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PREDICTING REGIONAL CROP PRODUCTION AN APPLICATION OF RECURSIVE
SCHALLER, W.N. DEAN, G.W. 1 OF 2

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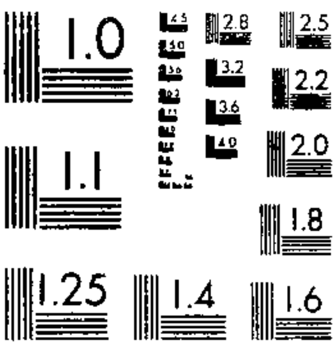

MICROCOPY RESOLUTION TEST CHART
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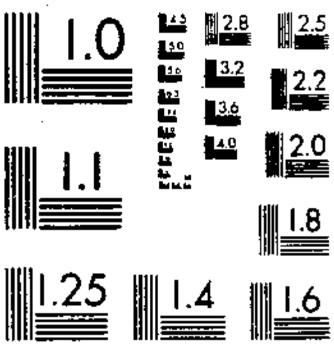

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TECHNICAL BULLETIN NO. 1329

PREDICTING REGIONAL CROP PRODUCTION

PREFACE

The farmer, the businessman, the banker, cannot escape "predicting." Whether his method of doing so is conscious or unconscious, formal or informal, simple or complex, prediction to some degree is an inevitable part of planning ahead. Public policymakers, too, must predict as best they can what farmers as a group will do in response to changes in such things as prices, technology, and Government programs.

An important aim of research in agricultural economics is to assist in this critical endeavor. Of course, predicting what farmers will do, in the real world, can be a very frustrating task. But our research is quite incomplete if it contributes only to a better understanding of the past or provides only a picture of how the economy might look under many simplifying assumptions about human and institutional behavior.

This study represents an attempt to go beyond explanation and toward prediction of economic phenomena. Yet the attempt is fairly modest and reemphasizes that useful predictions require much more in the way of theory, methodology, and data than has yet been developed.

The particular methodology we have used owes much to Richard H. Day, University of Wisconsin, formerly of the U.S. Department of Agriculture. His research on the development and application of recursive programing for predicting farmers' production response laid much of the groundwork for this study. Thanks are due to others in the Department of Agriculture, especially to Glen T. Barton, who arranged and supported the study, and to Frederick V. Waugh, and Walter R. Butcher (now with Washington State University) who suggested improvements in the manuscript. Douglas D. Caton and M. L. Upchurch also contributed to the planning stage. Harold O. Carter, University of California, assisted in the development of the study.

A number of people in California contributed their knowledge of the study area (Fresno County) and special data. Among them we wish to thank Leslie K. Stromberg, Farm Advisor, Fresno County; Roy Haley and Louis R. Mitchell, California State Department of Water Resources; A. Doyle Reed and Philip S. Parsons, Extension Economists, University of California; and Edward J. Griffith, Pacific Gas and Electric Company. The use made of the assistance from all of these people is of course the sole responsibility of the authors.

April 1965

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SUMMARY AND CONCLUSIONS

The problem of production imbalance in U.S. agriculture continues to underscore the need for policy-oriented research. We especially need improved techniques of *predicting* changes in the *aggregate* production of major farm commodities to detect emerging maladjustments and to appraise the effects of alternative policies or programs.

The primary objective of this study is to evaluate the characteristics and performance of a relatively new predictive technique called *recursive programing* (abbreviated RP). The RP "model" employs linear programing to generate a series of year-to-year adjustments. The recursive feature of the RP model is that it can be used to estimate these changes sequentially over time—based on data for preceding years—and thus to predict output and prices several years in advance.

The conventional linear programing technique indicates the adjustments that would maximize farm income. The particular model we have used includes "flexibility restraints," that is, upper and lower bounds on year-to-year changes in crop acreages, and "technological capacity" restraints, limits on the expansion of different technologies. These additional restraints add a predictive quality to the conventional programing model.*

To evaluate the RP technique, a recursive programing model was applied to the problem of explaining and predicting changes in the production of cotton and 11 alternative crops in Fresno County, Calif. Results were compared with actual outcomes and with estimates obtained by using separate regression equations for individual crops.

