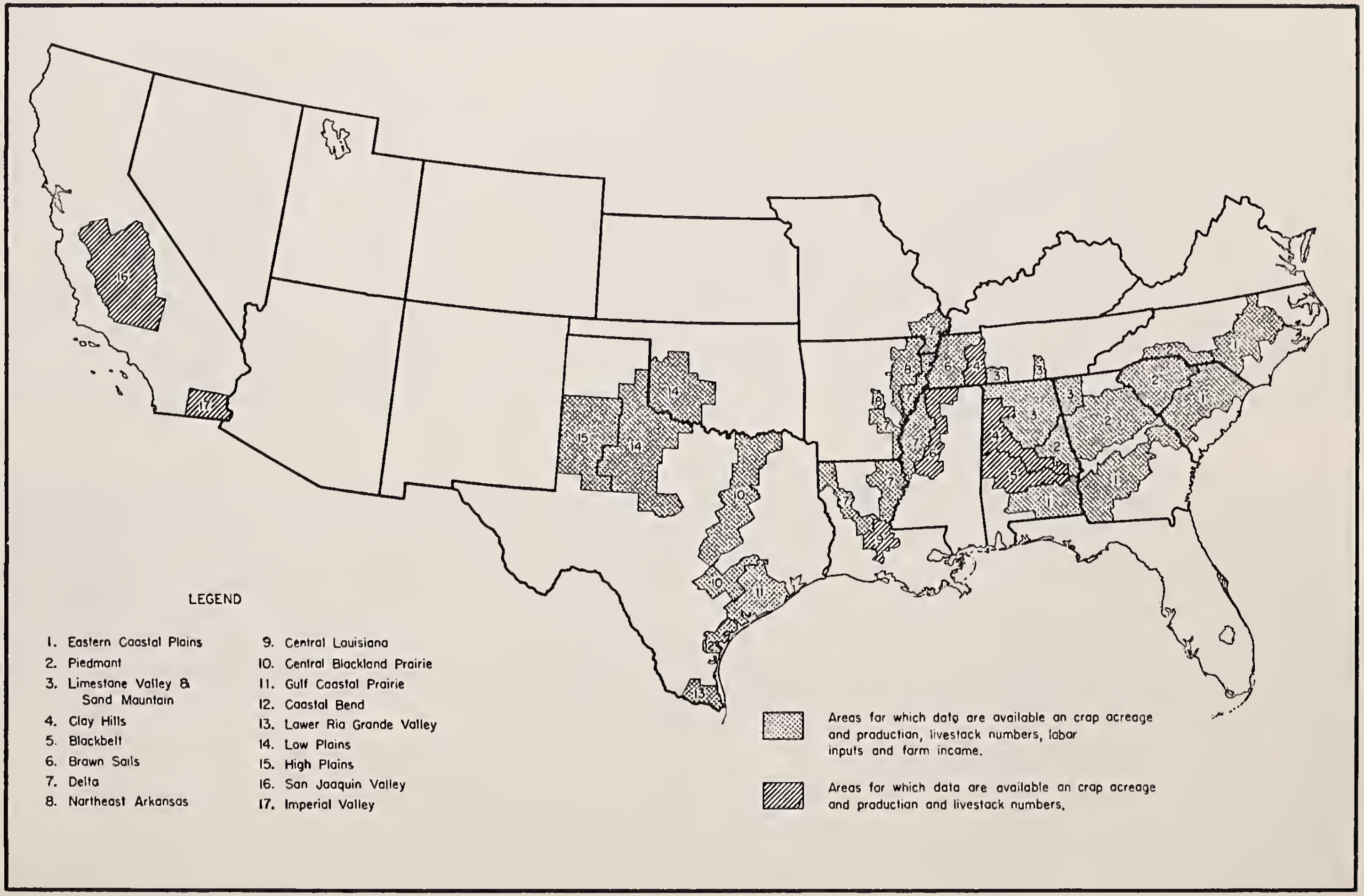

Figure 1.--Geographic areas included in the study.

Table 2.--Cotton production at specified cotton prices, with historical comparisons, 17 study areas[a]

(1,000 bales)

Area	Production		Production at assumed U.S. average price per pound of cotton[b] of--								
	1953	1962	$0.15	$0.20	$0.21	$0.22	$0.23	$0.24	$0.25	$0.30	$0.35
Southeast:											
1. Eastern Coastal Plains------	1,172	913	246	1,140	1,542	2,267	2,630	2,848	3,220	3,949	4,168
2. Piedmont-------------------	542	234	0	360	360	360	530	578	744	878	878
3. Limestone Valley and Sand Mountain-----------------	523	364	0	914	926	1,033	1,169	1,506	1,857	2,407	2,407
4. Clay Hills, Ala.-Tenn-------	211	169	2	7	7	7	7	29	360	598	683
5. Black Belt, Ala.------------	128	92	0	0	0	0	0	458	458	776	776
Mississippi Valley:											
6. Brown Soils, Miss.-Tenn.----	938	784	14	284	844	1,018	1,361	1,543	1,817	2,218	2,218
7. Delta----------------------	2,928	2,640	3	1,979	2,701	3,227	3,402	4,897	5,310	6,125	6,353
8. Northeast Arkansas---------	528	515	81	782	850	1,002	1,148	1,346	1,346	1,444	1,444
9. Central Louisiana----------	114	97	5	91	119	147	174	202	230	297	300
Texas and Oklahoma:											
10. Central Blackland Prairie---	1,124	462	0	0	0	401	401	401	489	522	522
11. Gulf Coastal Prairie--------	265	232	0	0	0	0	0	0	87	591	600
12. Coastal Bend---------------	75	151	0	0	0	0	0	47	143	286	286
13. Lower Rio Grande Valley-----	258	413	0	1	406	407	559	638	638	707	728
14. Low Plains, Okla.-Texas-----	724	860	30	254	324	533	789	1,607	1,622	1,899	1,914
15. High Plains, Texas----------	1,366	2,270	759	1,760	4,109	4,109	4,132	4,142	4,180	4,528	4,528
California:											
16. San Joaquin Valley----------	1,534	1,665	444	1,862	2,426	2,628	2,708	2,761	2,762	2,768	2,768
17. Imperial Valley-------------	175	181	0	318	459	459	475	578	578	609	609
Total:											
17 areas---------------------	12,605	12,042	1,584	9,752	15,073	17,598	19,485	23,581	25,841	30,602	31,182
U.S.[a]------------------------	16,465	14,867	1,946	12,040	18,609	21,720	24,056	29,112	31,902	37,780	38,510

[a] Data from (1): See figure 1 for study areas.
[b] Prices of products other than cotton held constant at levels shown in table 1.
[c] Total U.S. production for selected cotton prices is based on the relationship between study areas and U.S. total production is 1962.

In each of the geographic areas, secondary data were used to determine estimates of total land area, total cropland, and number of farms. These data were also used to estimate the resources devoted to producing the specialty crops and other production alternatives not considered for adjustment. Since these alternatives were not considered as adjustment possibilities, the resources devoted to them were subtracted from the total area resources to obtain the resource base for aggregation.

Within each geographic area several resource situations were delineated to represent relatively homogeneous groups of resources. Representative resource situations within each area were delineated on the basis of such factors as size of farm, available allotments, soil capability, topography, availability and cost of irrigation water, adjustment problems, and opportunities for adjustment. Data obtained from the U.S. Census of Agriculture, records of the Agricultural Stabilization and Conservation Service and the Soil Conservation Service, and information from recent farm management studies were used for developing the representative farm resource situations and for estimating their relative weights. The total number of resource situations was 234.

Input-output budgets which had been developed for use in the overall S-42 project provided the technical coefficients for use with linear programming techniques to determine the optimum combination of enterprises for each representative farm. All cost items which could be reasonably allocated to individual enterprises were covered in the enterprise budgets. General overhead costs which could not be allocated to specific enterprises and land interest charges were subtracted from the programmed return to obtain a return to operator's labor and management.

Deriving Aggregates

The optimum farm plans computed for each representative farm resource situation by linear programming and their appropriate weights were used to develop geographic aggregations. Items for which area and interregional aggregations were developed include crop acreages and production, livestock numbers, labor inputs, and farm incomes.

Results

Programmed estimates of the output of cotton at selected cotton prices ranging from $0.15 to $0.35 per pound, given the underlying assumptions of the study, are depicted in table 2 and figures 2 and 3. The increase in cotton production as the price is increased from $0.15 per pound to $0.35 per pound is substantial in all areas (fig. 2). Estimated production in the 17 study areas increased from 1.6 million bales to 31.2 million bales. Actual production in the areas totaled 12.6 million bales in 1953 and 12.0 million bales in 1962. The width of the graphic area for each region may be viewed as the supply curve. It is characterized as an inverted "lazy S." From low prices to $0.20 per pound, the supply curve rises steeply because cotton is not then competitive for the use of resources at prices shown in table 1 for other commodities. From $0.20 to $0.30 per pound, the most frequent range of actual prices, cotton becomes more profitable than alternatives and acreage is expanded rapidly. Also yields rise because fertilizer and irrigation become more profitable. The result is a somewhat elastic section of the supply curve for cotton in each area within this range of prices. Above $0.30 per pound, the supply curve is steep (inelastic) as land suitable for cotton production is exhausted and the cost rises for additional production.

The average price for cotton in 1963 was $0.32 per pound. Production in that year in the four regions in figure 2 was 12.6 million bales and in the United States was 16.5 million bales. Production in that year was restrained by allotments. Prices would have a fall to nearly $0.20 per pound, according to figure 2, to reduce production to that level without production controls.