The Fresno model includes up to 98 activities representing different ways of producing crops (and Government program alternatives), and up to 76 restraints defined for land, irrigation water, mechanical cotton picking capacity, Government programs, and crop flexibility.

The analysis includes three different tests: An *Explanatory Test* for 1951–58, so called because year-to-year changes are estimated using information for the entire period; a *Predictive Test* for 1959–61, in which the estimates for each year are based on actual data through the preceding

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*In mathematical terminology, a "restraint" or "bound" represents a limit on a variable. As an upper limit, a restraint represents the maximum quantity of any resource available to farmers for their use in planning, organizing, and operating their farms. Thus the amount of capital a farmer has to work with, and the amount of irrigation water allotted to him, are restraints. An example of a restraint as a lower limit would be the growing of a minimum acreage of a given crop as part of a rotation system even though that crop might not, in itself, be as profitable as others.

year only; and a *Projection Test* in which the recursive, year-to-year estimating procedure is extended through 1965, using the solution for the preceding year as a point of departure for each new problem.

The comparative regression equations for individual crops have relatively high $\overline{R}^2$ values, and in comparison the results of the RP model are generally less accurate. The Explanatory Test shows that the RP model tends to overestimate relatively small changes in acreage, although it may be more effective than regression when substantial changes in structure occur—such as the introduction of a new Government program. Production results (estimated acres times expected yields) are somewhat less accurate than the acreage results for both techniques, due in part to unexplained yield-affecting variables.

The major advantages of the RP model over regression are as follows:

1. The RP solutions indicate *why* certain changes occur. This is because the model goes back to basic production relationships and the interplay of crop returns and restraints.

2. The RP model provides estimates of any crop defined as an activity regardless of whether the crop is controlled or operates in a free market. Regression results, based on a continuation of previous conditions, have limited use except for estimating production of uncontrolled crops.

Results of the Predictive Test, a truer test of forecasting ability, show the RP model gaining in relative accuracy but still somewhat less accurate than regression. An important cause of predictive error for the RP model again traces to the interrelation of crop returns in an optimizing framework that is restrained by reasonably wide bounds and a limited number of resources. The model underestimates Fresno participation in Plan B of the cotton program for 1959–60, and this seems to be associated in part with an overestimation of the acreages of certain other crops.

The Projection Test is included chiefly to illustrate certain characteristics of the RP approach, such as the generation of predictive cotton supply functions for specified years in the future. The projected acreage paths assume no allotments on cotton after 1960 and a cotton price equal to 80 percent of a historical average price. Controls or other maximum acreage limits are retained for wheat, rice, sugarbeets, and melons.

The Projection Test shows (1) that the RP results appear to be more stable than comparable regression estimates, (2) that the RP results do not lose more accuracy than the regression results when the estimates are made 2 years ahead instead of 1, and (3) that the RP acreage paths change direction due to the interrelations of crop returns and restraints, whereas the independent regression estimates, as expected, do not change direction.

This study analyzes only one region. A more advanced use of the RP approach would include a set of regional models in an "interregional system." Their solutions would be summed and superimposed on aggregate (national) product demand functions to estimate market prices for the next year.

Predicting Regional Crop Production

An Application of Recursive Programing

By W. NEILL SCHALLER and GERALD W. DEAN [1]

INTRODUCTION

One of the critical components in formulating intelligent farm policy is understanding and accurately predicting farmers' production response under alternative conditions. In retrospect, why have farmers reacted as they have to changes in prices, technology, Government programs, and other forces? How are they likely to react next year? Five years from now? In the aggregate? By area? To economic and institutional conditions not heretofore experienced?

Answers to such questions are not in themselves sufficient bases for broad policy decisions—but they are crucial ingredients. The importance of accurately predicting production response is recognized in the continuing research effort directed toward this end by Federal and State agencies in the United States. Several different research approaches have been used. Each has its advantages and disadvantages. None has been consistently "successful."

The major objective of this study is to critically evaluate and put to rather extensive empirical test one of the more recent approaches to explaining and predicting production response—namely, *recursive programing.* While important applications of the technique have been made already by Henderson (*33*) and Day (*21*), further application and testing of it are needed to determine its proper place and promise relative to alternative approaches.[2] Hence, this study emphasizes a direct empirical comparison of the characteristics and results of recursive programing (RP) with those of the widely used technique of regression analysis of time series data.

The empirical setting for the problem is the geographically small (1.4 million cropland acres in 1959) but agriculturally important area of Fresno County, Calif. The area's main crop, cotton, is one of the major "prob-

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[1] W. Neill Schaller, *Agricultural Economist, Farm Production Economics Division,* Economic Research Service, U.S. Department of Agriculture; and Gerald W. Dean, *Associate Professor, Department of Agricultural Economics, University of California.*

[2] Italic numbers in parentheses refer to items in Literature Cited and Selected *References, page 70.*

lem" crops under Government control in the United States.[3] Despite the use of various supply control measures and export subsidies over the past decade, large cotton surpluses remain one of the major problems in U.S. agriculture (table 1).

TABLE 1.—*Total annual production and August 1 carryover of U.S. cotton, 1953–63*

Year	Total U.S. production	Total carryover, August 1	Carryover as percent of production
	Million bales	*Million bales*	*Percent*
1953	16.5	5.6	34
1954	13.7	9.7	71
1955	14.7	11.2	76
1956	13.3	14.5	109
1957	11.0	11.3	103
1958	11.5	8.7	76
1959	14.6	8.9	61
1960	14.3	7.6	53
1961	14.3	7.2	50
1962	14.9	7.8	52
1963 [1]	15.5	11.2	72

[1] Preliminary.

Source: *Cotton Situation*, CS–209 (November 1963) and CS–210 (January 1964) (*45*).

Since 1957, about one-fifth of the total U.S. cotton production has come from the West (table 2). Sixty percent of the western cotton is produced by California, chiefly in six counties of the San Joaquin Valley (fig. 1). Fresno is the most important of these counties, with one-fourth of the State production (*6, 7*). This study, and an earlier study by Richard H. Day (*21*) analyzing changes in cotton production in the Mississippi Delta, might serve as building blocks toward a later model of U.S. cotton response useful for policy purposes.

The major remaining sections of this report (1) briefly describe and compare the most common research tools in production response work, (2) describe the empirical problem and the particular recursive programing and regression models used in this study, and (3) evaluate the empirical results of recursive programing by means of various test comparisons with the results from regression analysis.

ALTERNATIVE METHODS OF PRODUCTION RESPONSE RESEARCH

In 1933, Cassels (13) divided supply response studies into two main groups:

"*First*, those in which conclusions about the responsiveness of supply are based upon investigations into the underlying conditions of produc-

[3] For an historical review, see Benedict and Stine (*2*), pp. 3–46.

TABLE 2.—*Cotton production in Western States, and U.S. totals, 1953–63*

Year	California		Arizona		New Mexico		Nevada		Total West	Total U.S.	West as percent of U.S.
	1,000 bales	Percent of West	1,000 bales	Percent of West	1,000 bales	Percent of West	1,000 bales	Percent of West	1,000 bales	1,000 bales	
1953	1,768	56	1,070	34	327	10	2	....	3,167	16,465	19
1954	1,487	55	911	33	316	12	2	....	2,716	13,697	20
1955	1,205	55	728	33	266	12	2	....	2,201	14,721	15
1956	1,446	56	829	32	301	12	2	....	2,578	13,310	19
1957	1,537	61	763	30	236	9	3	....	2,539	10,964	23
1958	1,604	61	734	28	301	11	5	....	2,644	11,512	23
1959	1,929	65	715	24	323	11	6	....	2,973	14,558	20
1960	1,939	63	849	28	291	9	7	....	3,086	14,272	22
1961	1,689	60	828	29	300	11	6	....	2,823	14,318	20
1962	1,912	61	942	30	268	9	6	....	3,128	14,867	21
1963 [1]	1,715	60	845	30	275	10	6	....	2,841	15,548	18

[1] Preliminary.

Sources: *Statistics on Cotton and Related Data, 1925–1962* (*46*) and *Cotton Situation*, January 1964 (*45*).