The line on the extreme right of figure 2 that borders California is the normative aggregate supply curve for cotton. Anticipated production outside the study areas was added to this supply curve to form the total supply. The aggregate

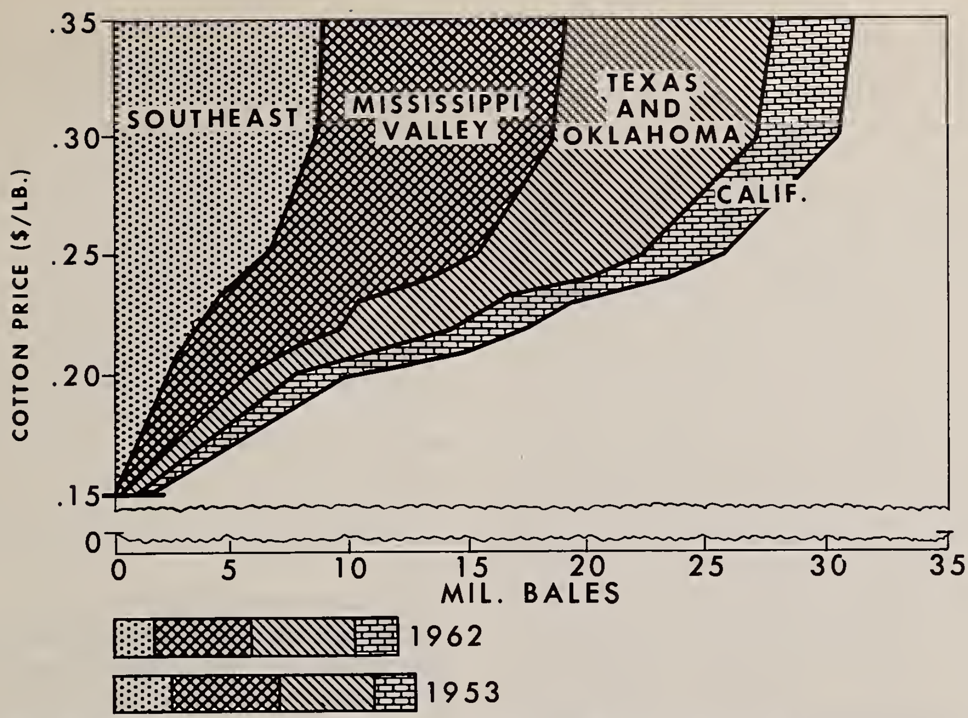

Figure 2.--Actual cotton production in 1953 and 1962, and estimated production at various prices in the absence of acreage controls or price supports, by major regions.

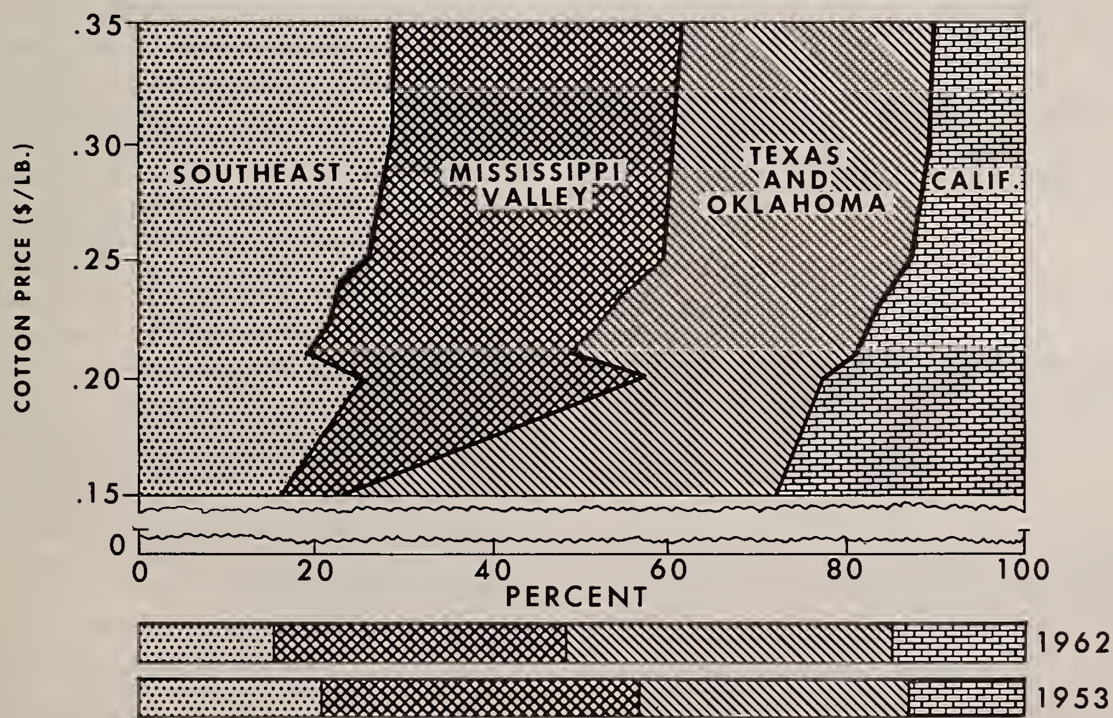

Figure 3.--Percentage shares of cotton production in 1953 and 1962, and estimated percentage shares of production at various prices in the absence of acreage controls or price supports, by major regions.

domestic and foreign demand for cotton was also estimated. The two curves intersected at an equilibrium production of 17 million bales and equilibrium price of $0.21 per pound (cf. 1, p. 52).

Figure 3 more clearly illustrates the comparative advantage of cotton production in the four regions. The share produced in the Mississippi Valley falls markedly as the price of cotton is reduced below $0.20 per pound due to profitableness of soybeans. The Southeast maintains a somewhat stable share of output at all prices. At low prices, California and the Texas and Oklahoma regions have a comparative edge in production. Their combined share is 78 percent of production at $0.15 per pound and only 38 percent at $0.35 per pound. If the free market price were below $0.24 per pound, California would profitably have a larger share of production than in 1962; and above that price it would have a smaller share. The equilibrium market price without production controls was estimated to be $0.21 per pound. California and the Southeast would raise their market shares under a free market. At the equilibrium price the percentage shares of production in the Southeast, Mississippi Valley, Texas and Oklahoma, and California regions respectively would be an estimated 19, 30, 32 and 19, compared with 16, 33, 36, and 15 in 1962. Thus a free market would not materially alter the distribution of cotton production according to the S-42 study.

It does not follow, however, that income would increase in areas where market shares expand. Actually, total farm income falls in all regions, including those that increase their market share, as the cotton price is lowered.

Some Limitations

Regional competition is a branch of general economic equilibrium theory. This theory stresses that prices in a region are continually adjusting to supply, demand, and institutions in the entire economy. To reduce the size of the model, it was necessary in this study to abstract from many interrelationships between supply and demand in the total economy.

Prices (except for cotton), transportation costs, wage rates, and interest rates were considered to be unaffected by the changes in the use of resources and production of commodities predicted by the programming models. Prices for commodities other than cotton were based on past history and anticipated future conditions, but their fixed level may be an inaccurate forecast of actual conditions. The price of feed grain, for example, may be influenced by the change in feed grain production as the price of cotton in varied. However, these macro effects are expected to be small and an unimportant source of error. In response to changes in cotton prices, the changes in production of alternatives would be a small part of national output. It follows that the price effects would be small.

Farm size and family labor were considered to be fixed in the portion of the study reported above. Over a longer time, these fixed assets would become variable. The farm size was allowed to change in another portion of the study (cf. 5). As the cotton price is lowered, farm size tends to expand to compensate for reduced income. That is, the farm operator expands his operation to obtain an income comparable to what he would earn with alternative use of his labor and capital. Results indicated that cotton production tended to vary proportionately with the farm acreage, so that farm size does not appear to be a crucial variable in predicting changes in total cotton production for a region.

The linear programming format used in the above analysis assumed that farmers make adjustments that are most profitable. The model itself is timeless--the adjustments are instantaneous. Comparison of linear programming results with actual behavior of farmers shows that farmers do in fact move toward the profit-maximizing program solutions. However, the adjustment takes time and costs money. Few, if any, farmers make the full changes in crop and livestock production that are called for by the model. Following a change in price, several years are required to make all adjustments. In other studies, recursive programming, which explicitly includes time lags in the model, has been used to introduce the time dimension.

Also positivistic techniques such as multiple regression have been used to predict from past behavior the response of farmers to changing prices. These positivistic techniques are limited by somewhat narrowly circumscribed past behavior, and are not yet flexible enough to include a wide, complex range of possible price and cropping alternatives, and the farming technology that is available but is not yet used by farmers. Thus the static programming model used in our analysis, despite its limitations, appeared to have fewer shortcomings than other approaches to answer the questions posed for this study.

Research Complementarities

The analysis of interregional competition in cotton production was feasible only because it was complementary with other research goals. The linear programming analysis of profitable plans for representative farms was an excellent base for improving farm management decisions. The extension service and land grant universities utilized the results in classroom teaching of farm management and in extension programs to help farmers find the organization of crops and livestock that raise income on individual farms. This was perhaps the major contribution of the study.

In another phase of the study, researchers estimated the minimum size farm that will pay all real and opportunity costs of farming, including a $5,000 income to the operator for his labor, management, and risk.[5] The results were used for farm management planning. They also were used to compute the maximum number of farms possible in a given area if all farmers were to have a "parity" $5,000 income. For example, the results indicated that the number of crop farms in Southwestern Oklahoma would need to decline by approximately 70 percent to assure at least a $5,000 operator labor income (6). These results of the adjusted farm structures were used to determine the farm population, and purchases of farm household supplies and production inputs associated with the adjusted structure through the use of income and population multipliers. The implications of this adjusted structure were determined for schools, machinery dealers, fertilizer dealers, stores, etc. (6). A final phase of the study, nearing completion, is an analysis of the implications for farm income of alternative cotton price supports and acreage allotments.

[5] Another approach to determine the impact of changing prices on farm sizes and numbers is found in Sobering and Tweeten (3).

Summary and Conclusions

The methodology of the S-42 study reported here was a microeconomic linear programming analysis of representative farms located throughout cotton growing areas of the Nation. The format for the study was carefully planned to insure comparable procedures and results that would be aggregated to answer macroeconomic questions.

The results suggest that at very low cotton prices the share of production would rise in California and in Texas and Oklahoma. At high cotton prices and with no allotments, these areas would have a smaller percentage of production than their historic share. At the estimated free market equilibrium price of $0.21 per pound of cotton, the shares of cotton production in the four major areas considered in this study would not differ substantially from the 1962 pattern.

References

(1) Agricultural Experiment Stations and Farm Production Economics Division, U.S. Dept. Agr. Cotton: Supply, demand and farm resource use. Southern Coop. Ser. Bul. 110, Nov. 1966.

(2) Heady, Earl O., and Norman K. Whittlesey. A programming analysis of interregional competition and surplus capacity of American agriculture. Iowa Agr. Expt. Sta. Res. Bul. 538, Ames, July 1965.

(3) Sobering, F. D., and L. G. Tweeten. "A simplified approach to adjustment analysis." Jour. Farm Econ., Vol. 46, No. 4, pp. 820-834, Nov. 1964.