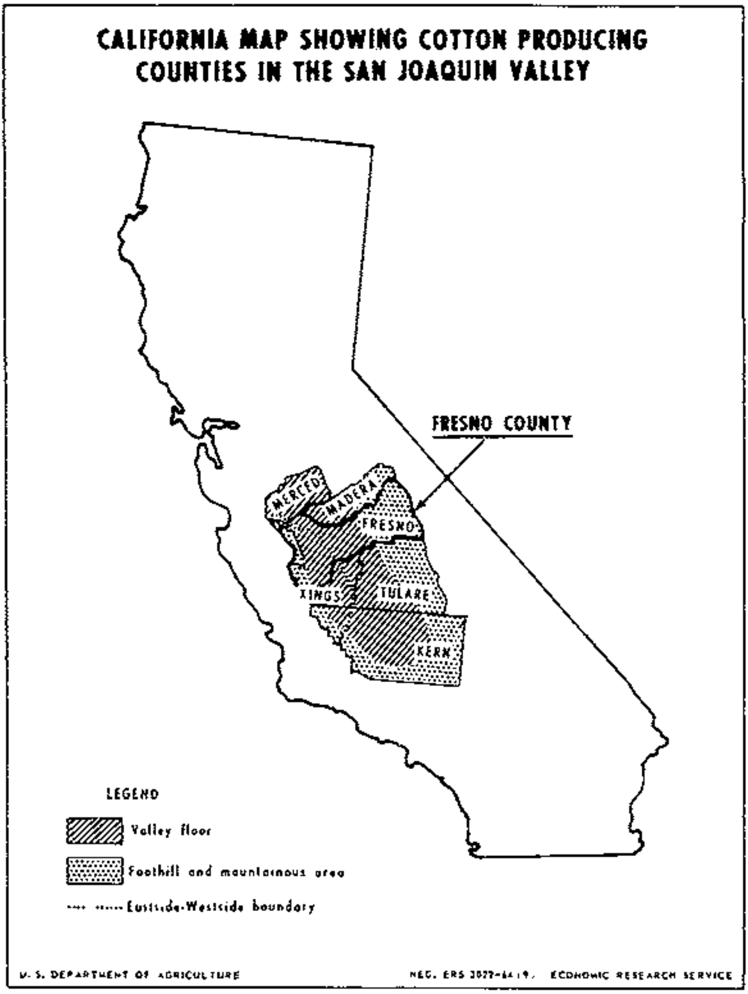

Figure 1.

tion; and *second*, those in which the conclusions are based directly on analyses of past experience with respect to prices paid and the response actually associated with them."

This classification is still appropriate. Currently, the most important method in the first group is activity analysis, or *linear programing*. The method commonly associated with the second is statistical analysis of time series data, or *regression analysis*.[4] The method of major interest

[4] The properties of linear programing and regression analysis are described throughout the literature and are not repeated here. Suggested references are Nerlove and Bachman (*37*) and Heady (*29*) for a review of both methods; Heady and Candler (*30*) for a treatment of linear programing alone; and Ezekiel and Fox (*26*) pertaining to regression analysis.

in this report—*recursive programing*—might be considered a synthesis of linear programing and time series analysis.

Linear Programing

Farm management research traditionally has focused on helping farmers determine what would be a "more profitable" or the "most profitable" farm organization under specific conditions. More recent research has emphasized problems of determining "optimum" interregional adjustments—those satisfying the condition of spatial equilibrium. Linear programing is well-suited for these problems because of its ability to optimize (usually maximize profits or minimize costs), while taking into explicit account the underlying production relationships of the firm or region. As generally used, it is a tool for specifying what firms or regions "must do" to maximize profits or minimize costs.

The question is to what extent the profit-maximizing solutions are useful for predicting what firms or regions "will do," or "would do" under specified circumstances. Profit-maximizing solutions may be good predictors in the *long run* on grounds that, through time, farmers overcome inertia, lack of knowledge, and other restraints and move toward the most profitable adjustments. But conventional linear programing solutions clearly are not intended to predict *short-* or *intermediate-run* adjustments, or the actual process of adjustment.