(4) Starbird, I. R., and B. L. French. 1965 Supplement to: Costs of producing upland cotton in the United States, 1964. U.S. Dept. Agr., Agr. Econ. Rpt. 99, Washington, D.C., Sept. 1967.

(5) Strickland, P. L., J. S. Plaxico, and W. F. Lagrone. Minimum land requirements and adjustments for specified income levels, southwestern Oklahoma. Okla. Agr. Expt. Sta. Bul. B-608, Stillwater, May 1963.

(6) Tweeten, Luther, and Odell Walker. "Estimating the socio-economic effects of a declining farm population in a sparse area." Reg. Devlpmt. Anal., pp. 101-119, Agr. Pol. Inst., N.C. State Univ., Raleigh, 1963.

The Relationship of Wheat Planted to Wheat Allotments in the Great Plains

By Thomas A. Miller

DURING THE past 6 years, U.S. July 1 wheat carryovers have been reduced from a 1961 high of 1,411 million bushels to an estimated 426 million bushels on July 1, 1967. In addition, the farm price for 1966 crop wheat was $1.63 per bushel, 38 cents over the U.S. Government support rate. This was the first time in recent history that the market price for wheat differed substantially from the support price. Both the reduction in carryover and the behavior of the market price indicate that the current U.S. wheat situation is one in which supply and demand are more nearly in balance than they have been for over a decade. Against this background, agricultural policymakers face the annual task of setting U.S. wheat allotments. Given the desire to maintain a small, economical, but adequate carryover and some degree of price stability, the wheat allotment level is the key variable controlled by policymakers. The current wheat situation suggests that the specific level at which allotments are set is more critical now than at any time in the recent past.

This article attempts to provide some insight into the relationship between wheat allotments and wheat planted under the current U.S. Government wheat program. It is not meant to imply that the relationship of wheat allotments and wheat planted is the only problem encountered in setting allotments to maintain a balance of supply and demand. Yield variation for a given planted acreage and changes in expected export and domestic demands after allotments are determined increase the difficulty of accurate determination of allotments. However, increased knowledge of the relationship between allotments and wheat planted should be quite helpful in the determination of future U.S. wheat allotment levels.

The amount of wheat planted deviates from allotment levels for several reasons. For example, under the voluntary wheat program now in effect (Food and Agriculture Act of 1965), producers have several alternatives after their wheat allotment has been set. These alternatives may be summarized as (1) participating in the program and producing wheat on all of the allotted acres, (2) participating in the program and producing less wheat than the allotted acres permit, (3) participating in the program and raising up to 150 percent of the allotment, the excess wheat being stored for later sale, (4) participating in both the wheat and feed grain programs, and substituting wheat for feed grains or feed grains for wheat, and (5) not participating in the program and producing the amount of wheat dictated by the production possibilities on the farm involved. Participation in the current wheat program earns food wheat certificate payments for the farmer and makes him eligible for price support loans on the wheat produced.[1] Nonparticipation allows the farmer to raise any amount of wheat to be sold at the existing market price. This voluntary wheat program has resulted in a somewhat loose relationship between wheat allotments and wheat planted.

Another source of deviation arises from the difficulty farmers often encounter in carrying out their intentions. Extremely wet or dry conditions at planting time will often prevent farmers from planting intended acreages. Thus, farmers who intend to plant wheat acreages equal to their respective allotments are often unable to do so. This problem is important to

[1] The participating farmer is also eligible for diversion payments during years when the wheat program offers a diversion option.

some extent in both arid and humid wheat producing regions and tends to lower the correlation between wheat allotment levels and wheat planted.

Technique of Analysis

A statistical model was used to estimate the relationship of wheat planted to wheat allotments in a major U.S. wheat producing region. This estimated relationship was in turn used to predict future wheat plantings for the region as a function of assumed allotment levels. The central part of the Great Plains was chosen for analysis. Confining the statistical analysis to such a region was desirable both because of the amount of data to be accumulated and because of the exploratory nature of the analysis. The importance of the defined region to the total wheat situation is illustrated by the fact that in 1965, the 27.4 million acres of wheat planted in this region made up 47.8 percent of the total U.S. wheat acreage.

Since different areas within the Plains vary greatly in their reaction to changes in allotment levels, the region was stratified into 10 smaller areas for the analysis. Figure 1 shows the 10 areas that were delineated. The boundaries of these areas were originally specified by the Production and Resource Response Group, Production Adjustments Branch, Farm Production Economics Division, ERS, for use in their regional linear programming work. Different cropland adjustment opportunities are present in different geographical areas. Since the response of wheat acreage to allotments is a function of overall adjustment opportunities, these areas provide a logical stratification for the present analysis.

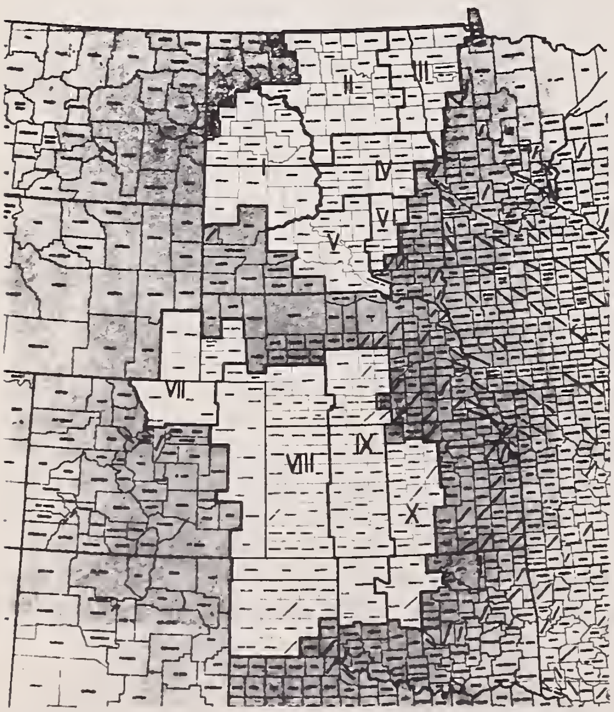

Figure 1.--Location of the 10 wheat-producing subareas of the Great Plains.

The model formulated to explain the relation between wheat planted and wheat allotment was:

$$(1) \qquad Y_{ij} = b_{1i} + b_{2i} X_{2ij} + b_{3i} X_{3j} + e_{ij}$$

for i = I, II, ... X areas and
j = 1958, 1959, ... 1967 years

where Y_{ij} = total acres of wheat planted in thousands in ith area in jth year. For 1967, Y_{ij} was estimated by farmer's March 1 planting intentions.

X_{2ij} = total acres of wheat allotment in thousands in ith area in jth year.[2]

X_{3j} = a dummy variable to recognize removal of the marketing quota penalty in 1964 for noncompliance with allotments. X_{3j} was zero for j = 1958 to 1963 and one for j = 1964 to 1967.[3]

e_{ij} = error in the ith area and the jth year.

---

[2] Wheat allotment figures published by USDA's Agricultural Stabilization and Conservation Service for 1962 are equivalent to a 55-million acre national allotment. However, a mandatory diversion requirement of 10 percent existed for farmers participating in the program in 1962 and rather severe penalties existed for those not participating. These requirements resulted in what may be called an "effective allotment" of 90 percent of the published figure for 1962. X_{2ij} was adjusted accordingly to make this allotment more comparable with allotments of other years. Minimum diversion was also required for participation in 1964, 1965, and 1966, but it was reflected in the published allotment figures during these years.

[3] For 1964, the marketing quota penalty was removed, but the provision was continued that any farmer who exceeded his allotment would lose allotment history in computing future allotments. This provision apparently deterred plantings to some extent in 1964. Beginning with 1965 this penalty was also terminated. However, inspection of the 1964 data suggested that $X_{3j} = 1$ better portrayed the situation in that year than did $X_{3j} = 0$.

The Y_{ij} and X_{2ij} variables of equation (1) are self-explanatory. X_{3j} was included to measure the shift in the relationship between Y_{ij} and X_{2ij} resulting from removal of the noncompliance penalty in 1964. This effect may be thought of simply as a shift in the intercept--from 1958 to 1963 the intercept was b_{1i} and for 1964 to 1967 the intercept was $b_{1i} + b_{3i}$. The error term, e_{ij}, includes variation due to (1) the factors discussed in the first section of this article and (2) other unidentified independent variables that affect Y_{ij}.

Equation (1) differs from more conventional regression equations that have been used to explain crop acres in that it does not include price as an independent variable. In addition, logic would suggest that other factors such as the loan level for wheat, incentives to divert additional acres, the opportunities for substitution between wheat and feed grains, and prospective returns from competing crops would also affect the acreage of wheat planted. However, a preliminary analysis revealed that a variable representing the ratio of average price received by farmers to loan level did not improve the reliability of the estimates. A variable recognizing the voluntary wheat diversion program available from 1962 to 1966 was also included at a preliminary stage of the analysis. However, it was finally omitted because of the high negative correlation between the voluntary diversion program and allotment acres. This correlation essentially negated the validity of the b_{2i} estimates when both allotment and diversion variables were included in the regression equation and as a result rendered the equation useless for the intended purpose. Thus, although equation (1) appears to be an oversimplification of a rather complex phenomenon, it was chosen only after several more sophisticated approaches failed to improve the results.

The parameters of equation (1) were estimated using time series data and the prediction equations

(2) $$\hat{Y}_{ij} = \hat{b}_{1i} + \hat{b}_{2i} X_{2ij} + \hat{b}_{3i} X_{3j}$$

were in turn used to estimate wheat plantings for each of the 10 areas as a function of assumed wheat allotments. The final estimate desired was the prediction for the entire Great Plains region,

(3) $$Y = \sum_i \hat{Y}_{ij}.$$

Results of Analysis

Parameters of the model were estimated using the principle of least squares. The estimated regression coefficients and the associated standard errors are presented in table 1. The

Table 1.--Estimated regression coefficients and standard errors

Area i	$\hat{b}_{1i}$	$\hat{b}_{2i}$	$\hat{b}_{3i}$	Standard errors		R^2	Standard error of estimate
				$s_{b_{2i}}$	$s_{b_{3i}}$		s_{e_i}
I..........	204.2	0.7129**	120.5	.2513	73.6	0.59**	113.8
II.........	557.6	0.7013***	368.4***	.1996	103.1	0.78***	159.6
III........	19.3	0.8817***	231.0***	.2621	59.6	0.81***	91.7
IV.........	292.1	0.6362*	68.1	.3070	73.9	0.42	114.5
V..........	-100.7	0.9899**	37.6	.3431	40.4	0.57*	62.5
VI.........	121.8	0.4883	8.7	.3474	24.0	0.23	37.2
VII........	155.8	0.8979**	56.2	.2698	34.2	0.65**	52.7
VIII.......	1,767.8	0.8108***	986.5***	.1007	139.5	0.94***	214.7
IX.........	1,255.4	0.7104***	160.8**	.0798	62.0	0.93***	96.0
X..........	295.1	0.9178***	550.5***	.2174	157.4	0.81***	243.9

***Significant at 0.01 level.
**Significant at 0.05 level.
*Significant at 0.1 level.

coefficients of determination, R^2, ranged from 0.23 in area VI to 0.94 in area VIII. These coefficients indicate that from 23 to 94 percent of the variation in planted acres of wheat was accounted for by the regression equations in the respective areas. In 8 of the 10 areas, the R^2 values indicate that the regression equations were significant at least at the 0.10 level. In areas IV and VI, the R^2 values indicate significance of about the 0.20 and 0.30 levels respectively.

The estimates of b_{2i} ranged from 0.4883 in area VI to 0.9899 in area V and were significant at the 0.1 level or better except in area VI. These coefficients indicate that a 1-acre change in wheat allotment will, for example in area V, be accompanied on the average by a 0.9899-acre change in the same direction in the planted acreage of wheat. The estimates of b_{3i} were significantly different from zero at the 0.10 or higher level in 5 of the 10 areas. These coefficients measure the effect of the 1964 removal of the penalty for noncompliance with allotments. For example in area II, removal of the penalty was accompanied by a 368,400-acre increase in the acres of wheat planted after the effects of changes in allotments were accounted for.

The regression equation explained only 23 percent of the variation in the acres of wheat planted in area VI. This area borders the Corn Belt in eastern South Dakota. Wheat is relatively unimportant in this area, which includes only 1.5 percent of the total wheat allotment of the Great Plains. It is hypothesized that the competitiveness of alternative crops with wheat in this area makes wheat planting decisions more complex than in the other areas. Nevertheless, the estimated regression equation for area VI was accepted considering the minor influence of the area on the desired regional total estimate, $\hat{Y}$.

As with the remaining columns in table 1, comparisons of the $\hat{b}_{3i}$ regression coefficients among areas are difficult because of the wide differences in the acres of wheat in the different areas. In table 2, these coefficients have been "normalized" by dividing each by the average number of acres of wheat planted for the 10-year period and expressing the result as a percentage. In this table, area I shows an 8.0-percent increase in average wheat acreage due to the removal of the noncompliance penalty. Percentage increases in other areas ranged from 2.7 in area VI to 18.0 in area III.

The last column of table 2 expresses the standard error of the estimate as a percentage of the average acres of wheat planted. These values indicate the magnitude of differences between the estimated regression lines and the actual acres of wheat planted. For example in area I, the interpretation would be that about two-thirds of the observed Y_{ij} values fell within a range of plus or minus 7.6 percent around the computed regression line.

Table 3 presents predicted planted acres of wheat for 1967 and 1968 along with the respective wheat allotments and, for 1967, the actual

Table 2.--Estimated regression coefficients and standard errors as a percentage of average acres of wheat planted, $\overline{Y}_i$

Area i	$\hat{b}_{1i}$	$\hat{b}_{3i}$	$s_{b_{3i}}$	s_{e_i}
	Percent	*Percent*	*Percent*	*Percent*
I............	13.6	8.0	4.9	7.6
II...........	19.5	12.9	3.6	5.6
III..........	1.5	18.0	4.6	7.1
IV...........	23.9	5.6	6.1	9.4
V............	-17.0	6.4	6.8	10.6
VI...........	37.4	2.7	7.4	11.4
VII..........	18.1	6.5	4.0	6.1
VIII.........	20.1	11.2	1.6	2.4
IX...........	27.2	3.5	1.3	2.1
X............	6.5	12.2	3.5	5.4

Table 3.--Wheat allotments and predicted plantings for Great Plains areas, 1 37 and 1968

Area i	1967			1968	
	Allotment	Predicted	Actual	Allotment	Predicted
	1,000 acres	*1,000 acres*	*1,000 acres*	*1,000 acres*	*1,000 acres*
I..........	2,115.3	1,832.7	1,783.4	1,839.3	1,635.9
II.........	3,724.6	3,538.1	3,584.6	3,240.0	3,198.2
III........	1,634.6	1,691.5	1,668.9	1,423.5	1,505.4
IV.........	1,719.9	1,454.4	1,402.5	1,496.4	1,312.2
V..........	834.0	762.5	730.8	725.6	655.2
VI.........	496.3	372.8	350.4	431.6	341.3
VII........	907.1	1,026.5	1,004.9	790.3	921.6
VIII.......	9,774.1	10,679.1	10,668.5	8,502.8	9,648.4
IX.........	5,630.4	5,416.0	5,389.4	4,900.0	4,897.2
X..........	5,265.7	5,678.5	5,629.4	4,574.5	5,044.1
Total......	32,102.0	32,452.1	32,212.8	27,924.0	29,159.5

acres of wheat planted.[4] The predicted planted acres for each area were computed using equation (2) and the estimated parameters of table 1 along with the actual wheat allotment for the respective area and year. The value of X_{3j} was one for both 1967 and 1968 since the penalty for noncompliance was not in effect. The desired $\hat{Y}$ values were determined using equation (3) and are found at the bottom of table 3 in columns 3 and 6. For the defined Great Plains region, the 1967 wheat allotment of 32,102,000 acres would be expected to result in 32,452,100 acres of wheat planted. The actual 1967 planted acreage of wheat as indicated by farmers' March 1 planting intentions was 32,212,800 acres, an error of 239,300 acres. For 1968, the smaller regional wheat allotment of 27,924,000 acres would be expected to result in 29,159,500 acres of wheat planted. Comparable U.S. wheat allotments for these 2 years were 68.2 million acres and 59.3 million acres respectively.

[4] For 1967, total wheat planted exceeded the total regional wheat allotment and some areas had wheat acreages considerably in excess of allotments. Such overplanting of wheat allotments does not in itself suggest noncompliance. Wheat abandonment rates due to winterkilling and other factors range up to 50 percent in some years in the Great Plains. Hence farmers may initially overplant and plan on abandonment and, if necessary, intentionally destroy wheat acreage to comply with allotments.

The standard error of the regional estimate, $\hat{Y}$, may be estimated as

$$s_e = \sqrt{\sum_i s_{e_i}^2} = 427.6$$

using the data from the last column of table 1. Converting to the equivalent form of table 2,

$$\frac{s_e}{\sum_i Y_i} = \frac{427.6}{26,580.2} \quad 0.016 \ .$$

This estimate suggests that two-thirds of the $\hat{Y}$ estimates will be within approximately 1.6 percent of the actual regional total, Y.[5] This standard error of approximately 1.6 percent is consistent with a comparison of the 1967 prediction with actual 1967 plantings, or more accurately, farmers' 1967 (March 1) intentions to plant. For the Great Plains region, the 1967 prediction was 239,300 acres or about 0.7 percent above the actual 1967 planted acreage.

Table 3 furnishes information which may be used in a shortcut prediction equation as long as the relative distribution of wheat allotment

[5] This procedure is an approximation. As it is based on values of independent variables that are different from their respective means, it ignores the finite correction terms and adjustments for the prediction. Both these adjustments would tend to increase the estimated error of $\hat{Y}$ by a small amount.

among the 10 areas is the same as it was during 1967 and 1968. Under these conditions,

$$(4) \qquad \hat{Y} = \hat{b}_1 + \hat{b}_2 \sum_i X_{2ij} + \sum_i \hat{b}_{3i} X_3$$

may be used instead of equation (2). For equation (4), a weighted average regression coefficient for the Great Plains, $\hat{b}_2$, may be computed as the 1967 to 1968 decrease in predicted wheat plantings of 3,292,600 acres divided by the 1967 to 1968 decrease in wheat allotment of 4,178,000 acres. The ratio of these,

$$\frac{3{,}292.6}{4{,}178.0} = 0.78808 = \hat{b}_2$$

is a weighted average coefficient for the total area. This value suggests that for a 1-acre change in wheat allotments, and given the 1967-68 distribution of wheat allotments, wheat plantings in the Great Plains will change in the same direction by 0.78808 acre. The $\sum_i \hat{b}_{3i}$ in equation (4) is the sum of column 4 of table 1 or 2,588,300 acres, the total additional wheat plantings in the Great Plains that accompanied removal of the noncompliance penalty in 1964. The intercept $\hat{b}_1$ may be estimated using the conventional procedure,

$$\hat{b}_1 = \hat{Y} - \hat{b}_2 \sum_i X_{2i} - \sum_i \hat{b}_{3i} X_3 = 4{,}564.9 .$$

The complete shortcut predictive equation for the Great Plains then becomes

$$(5) \quad \hat{Y} = 4{,}564.9 + 0.78808 \sum_i X_{2i} + 2{,}588.3 \; X_3$$

where X_3 equals zero when the noncompliance penalty is in effect and equals one when the penalty is not in effect, as in 1968.

For 1967 and 1968, equation (5) yields the same results as equations (2) and (3) because the equation (5) parameters were estimated using the 1967-68 distribution of wheat allotments among the 10 areas as weights. Since the relative distribution of allotments among areas does change slowly over time, equation (4) and (5) should be used with care. Greater accuracy would generally dictate the use of equations (2) and (3) for other years.

Several limitations to this analysis should be mentioned. In some areas, the coefficients of determination, R^2, suggest a sizable amount of still unexplained variation in the acres of wheat planted. The unexplained variation ranges from 77 percent down to a more reasonable 6 percent and is due to (1) random and unrelated occurrences, such as weather at planting time, and (2) unidentified independent variables not considered in the regression, such as the prices of other crops and Government farm programs for other commodities. Statistics texts warn about the pitfalls of speculating about cause and effect for relations with a low R^2. Nevertheless, the two areas with the lowest R^2 values, IV and VI, have estimated regression coefficients that have the correct signs and generally agree with a priori knowledge of these coefficients.

The search for yet unidentified independent variables involves several problems. A quick review of the residuals from regression for all areas and years suggests no one independent variable is important in all areas in explaining the remaining variation. In addition, many hypothesized independent variables are so highly correlated with each other that they do not behave sensibly when included in the same regression equations. This problem is made acute by the rather short period of data involved. To be useful as a predictive tool, the independent variables must also either lead wheat plantings or be capable of being estimated accurately in advance. Identification of such variables is not easy.