These solutions can be made more predictive in the shorter run by adding restrictions to reflect preferences or dislikes of the operator and by using *actual* rather than *highly efficient* production practices. However, there appears to be little widespread or systematic effort to augment programing models so as to reduce the inevitable discrepancy between profit-maximizing behavior and farmers' actual response.

Regression Analysis

In many respects, regression analysis is more directly useful for predicting farmers' response than conventional linear programing. Because regression results are based on actual past changes in production, they are more likely to take into account farmers' likes, dislikes, and other considerations which are omitted in the usual programing model. Further advantages of regression are (1) the relative accessibility of aggregative data compared with the difficulty of obtaining more detailed input-output and resource data required in linear programing, (2) relatively low cost and quick aggregative results and, (3) the ability, given the satisfaction of certain statistical assumptions underlying the model, to make probability and confidence statements about the results.

Despite these advantages, the regression technique cannot account for the effects of changes in the decision-making environment with the same degree of realism as is possible with linear programing. Estimated regression coefficients reflect only a historical structure. Thus, sharp changes in structure, due to forces such as technological change and Government programs, make it exceedingly difficult to use regression analysis for direct prediction. Purely statistical problems also occur when the number of past observations is limited or when the intercorrelation among "independent" variables is high.

In summary, the major advantage of regression in supply analysis is to explain past changes in production and to predict short-run future response under a continuation of the prevailing historical structure.

Recursive Programing (RP)

The RP model uses linear programing to make year-to-year sequential predictions of output, prices, and incomes over a period of years. The basic idea of recursive analysis has been explained by Wold and Jureén (*53*, p. 12–15), and has been used extensively by Professor Wold. The theory is that current production depends upon past prices, while current prices depend upon current production. Thus, if we know prices and production prior to year t, we can predict the probable production in year t; from this we can predict probable prices in year t; from this we can predict production in year $t+1$; and so on.

One of the simplest recursive analyses is the cobweb model described by Ezekiel (*25*). Many cobweb models have been derived statistically from regression analysis of aggregate time series data on prices and production. Our RP model is a more elaborate kind of cobweb model in many dimensions, based upon linear programing, with suitable limits to the year-to-year changes that can be made in output.

Dr. Frederick V. Waugh, Economic Research Service, U.S. Department of Agriculture, presents an up-to-date review and interpretation of cobweb model developments in the November 1964 issue of Journal of Farm Economics (*52*).

Richard H. Day recently developed and applied an RP model in a pioneering study of the Mississippi Delta (*18, 21*). His study explains past changes in the production of cotton and eight alternative crops during the period 1940–57. Among Day's contributions is the basic idea that programing restraints can be generated in a recursive manner, thus giving the linear programing model a dynamic property. Marshall K. Wood presented a similar idea in 1951 (*54*).

Referring to the RP model, Day points out that ". . . any particular model of this kind belongs to a quite general class of dynamic programming models which are dynamic not only in the Hicks sense, as are most so-called 'dynamic programming' problems, but also in the Frisch-Samuelson sense. Consequently, the system called for a new name which would recognize this distinction. Thus, 'Recursive Programming.'

"The essential difference between the two is that in 'Dynamic Programming' planning is determined by a single optimizing decision, while in recursive programming economic plans are determined by a sequence of optimizing decisions" (*21*, pp. vii-viii).

The Day model was influenced also by James M. Henderson's study of changes in land utilization (*33*). Henderson developed, and tested for one year, the idea that a profit-maximizing model with "flexibility" restraints on year-to-year adjustments can be used as a predictive device. Henderson applied his model to explain changes in the acreages of 11 field crops for the United States as a whole, between 1954 and 1955. He divided the country into regions, solved a programing problem for each region, and summed the results to obtain national estimates.

A separate RP "problem" can be defined for each year, or other suitable planning period, based on data for the preceding year(s). Farmers' decisions are assumed to be independent *in the short run.* We assume that these decisions (or plans) are based on farmers' "expected" earnings from production alternatives and on their available resources. Next year's plan is viewed as a deviation from the current cropping plan or farm organization. Accordingly, the data used in the RP model are "expected" values. For example, actual prices received in year t-1 may be defined as the expected prices for year t. Similarly, model restraints depend on the previous level or use of resources.