Finally, the analysis of this paper was rather limited in geographical scope. Expansion of the analysis to additional wheat producing areas should both increase knowledge about wheat acreage-wheat allotment relations in different areas and improve the value of the final estimates.

Implications

The technique used in this analysis provides a reasonably accurate method for estimating the acres of wheat planted in the Great Plains as a function of acreage allotments. The standard error of the regional estimate was estimated to be in the neighborhood of 2 percent of the true acreage of wheat planted.

For 1968, the U.S. wheat allotment was decreased from 68.2 million acres to 59.3 million acres, a reduction of 13.05 percent. This analysis has suggested that the acres of wheat planted in the Great Plains will decrease by 3.29 million acres or about 10.1 percent as a result of this change in allotments.

For the 1967-68 distribution of allotments among areas, and assuming no major changes in farm programs, the wheat plantings in the Great Plains change about 0.788 acre for each 1-acre change in allotments. This finding should furnish policymakers with useful foresight in making year to year adjustments in U.S. wheat allotments to balance supply and anticipated demands.

The scope of this paper is rather limited. The technique, however, shows promise. It is entirely possible that the current standard errors could be reduced through inclusion of yet unidentified independent variables. This additional accuracy, accompanied by expansion of the analysis to cover additional wheat producing regions, should provide a technique of analysis that can be efficient and timely and at the same time useful to policymakers.

Squared Versus Unsquared Deviations for Lines of Best Fit

By Harold B. Jones and Jack C. Thompson[2]

REGRESSION AND CORRELATION are widely used and commonly accepted as a basis for work in many applied fields. These techniques are usually based on the principle of least squares. The method of least squares, however, involves minimum squared deviations, and is subject to a number of inherent characteristics that differ from those of minimum unsquared deviations. The differences in the two concepts are frequently unrecognized or ignored except in studies oriented primarily toward mathematical theory (1).[3] The purpose of this paper is to compare and contrast the two approaches in the hope that more effective utilization of both techniques will result.

Standard textbooks often state that the least squares method provides the line of best fit, and imply that there is only one line of best fit for a given set of data. For example, "one must choose that line which 'best' fits the data . . . Our criterion of 'best' is the least-squares criterion" (11, p. 163). Many researchers and students have accepted least squares as a working tool without further questioning. It is the apparent widespread acceptance of this method as the only reliable means for establishing the true relationship between variables that has prompted this paper. In reality, the least squares relationship is only one of a number of possible relationships, each of which has its own assumptions and biases.

[1] Submitted as Journal Paper No. 26, University of Georgia College of Agriculture Experiment Stations, College Station, Athens.

[2] This paper represents a joint contribution of the authors with no attempt to establish senior authorship. Ideas expressed do not necessarily imply endorsement by the University of Georgia or the U.S. Department of Agriculture.

[3] Underscored numbers in parentheses refer to items in the Literature Cited, p. 69.

Editor's note: As working economists we need to remind ourselves now and then that the choice of an appropriate line of best fit may depend more on the characteristics of the relationships we are measuring than on the statistical techniques with which we may be most familiar. This paper is intended to help the general but less statistically minded economist better understand a problem that may already be clear to the statistical specialist, and thus to choose more efficient working methods.

The Central Problem

The method of least squares originated from mathematical theories developed by astronomers in the early 1800's for the purpose of determining the paths of comets and planets. These theories were an outgrowth of early probability theory suggested by Laplace and later modified by Legendre and Gauss (14, pp. 92-95). The early theories were combined with the later work of Galton on regression analysis (1889) to form the basic foundation upon which modern correlation and regression techniques rest.

From a mathematical standpoint the least squares method rests on one rather fundamental point: "that a number w will be called the best approximation to a set of numbers $(x_1, x_2 \ldots x_n)$, or the best representative for the set, in case the sum of the squares of the deviations of the x's from w is less than the sum resulting if w is replaced by any other number" (6, p. 330). Furthermore, "in view of the possibility of other definitions of a best approximation, we shall say that Definition I describes the best approximation in the sense of least squares." Thus these basic definitions point out two critical assumptions that underlie the principle of least squares: (1) that it is a method of approximation, and (2) that it is the best only in the sense of least squares. If we want to measure deviations in terms of actual data or cubed data or logarithms rather than squared data, then the best approximation may be entirely different. It is these two points which are crucial to a clear understanding of least squares analysis in relation to any alternative method.

One of the major advantages of using the least squares method is that it will provide the most probable estimate of the underlying relationship between certain factors when all other variables, including errors of measurements, are omitted. In other words, the method has predictive power, at least in a probability sense. The question is--how do you interpret what is the most probable estimate? Historically observed facts are one thing but future changes are another. Statistical inference and probability theory are highly interrelated. Yet the attempt to substitute probability for logic or cause-and-effect relationships carries one beyond the realm of true scientific inquiry.[4] This line of reasoning is more fully explained by Waugh, who states that "unless one has faith in the crystal ball or the Ouija board, he can never know what would have been true if some forces had been different. We are therefore forced to guess what would have happened" (15, p. 307). He goes on to state that "students more often put too much faith in the results of least squares than too little. They think that somehow the mathematical processes of the least-squares method give them an answer that is 'correct,' rather than an estimate or guess of what is correct."

Ezekiel and Fox recognize that "the least-squares line gives the line of best fit under the assumptions of that method: a normal distribution of the observations around the line and the reduction of the squared residuals to a minimum" (3, p. 68). However, it has been shown by the Markoff theorem that the assumption of normality is not necessarily essential to the theory of least squares (2, p. 105). But there does have to be a distribution of some kind which is based on the existence of a random variable (y) and which is independent of any of the other variables considered (x's). The least squares assumption thus becomes the relevant criterion when these conditions are met.

Another theoretical advantage of least squares is that the method is mathematically rigorous and thereby reduces the errors of measurement when compared with more subjective measures. In other words, it is a more consistent method of estimating. Yet, it does not necessarily follow that a consistent estimate is more accurate in describing a given relationship than an inconsistent estimate. Subjective methods of measurement may be more accurate even though less consistent than other methods. This reflects the old conflict of "precision" versus "accuracy." Is it better to be "approximately right" or "precisely wrong"? This point is well stated by A. N. Whitehead, the noted philosopher: "There is no more common error than to assume that, because prolonged and accurate mathematical calculations have been made, the application of the result to some fact of nature is absolutely certain" (9, p. 271).

Regardless of the assumptions involved, most statistical authorities have emphasized the usefulness of least squares in measuring the deviation of items about a mean or a line of best fit. Snedecor states that the simple average of individual variations is not relevant because it leads into a blind alley so far as statistical theory is concerned (10, pp. 36-37). Yet when considering why the deviations should be squared he says that, "in a non-mathematical discussion, it is quite impossible to give an adequate answer to this question."

Thus, the question of squaring deviations has usually been considered to hinge upon advanced statistical theory; perhaps not enough thought has been given to the judgment or logic to be used in individual situations that may not require advanced statistical technique.

A Hypothetical Example

The following hypothetical example was designed to illustrate the differences in results obtained when the best approximation in terms of least squares is compared with the best approximation in terms of least absolute deviations.

The example represents a simplified case in which a relationship exists between X and Y and the objective is to predict values of Y from

[4] The validity of the inductive approach is at best based on highly problematical grounds and has been the subject of philosophical controversy for many centuries. See Hume's essay (8) first published in 1777. Fisher calls this inverse probability and states that "the theory of inverse probability is founded upon an error, and must be wholly rejected" (4, p. 9).

the values of X. Fitting a line on the basis of least squares gives the type of relationship shown in figure 1a. Fitting a line on the basis of least actual deviations by a freehand or judgment method gives the relationship in figure 1b. The basic data for these charts are given in table 1. This table shows that the least squares approach provides a line where the sum of the deviations without regard to sign is nearly twice the sum of the unsquared deviations. The sum of the deviations from the line of regression fitted by the least squares technique is 18.5 points whereas the sum of the deviations from the line based on the unsquared method is 10 points.

Carried one step further with both sets of estimates evaluated on the basis of squared deviations, the least squares technique gives the lower total sum of squares with a correspondingly lower average (column 7, table 1). Transposed into the traditional measure of correlation this provides a coefficient of determination (r^2) of 0.75 for the least squares method and an r^2 of 0.62 for the unsquared method (table 2). Only 62 percent of the actual variation is explained by this line whereas the coefficient of determination indicates that 75 percent of the squared variation (variance) is explained. However, if the

TWO METHODS OF FITTING A REGRESSION LINE

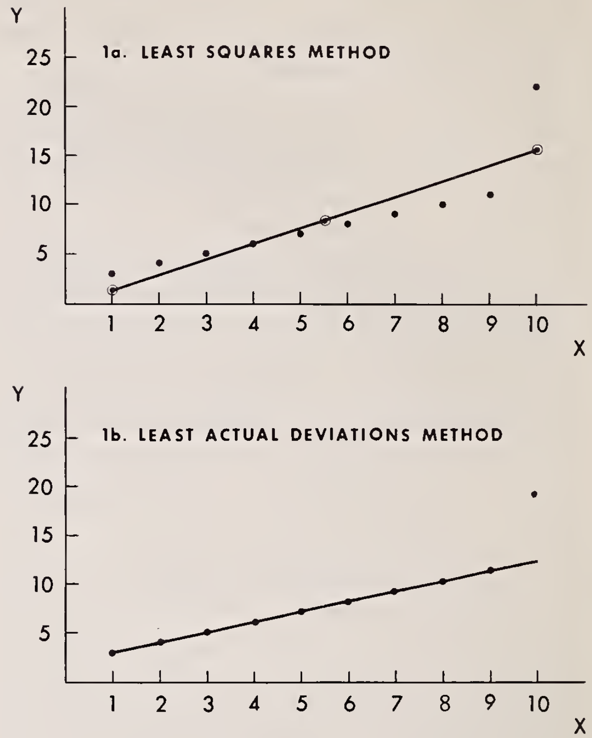

Figure 1

Table 1.--Basic data for calculation of regression equations and correlation coefficients by squared and unsquared methods

Basic data				Least squares method[a]					Non-squared method		
X	Y	XY	X^2	Yc	Y-Yc	$(Y-Yc)^2$	$Y-\bar{Y}$	$(Y-\bar{Y})^2$	Yc	Y-Yc	$(Y-Yc)^2$
1	3	3	1	1.5	1.45	2.10	5.5	30.25	3	0	0
2	4	8	4	3.1	.91	.83	4.5	20.25	4	0	0
3	5	15	9	4.6	.36	.13	3.5	12.25	5	0	0
4	6	24	16	6.2	.18	.03	2.5	6.25	6	0	0
5	7	35	25	7.7	.73	.53	1.5	2.25	7	0	0
6	8	48	36	9.3	1.27	1.61	.5	.25	8	0	0
7	9	63	49	10.8	1.82	3.31	.5	.25	9	0	0
8	10	80	64	12.4	2.36	5.57	1.5	2.25	10	0	0
9	11	99	81	13.9	2.91	8.47	2.5	6.25	11	0	0
10	22	220	100	15.5	6.55	42.90	13.5	182.25	12	10	100
Σ 55	85	595	385	--	18.54	65.48	36.0	262.50	--	10	100
M 5.5	8.5	--	--	--	--	6.55	--	26.25	--	--	10.00

[a] Deviations expressed without regard to signs. Certain columns rounded.

Table 2.--Coefficients of correlation and determination based on squared and unsquared deviations

Type of regression line	Value of coefficients	
	r^2	c
Least squared deviations...	0.75	0.49
Least actual deviations....	.62	.72

Coefficients based on the following formulas:

$$r^2 = \frac{\sigma y^2 - Sy^2}{\sigma y^2}$$

$$c = \frac{\Sigma(|Y-\overline{Y}|) - \Sigma(|Y-Yc|)}{\Sigma(|Y-\overline{Y}|)}$$

where r^2 = coefficient of determination and c = correlation coefficient based on unsquared deviations.

correlation coefficient is calculated on the basis of unsquared data the situation is reversed. The coefficient c for the unsquared method would then be 0.72 and the c for the least squares line would be 0.49. In this case then, 72 percent of the actual variation is explained and only 49 percent of the squared variation.

Obviously the least squares method provides the line of best fit when best fit is interpreted in terms of least squares. This is a circular process that defines the line of best fit in terms of one criterion and then evaluates the effectiveness of the fit in terms of the same criterion. This procedure yields an optimum line of regression when least squares are the appropriate criteria. By shifting the line on a trial and error basis, it is frequently possible to improve the accuracy of the actual predictions of Y from given values of X, but this would not be logical unless justified by the underlying relationships.

Even if the least squares criteria are accepted, there is still the problem of selecting the type of line which best represents the data being analyzed. The real significance of the correlation coefficient will depend not only on the goodness of fit, but on the type of relationship that is presumed to exist. A priori knowledge becomes extremely important here. Otherwise, one could not know whether the data are best represented by a straight line relationship, a curvilinear relationship, a relationship linear in the logarithms, or one of many other types of relationships that could exist between variables. If the nature of the relationship is not known and the wrong type of curve is fitted, the explanatory value will be relatively poor. This could still be the "line of best fit" as determined by the statistical method selected, but this would be no indication of the true underlying relationship, it would only mean that you have the best fitting line for that particular type of curve.

Another Approach

If the primary objective is to predict values of Y from values of X in terms of minimum actual deviations rather than minimum squared deviations, other methods than that of least squares may be appropriate. However, in certain special cases the results may be the same. Where the distribution of errors is such that there is a counterbalancing effect on either side of the line of regression, then minimizing squared deviations will result in minimum actual deviations (note that the errors could be, but do not necessarily have to be, in the form of a normal distribution). In too many cases, however, minimum squared deviations are used when the evidence does not suggest the presence of a "balanced" or normal distribution.

In such situations, it may be better to try to minimize actual unsquared deviations by an iterative process similar to that already described, either by starting with a least squares solution or a group average method and working toward an optimum solution by the graphic method, or by more advanced linear programming techniques (see 7, p. 239, and 13). The regression coefficients could be calculated from the indicated functional relationships, and a correlation coefficient could be computed in terms of c rather than r where c is defined as:

$$c = \frac{\text{average deviation from mean} - \text{average deviation from regression line}}{\text{average deviation from mean}}$$

based on unsquared deviations (see footnote to table 2 for a statement of this formula in more familiar terminology).

These methods make it necessary to disregard signs, but they do provide a workable solution which could have a considerable advantage over the traditional method. They also allow the possibility of using the median rather than the mean as the base point from which to measure deviations. Since the median is the middle point, it has the useful property of being that point around which the sum of the absolute deviations is minimized.[5] Although the median is not as stable as the mean from a mathematical standpoint, it could sometimes yield a more useful result.

Another measure to consider is the coefficient of forecast efficiency (5, p. 178). Most statistical textbooks describe the difference between the coefficient of correlation and the coefficient of determination where the latter is a squared version of the former, but they sometimes fail to call attention to the coefficient of forecast efficiency which has been designed to explain the predictive efficiency of a given correlation coefficient. The coefficient of forecast efficiency (E) is based on the coefficient of alienation which in itself is a measure designed to show the absence of relationship between two variables.[6]

This coefficient of forecast efficiency (E) is calculated by subtracting the coefficient of alienation from 1, as indicated by the following formula:

$$E = 1 - \sqrt{1 - r^2}$$

It is based upon the standard error of estimate, and it shows to what extent a prediction is improved if the variables in the correlation are used rather than the mean of the dependent variable for all estimates. Since it is based on squared deviations and considers the square root of the coefficient of alienation, the coefficient of forecast efficiency might be a more practical measure than either the coefficient of correlation or the coefficient of determination. The three measures are compared in table 3. The E coefficient reflects more nearly the relationship which is explained by actual deviations rather than squared deviations. For instance, in the example previously cited the coefficient of forecast efficiency is 0.50, which is remarkably close to the c value of 0.49 calculated on the basis of actual deviations from the least squares line. Thus, even though the E coefficient only approximates the actual efficiency of the independent variables in explaining unsquared deviations, it is computed in terms of squared data which makes it advantageous for use in conjunction with traditional regression and correlation analysis.

In the final analysis, it is only when research results are disseminated to others that anything worthwhile can be achieved. This is a matter of communication, and communication must take place with nonprofessional as well as professional groups. These people not only need to know what the results are, but also how they were obtained. Presenting research findings to the layman or the nonmathematical economist can be a real problem when the research has been based on more advanced analytical techniques. In economics and the social sciences the necessity of making allowances for changing conditions makes it even more imperative that the uninitiated user of research findings be able to understand the methods used. As Stigler aptly put it in reference to mathematical economics,

Table 3.--Comparative values for the coefficient of correlation, coefficient of determination, and the coefficient of forecast efficiency

r	r^2	E
1.00	1.00	1.00
.90	.81	.56
.80	.64	.40
.70	.49	.29
.60	.36	.20
.50	.25	.13
.40	.16	.08
.30	.09	.05
.20	.04	.02
.10	.01	.005

[5] This is not the first time these ideas have been considered. See, for example, Gauss and Fechner's work in the early 1800's (14, pp. 83-85), and some of Yule's later work on the association of attributes (1897) (14, pp. 125-131). Thorndike and Spearman also did substantial work on this in the early 1900's (14, p. 136).

[6] Technically, the coefficient of alienation $1 - r^2$ indicates the extent to which the relationship departs from a perfect correlation.

"from the viewpoint of the profession, the translation (of research results) is absolutely necessary, not merely desirable . . . If the mathematical economist's results are suggestive or useful, these people have a right to know them. If the results are tentative and conjectural, these people have a right to test them. It is the fundamental obligation of the scholar to submit his results and methods to the critical scrutiny of his competent colleagues in a comprehensible fashion" (12, p. 37).

Thus, as researchers we need to think in terms of the basic problems that need to be solved and adapt our methods accordingly. Any given method should be used, but only where it is appropriate and preferably where the results are easily understood by those concerned with the problem. With this kind of philosophy we can expect a wider acceptance of our research results.

Literature Cited

(1) Ashar, V. G., and T. D. Wallace. "A sampling study of minimum absolute deviations estimators." Oper. Res., Vol. 2, No. 5, Oct. 1963.

(2) David, F. N., and J. Neyman. "Extension of the Markoff theorem on least squares." Statis. Res. Memoirs, Vol. 2, Univ. London, Dec. 1938.

(3) Ezekiel, Mordecai, and Karl A. Fox. Methods of Correlation and Regression Analysis. John Wiley and Sons, New York, 3rd ed., 1959.

(4) Fisher, Ronald A. Statistical Methods for Research Workers. Hafner Publishing Co., New York, 13th ed., rev. 1958.

(5) Garrett, H. E. Statistics in Psychology and Education. David McKay Co., Inc., New York, 6th ed., 1966.

(6) Hart, William L. College Algebra. D.C. Heath and Co., Boston, 3rd ed., 1947.

(7) Havlicek, J. "Use of linear programming for estimating regression relationships." Proc. Assoc. Southern Agr. Workers, Atlanta, Ga., Feb. 1964.

(8) Hume, David. "An inquiry concerning human understanding." The English Philosophers from Bacon to Mill. E. A. Burtt, ed., Modern Library, New York, 1939.

(9) Moroney, M. J. Facts from Figures. Penguin Books Ltd., Great Britain, 3rd ed., 1956.

(10) Snedecor, George W. Statistical Methods. The Iowa State College Press, Ames, 4th ed., 1946.

(11) Steel, R. G. D., and J. H. Torrie. Principles and Procedures of Statistics. McGraw-Hill Book Co., New York, 1960.

(12) Stigler, George J. "The mathematical method in economics." Five Lectures on Economic Problems. London Sch. Econ. and Polit. Sci., Macmillan Co., New York, 1950.

(13) Wagner, H. M. "Linear programming techniques for regression analysis." Jour. Amer. Statis. Assoc., Vol. 54, 1959.

(14) Walker, Helen M. Studies in the History of Statistical Method. The Williams and Wilkins Co., Baltimore, Md., 1929.

(15) Waugh, Albert E. Elements of Statistical Method. McGraw-Hill Book Co., New York, 3rd ed., 1952.

Book Reviews

The Balance of Payments: Free Versus Fixed Exchange Rates

By Milton Friedman and Robert V. Roosa, American Enterprise Institute for Public Policy Research, Washington, D.C. 193 pages. 1967. $4.50.