Restrictions in the model include, in addition to the resource restraints commonly specified in linear programing, "flexibility" and "technological capacity" restraints on the maximum allowable year-to-year changes in the solution from the preceding year. Estimation of the allowable rates of change is based on time series data of past changes. Consequently, although the solution to the model is "optimum," it is a highly restrained optimum in conformity with farmers' past actual behavior, thus approximating a more *predictive* solution.

Apart from an explicit treatment of time and the addition of recursive restraints, the RP model is quite like the conventional linear programing model. The basic unit of analysis may be a single farm, a group of homogeneous farms, or a geographic region. The "activities" in the model are the production alternatives or other choices open to the unit. The "objective" of the model is to maximize total net returns or profit to the unit, subject of course to the restraints estimated recursively for the particular year. As these restraints are perhaps the most critical component of the model, they are discussed below in some detail.

Flexibility Restraints

The flexibility restraints are simply upper and lower bounds on the allowable year-to-year change in the solution *acreage* of each crop in the model. Their role is to account for the many forces causing lags in adjustment, such as farmers' inability or unwillingness to maximize profit because of risk and uncertainty, personal preference or dislike for growing certain crops, minimum leisure requirements of operators, and conflict of short-run profit maximization with longer-run objectives.

The acreage bounds for year t are represented by the inequations,

$$X_t \leq (1+\bar{\beta})\ X_{t-1}$$

and

$$X_t \geq (1-\underline{\beta})\ X_{t-1},$$

where X_t refers to the total solution acreage of all activities producing a given crop in year t; X_{t-1} is the *actual* acreage of the crop in year $t-1$, or the *solution* acreage in year $t-1$ if t is more than 1 year into the future; and $\bar{\beta}$ and $\underline{\beta}$ are the maximum allowable percentages (decimal form) of increase and decrease, respectively, from the acreage in the preceding year. For example, if the acreage of cotton in year $t-1$ is 1,000 acres, and $\bar{\beta}$ and $\underline{\beta}$ equal 10 percent and 40 percent, respectively, the solution acreage of cotton in t is restrained to fall between 600 and 1,100 acres. Empirically, $\bar{\beta}$ and $\underline{\beta}$ are estimated from time series data by one of several methods.

The simplest estimates of flexibility coefficients are the averages of positive and negative percentage changes in the past. A more formal approach involves fitting a regression equation of the form $X_t=f(X_{t-1})$, or possibly a more complex function including additional independent variables. The data might also be stratified into years of positive and negative change before analysis in order to permit $\bar{\beta}\neq\underline{\beta}$. Still another possibility is to base the estimates of $\bar{\beta}$ and $\underline{\beta}$ on the *maximum* changes that took place in a previous "similar" period.

The general rationale for one or another of these empirical procedures is as follows: Various forces interact to explain past changes in crop production. Some are measurable; some are not. The measurable quantities are introduced explicitly in the analysis (changes in technology, resource levels, yields, costs, and prices). Since the other forces are not measurable, we include restrictions that reflect the past sum effect of *both* measurable and nonmeasurable forces—that is, actual past acreage or production changes resulting from *all* forces. These restrictions may not be effective when the explicit forces are sufficiently binding to determine a solution. More often, they are effective for certain crops.

In a sense, the flexibility restraints can be viewed as naive forecasts of future production under "favorable" (upper bound) and "unfavorable" (lower bound) conditions. The RP model then refines the forecasts by taking into account all the additional explicit information available. If this "refinement" did not take place, there would be no advantage (and probably a disadvantage) to the RP method as compared to conventional regression analysis on a crop-by-crop basis.

Technological Capacity Restraints

To make the RP model as predictive as possible, restraints on the capacities of factors of production associated with alternative technologies are included. For example, where cotton can be picked by hand or by machine, the maximum production of cotton that can be machine picked is included as a restriction. Like the upper and lower crop bounds, the technological capacity restraints are determined from past, year-to-year changes in the actual acreage or production associated with that technology.

This procedure assumes that the rate of adoption of technology is limited by factors such as lack of knowledge and limited supplies. It assumes that the demand for the asset equals or exceeds the supply. The resulting restraint on the expansion of a profitable technology indirectly restricts the abandonment rate of other, less profitable techniques. Thus, the technological capacity restraints isolate certain of the forces accounted for indirectly by upper and lower crop acreage bounds.