THE RECENT UPHEAVALS in the international monetary sphere--the British devaluation, heavy speculation in the gold markets, and the apparently substantial rise in the U.S. balance-of-payments deficit which led to the President's hardened balance-of-payments program on January 1, 1968--have served to focus attention on what many feel to be the inadequacies of present international monetary arrangements and to cause a look around for possible alternative arrangements. The most frequently heard alternative to the present system of fixed exchange rates is a switch to floating or flexible exchange rates without the underpinning of gold. The most ardent and eloquent exponent of this latter arrangement is Milton Friedman of the University of Chicago. The book reviewed here appeared just before the above-listed series of events started. Its timeliness will no doubt guarantee it a wide and deserved audience, particularly since it also contains the views of a well-known spokesman for the present system, Robert V. Roosa, former Under Secretary of Treasury for Monetary Affairs, who presently is a partner in Brown Brothers, Harriman and Company in New York.

The book is a record of a debate between Roosa and Friedman held in May 1966 at the George Washington University, sponsored by the American Enterprise Institute for Public Policy Research. The format of the debate, in which each participant gave a lengthy lecture espousing his viewpoint, then rebutted the other's statements before engaging in both direct exchanges and in exchanges with an audience composed of experts in their field, led to a book which laymen will find quite useful. It is not deeply theoretical, although the case for flexible exchange rates must be made for the most part in theoretical terms since the actual use of flexible exchange rates has not been widespread. The debate format assured that the problems of each system and the differences between them were adequately illuminated and explored.

The shortcomings of the present system--such as the failure of reserves to grow as fast as trade (the liquidity problem), and the reluctance of deficit and surplus nations to enact their proper roles (domestic deflation for the deficit nations and expansion and thus ultimately inflation for surplus nations)--are well enough known so that the system makes a ready target. Roosa did not contend that the present system did not need improving, in fact he flatly stated that the liquidity problem was a potentially fatal flaw if not corrected. Nevertheless, he still felt it was preferable to a flexible rate system.

A good case for floating exchange rates is made by Friedman, but it too has many potential flaws which are well discussed. The most appealing aspect of the system Friedman advocates is that internal domestic policies could be determined solely on the basis of domestic needs without reference to the effects the policies may have on the balance of payments. There will be no effects under a system of floating exchange rates because the market is always cleared and there is no surplus or deficit. The flaws may be grouped under the categories of operational and theoretical. Roosa places great stress on the strictly operational problems that would arise under a flexible rate system. He questions how forward markets would operate, or even how the multiplicity of combinations of spot rates would be dealt with, but problems such as these have been surmounted in the past and with today's information-retrieval machines and communications systems it should be possible to overcome them.

A major theoretical flaw is the effect on exchange rates due to large capital movements. Changes in the rates due to purely current trade items most likely would occur gradually and in small increments, but capital movements, particularly speculative movements, could result in tremendous changes in the rate over a very short time and this would severely disrupt trade.

While the problems of both systems were adequately isolated and explored in considerable depth, they were not convincingly disposed of by the proponent of either system. The reader comes away with a feeling that Friedman has not made a convincing case, particularly as concerns the effects of capital flows, and that therefore by default the fixed rate system remains the choice of the two, due, as Friedman cynically puts it, to the preference for the status quo. Still, an exchange rate system in which a change in the rate occurs only once every 15 to 20 years for any given major currency is more acceptable than the unknown effects of one where the changes may, potentially, be daily.

George R. Kruer

The Economics of Irrigation

By Colin Clark. Pergamon Press Inc., New York. 116 pages. 1967. $6.

COLIN CLARK is something of a pioneer. In 1932, as a Lecturer in Statistics at Cambridge University, he published "The National Income, 1924-1931." It was delayed because figures from the "Census of Production for 1924 have just now become available." (Does this sound familiar?) Clark put together his estimates of national income from various and sundry sources, with an ingenious use of factors, ratios, indices, and so on. "After estimating the total of the National Income this book proceeds to an analysis of how it is produced, distributed and spent." He described his work as "a statistical framework which should be capable of holding together a good deal of hitherto disjointed information." He asked the reader to "be indulgent to one who has had to work through this large mass of material largely single-handed." The book as well as his Cambridge title soon marked Colin Clark as a builder of statistical estimates.

In succeeding years, Clark's researches and writings included the economic position of Britain, its investment in fixed capital (he met the problem of new construction versus repair and maintenance), and a lecture, "Australian Economic Progress Against a World Background," given in Adelaide, August 1938. A year later appeared his critique of Russian statistics, his purpose being "to collate and test...by internal consistency and by comparison of statistics of the external world. . . . analysis of changes during the last thirty years in what is generally described as real income per head in that country."

In 1942, he published "The Economics of 1960," as Director of the Queensland Bureau of Industry and Financial Advisor to the Treasury (Australia). He predicted that "the U.S.A. will become a substantial importing country" and he cited the downward trend of farm exports as a percentage of total U.S. farm production. He could be pardoned for not anticipating (in 1942) the impact technology would have on U.S. production, permitting ever larger exports of farm products.

"The Economics of Irrigation," recently published, is a descriptive and comparative analysis of irrigation economies. The materials in the 156 cited references ranging from research reports to magazine and newspaper articles (London Times), were of uneven quality and with little semblance of similarity. Five articles in this journal were cited. He painstakingly classified, sorted, and reassembled the facts and materials according to economic returns to irrigation water, water costs per cubic meter, charges for water, and potential water sources.

Clark says, in the preface, the "book is addressed to all those who may have any responsibility for spending money on irrigation, whether for small schemes or large, whether private or public, whether in arid or in humid climates and . . . those who help to form political and business opinion." No one can object to such a grand aim.

"All measures in this book are made in metric units. Costs are measured in American cents of 1964 purchasing power per cubic metre [of water]. All costs of other countries, or other periods, are converted into cents of 1964 purchasing power by coefficients of the purchasing power of money (which are not the same as the official exchange rates)." Returns to water are computed in kilograms of wheat (world price).

Table 11 shows gross and net returns to irrigation for 62 crops or trials in 12 countries stretching from India to the United States. However, on account of missing data in his sources, in only 34 items is the product converted to kilograms of wheat; in 36 cases quantity of water is specified (in 14 it is approximated); and in 13 cases only, is net marginal return computed. The chapter on economic returns to irrigation suffers because Clark found it necessary to improvise data or values "from experience in other low-income countries."

Comparative costs and returns among countries may be useful to the governments of developing countries. However, it would seem the more important question is the best allocation of public investment among the various alternatives within the same country.

Clark delights in taking issue with the accepted conception that water requirements differ with the kind of crop. He reasons that most of the water that plants use is for transpiration to keep the plant's temperature within tolerable limits. Thus under similar soil and weather conditions "there should be no differences between the water requirements of different crops per day of growing season. . . a heavy crop also requires no more than a light crop." He seems to contradict himself where he refers on page 15 to "the economic disadvantage of rice's high water requirements".

Actually water requirements do vary with the vegetative mass, e.g., a 2-ton cutting versus a 1-ton cutting of alfalfa. And an acre of it irrigated over a period of 7 to 8 months requires more water per season than cotton irrigated for its season of 3 1/2 months (Southern California). So the choice of crops does matter, despite Clark's assertion to the contrary in both his introduction and summary. Actually, he makes no use of this point in his analysis--it is a gratis contribution.

Most American readers will not easily read "1.5 c/m^3" as 1.5 U.S. cents per cubic meter, for example, nor will they convert this easily into dollars per acre-foot (about 1,233.5 cubic meters). And yet the narrative is engagingly written, well worth what ever time it holds the reader's interest. Besides a reader will find such gems as: In costing net product in West Pakistan, a man's labor is valued at 400 rupees a year, and a pair of bullocks at 1,600 rupees a year.

Warren R. Bailey

Farmers and a Hungry World

By the National Farm Institute. Iowa State University Press, Ames. 136 pages. 1967. $3.50.

IN A YEAR of increasing concern over the problem of world food supplies, The National Farm Institute of Des Moines, Iowa, chose as the theme of its 29th conference the role of American agriculture in a hungry world. It invited as participants in its discussions Lawrence W. Witt, Michigan State University; Thomas C. M. Robinson, Food and Agriculture Organization; John F. Timmons, Iowa State University; J. Burke Knapp, International Bank for Reconstruction and Development; Alvin Hamilton, Member of the Canadian House of Commons and formerly Canadian Minister of Agriculture; Gavin Jones, Population Council of New York City; Edward W. Pierce, Peavey Company; D. Gale Johnson, University of Chicago; John A. Schnittker, Under Secretary of Agriculture; and four farmers from Iowa and North Carolina. This book presents their addresses and the highlights of their discussions.

These men agree that the farmers of the United States cannot feed the world, and that, consequently, American technical assistance in agriculture should concentrate on helping the farmers of developing countries increase their productivity. They also agree that trade is preferable to aid. However, Gale Johnson notes that our export subsidies and import quotas, especially those regulating trade in peanuts, sugar, and manufactured dairy products, are hindering economic development abroad.

The participants are also agreed that multilateral aid is preferable to bilateral. Thomas C. M. Robinson speaks favorably of the World Food Program, which was initiated in 1961-62 by FAO and the General Assembly of the United Nations to use food as development capital as well as for emergency relief. As of December

31, 1964, 70 nations had pledged an equivalent of $94 million to the support of this multilateral effort. J. Burke Knapp describes the successes of the World Bank in increasing agricultural production in Malaysia, Thailand, Kenya, Uruguay, and India. He points out that in Malaysia the introduction of double-cropping and other agronomic practices has nearly tripled the production of rice.

Gavin W. Jones presents the demographic aspect of the food problem. He expects "no major relief from the pressure of increasing population on the food supply in the next 15 years," but after that he believes that effective birth control efforts will substantially reduce population growth.

In short, this little book provides a quick introduction to current thinking concerning the world food problem.

Robert G. Dunbar

French and EEC Grain Policies and Their Price Effects, 1920-1970

By Helen C. Farnsworth and Karen J. Friedmann. Food Research Institute Studies, vol. VII, No. 1. Stanford University, Stanford, Calif. 158 pp. 1967. $2.50.

THE HISTORY of our agriculture seems to be written on the margin of our history as a whole . . . [In] the usually brief chapter devoted to agricultural policy . . . the documentation becomes less precise, less relevant; the total plan breaks up into a series of disparate remarks; care for exact analysis gives way to approximations, to descriptions loaded with detail and indifferent to what is essential." This was the complaint of the French historian-demographer, Louis Chevalier, in 1947.

Now, 20 years later, two American economists have placed the history of French agriculture on the center of the page. Unlike the "marginal" attempts to which Chevalier refers, Farnsworth and Friedmann present a scholarly, well-documented study on French agricultural policy; a study which though "loaded with detail" is not merely descriptive but also perceptive and analytical. The consequences of policies made are traced through to their price effects. Thus, the reader is given the historical perspective necessary for understanding the French grain economy: past, present, and future.

And these authors are aware of what is essential: Grain policy is the essence of the Common Agricultural Policy of the EEC. Because France is the leading grain producer and exporter in the Community, the voice which spoke for French agriculture was an important one in the negotiations which resulted in uniform import or threshold prices and in a Common Market for grains. After a 5-year transitional period, this unified and harmonized agricultural policy for grains became effective on July 1, 1967, with only a few transitional provisions remaining in force, primarily those for lower feed grain prices in Italy.

"The French government has long played a highly important though varying role in the pricing of French grains," the authors explain. "This role was significantly but not greatly modified under the transitional grain regulation of the European Economic Community during 1962-66 and will be further and more substantially altered after the unification of the community grain market on July 1, 1967."

An understanding of the role the French Government plays is all the more important now that a new dimension--the EEC--has been added in the past decade.

The complexities of the Common Agricultural Policy (CAP) can be considered simple in comparison with the rigidities of French agricultural policy in the past, and one should remember that French agricultural policy comprises only one of six national agricultural programs which have been compromised and coordinated to create an agricultural policy which is EEC-wide. Not only did the French Government play an important role in the negotiations which led to CAP's creation, but by taking advantage of special provisions of the CAP grain program, the French Government retains elements of its earlier pre-CAP role.

For example, EEC negotiations permit the continued operation of the Office National Interprofessionel des Cereales (ONIC), the semi-official French price support agency, and ONIC is permitted to continue its old "Type B" price support (or intervention) program. Under that program, ONIC may strengthen the market by buying grains from growers at prices higher than the regular EEC support or intervention price and it may withhold supplies from the market. This policy resembles that of U.S. fruit and vegetable marketing orders and agreements, as the authors point out.

In this connection, a crucial difference between the basic EEC price support or intervention method and that of the Commodity Credit Corporation in the United States must be pointed out: In the EEC, price "intervention" constitutes an irreversible sale. By contrast, the U.S. farmer can obtain a price-support loan, i.e., get cash when needed, without selling his crop. He can, if he wishes and if the price situation makes this desirable, pay off the price-support loan, reassume title to his crop, and sell it in the free market for his own account.

The authors illustrate the impact of the Common Agricultural Policy not only in France but in other nations. For example, they observe that the levy-paid c.i.f. price of representative North American, and particularly Canadian, wheat has been higher than the threshold price plus the EEC-established quality differential for such wheat. Thus, the price of North American wheat in EEC markets has been raised even above the high and irreducible price level inherent in the Common Agricultural Policy with its variable levies. The only consolation for North American sellers and EEC buyers is that some price concessions are possible under these circumstances without forcing up the variable levy at the same time. If the predetermined fixed regulatory differentials for quality wheat were in line with actual market price differentials, any price concession offered by a seller would tend to result in a lower standardized c.i.f. price quotation and thus in a levy increase.

The study under review seems somewhat less complete and less well coordinated than the authors' earlier publication on the German Grain Economy. A principal reason for this is the authors' failure, at the outset, to refer to the senior author's separate earlier study on French grain production, which answers most of the questions that come to the reader's mind as he works his way through the study. The German study has a less obvious division between policies and prices; the dichotomous arrangement of the French study into a first part, French Grain Policies and Programs, and a second part, Influences of Government Intervention on French Grain Price, seems awkward, too sharp and neither necessary nor helpful. This arrangement forces the reader to trace the chronology of events a second time and to deal with many of the policy-price interrelations a second time. Because of this, the absence of an index is particularly regrettable.

The "Summary View of 1920-1970," at the end of the study, mentions the authors' expectation that wheat producers' prices will average almost 15 percent higher in 1967/68 than in 1964-67; they will rise 7 percent for small producers and almost 20 percent for many of the larger producers. Barley producers are also expected to obtain a price increase of about 20 percent. However, the seemingly crucial observation, "In view of France's large agricultural resources and past developments, these planned prices seem certain to stimulate production of both grain and livestock products, with wheat and barley apparently favored most by the new price-cost structure," remains buried in the body of the study and, amazingly, is not mentioned in the Summary View.

A major analytical conclusion of the authors is that "improved estimates of national margins of support offer a much more promising basis for comparison of the protective effects of widely differing national grain programs than does any measure now in common use." From an analytical standpoint, a similar view has recently also been stated by R. Dardis and E. W. Learn in "Measures of the Degree and Cost of Economic Protection of Agriculture in Selected Countries," U.S. Department of Agriculture, Technical Bulletin No. 1384, November 1967.

As to future developments, the study concludes with unresolved contrasting expressions of hope and fear. First, there is a note of hope--"the expressed willingness of Community leaders to join with other countries in GATT agreements to bind and perhaps later reduce existing margins of support on major agricultural products is, we believe, one of the most constructive proposals yet made to bring realism and effectiveness to GATT negotiations relating to international trade in such products." But the final note is one of fear because of "the threat of further increases in EEC grain target prices." Unfortunately, already the latter rings truer: In late 1967, the EEC raised the feed grain price for 1968/69.

Ann Miller and Hans G. Hirsch

Growth and Structure in the Economy of Modern Italy

By George H. Hildebrand. Harvard University Press, Cambridge. 475 pages. 1965. $11.95.

ITALY'S ECONOMIC ACHIEVEMENTS of the past two decades have been widely discussed in literature that is informative but fragmentary. Now Hildebrand presents the background and the step-by-step development of Italy's economic "miracle" of 1947-61.

The author describes Italy's postwar economic background "...as a puzzle, a thing, of paradoxes and contradictions..." as a result of the two decades of Fascist rule, followed by the destruction of World War II. He traces the economic problems of credit, unemployment, wages, prices, and public finance chronologically, and praises the Italian Government's success in dealing with them. He also spells out the economic factors of the "boom" period and expresses them in terms of gross national product.

Hildebrand lists three major reasons for Italy's economic achievement: (1) The flexibility of Italy's monetary policy in meeting changing economic situations; (2) the effectiveness of Government fiscal policies, which controlled rampant inflation during several periods by credit control, tax measures, and the flexible money supplies; and (3) the success of Government intervention in stimulating economic growth in both the North and the South.

He emphasizes the dual character of the Italian economy, and the economic problem of the South. Since dualism signifies a markedly incomplete transformation to industrialism, the Italian Government intervened to narrow the economic gap between the North and the South. The establishment of the Southern Development Fund in 1950, with an appropriation of over $3.0 billion to cover the years from 1950 to 1965, was designed to achieve this end. The Fund's initial scope embraced land reform, land reclamation, and infrastructural measures. Priority was given to agriculture, followed by transportation and communication, water and sewage systems, and tourist facilities. The Fund was extended another fifteen years after it expired in 1965.

Hildebrand discusses at length the problems of the South, going back to the second century. He points out that the present dual system stems from the fact that, geographically, the South was destined to be culturally and politically distinct from the rest of Italy. He examines contrasting data for the North and the South on population growth, economic status of the population, and occupational categories. All of these show the noncohesiveness of Italy's society and the causes of its political unease. While Hildebrand describes the weakness of Italy's economic background, he maintains an optimistic attitude throughout. He points out that whenever there was a great economic crisis, there was always a strong political figure such as De Gasperi or Einandi to provide the necessary leadership.

Those interested in agricultural development will find that Hildebrand does not discuss the agricultural sector in detail, nor explore the role which the agricultural sector has played in Italy's economic growth. However, readers interested in the reasons for Italy's economic growth should find that this book is the most valuable reference to date.

Sheldon Tsu

Production Yearbook 1966

By Food and Agriculture Organization, Rome. Available from Columbia University Press, New York. 763 pages. $9.

THE TWENTIETH issue of this standard work contains data by countries on population, agricultural production, food supplies, prices, wages, and freight rates. It also includes, for the first time, a large number of estimates made by FAO on area and production of major crops and on livestock numbers and products, where no official or semiofficial figures were available from the countries themselves.

The Cotton Industry: An Essay in American Economic History. Part I. The Cotton Culture and the Cotton Trade

By M. B. Hammond. Reprinted by Johnson Reprint Corporation, New York and London. 382 pages. 1966. $12.50.

THIS CLASSIC STUDY of cotton from precolonial times to the 1890's was first published in 1897 as a publication of the American Economic Association, New Series, No. 1. It is now reprinted for the series called History of the American Economy: Studies and Materials for Study, edited by William N. Parker. The series will be made up of reprints of the important studies and source books relating to the growth of the American economic system. The present volume is of particular value to those interested in agriculture's part in economic development.

U. S. GOVERNMENT PRINTING OFFICE : 1968 O - 298-263

Suggestions for Submitting Manuscripts for Agricultural Economics Research

Each contributor can expedite reviewing and printing his manuscript by doing these things:

1. SOURCE. Indicate in a memorandum how the material submitted is related to the economic research program of the U.S. Department of Agriculture and its cooperating agencies. State your own connection with the program.
2. CLEARANCE. Obtain any approval required in your own agency before sending your manuscript to one of the editors or assistant editors of Agricultural Economics Research.
3. NUMBER OF COPIES. Submit one ribbon copy and two additional good copies of the manuscript for review.
4. TYPING. Double space everything, including footnotes.
5. MARGINS. Leave generous margins on four sides.
6. FOOTNOTES. Number consecutively throughout the paper.
7. REFERENCES. Check all references carefully for accuracy and completeness.
8. CHARTS. Use charts sparingly for best effect. Include with each chart a page giving essential data for replotting.
9. FINAL TYPING. Manuscripts accepted for publication will be edited and returned to author with instructions for retyping if necessary.

332

T J LANAHAN, JR
USDL BUR OF LABOR STAT
DIV LIVING COND STUDIES
WASHINGTON D C 20212

U.S. DEPARTMENT OF AGRICU[LTURE]
Economic Research Service
Washington, D.C. 20250

- - -

Official Business

U.S. Department of Agriculture

AGRICULTURAL ECONOMICS RESEARCH

Is published quarterly by the Economic Research Service, U.S. Department of Agriculture. Use of funds for printing this publication approved by the Director of the Bureau of the Budget (July 31, 1964).

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. 25 cents a single copy, $1 a year domestic, $1.25 foreign.