Physical Resource Restraints

An RP model may include any number of physical resource restraints commonly imposed in other programing models, such as available land, labor, fertilizer, and irrigation water. Often the restraint magnitude is known in advance, like the total land area. However, future resource restraints are often unknown and must be estimated from data on past rates of change and resource levels. The inequation in this case is of the form,

$$Z_t \leq (1+\gamma)Z_{t-1},$$

where Z_t is the restraint value in year t; Z_{t-1} is the magnitude in year $t-1$; and γ is a coefficient representing the maximum allowable percentage change.

THE EMPIRICAL PROBLEM, MODELS, AND TESTS

The Problem

The empirical problem of this study is to (1) "explain" changes in the production of cotton and alternative crops in Fresno County, Calif., from 1951 through 1958, (2) to "predict" the changes for 1959–61, and (3) to "project" changes through 1965 under assumed program conditions. Cotton production response is emphasized because of its importance in U.S. farm policy. For example, if present acreage controls were relaxed, what types of adjustment would take place in the quantities of cotton produced? Would cotton production continue to expand in the West and the Southwest? What would be the impact of cotton response on other segments of agriculture? Our principal interest is to assess the relative usefulness of RP for answering these and similar questions.

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Fresno County was selected for analysis not only because it is an important cotton-producing area but also because it has a great diversity of characteristics. The area presents essentially all of the problems that would be expected in an analysis of a larger area—different types of farms, irrigated and nonirrigated agriculture, and a wide range of crop production. Soil, water, and even climatic conditions vary widely within the county.

Fresno has a semiarid climate with relatively mild winters and hot summers. The length of the growing season on the valley floor averages over 225 days and favors the production of a large number of crops including fruits, nuts, vegetables, and field crops (*15*, *16*, *34*). Many of the soils in cultivation are among the most productive in the State. As Fresno's annual rainfall averages 5–12 inches, occurring almost entirely between October and May, irrigation is essential for summer crops.

Differences in the sources, cost, and quality of irrigation water divide the valley floor into two distinct parts, the *Eastside* and the *Westside* (fig. 1).[5] These are treated as separate subregions in the RP model to reduce the degree of heterogeneity. The Eastside is adjacent to the chief source of water, the Sierra Nevada Mountain range. For that reason, Eastside farms were developed first and today have access to a reliable supply of relatively low-cost, high-quality surface water distributed by irrigation districts and to groundwater pumped from relatively shallow wells. This allows production of many high water-using crops.

Eastside farms are comparatively small in terms of acreage, partly because of the historical pattern of settlement and partly because large units are not required for operators to earn satisfactory farm incomes. For example, in 1954, the Eastside had 4,180 farms holding cotton allotments; and over 80 percent of these farms contained less than 100 acres of cropland (*31*).

In sharp contrast, the Westside of Fresno County has access only to groundwater which, due to a peculiar subsurface formation, must be pumped from deep wells. Irrigation development on the Westside did not begin until the 1940's. Prior to that time, grain and pasture were the chief crops and large units were needed to provide acceptable incomes. After World War II, the increasing profitability of cotton and the timely development of the deep-well turbine caused a rapid transition of the Westside to a more intensive irrigated agriculture. Typically, there is one well, pumped continuously during the peak season, to irrigate a section of land. Thus, fixed costs per acre-foot of water are reduced as much as possible and wear and tear on deep-well turbines is less than if they were turned on and off frequently during the irrigating season.

[5] The Eastside is defined as the area east of the Fresno Slough, including a small portion of the county west of the San Joaquin River, which has been supplied with surface water for the past decade. The Westside includes the rest of Fresno County, which has access to groundwater only.

During the transition to more intensive production there was little change in farm size. For example, in 1954, the Westside had 155 cotton allotment-holding farms; 59 percent of these had over 1,100 acres (*31*). The sharp contrast in size of farming units between the Eastside and the Westside is clearly illustrated in the aerial photographs in figure 2.

The historical size distribution on the Westside was maintained, first, because much of the area is owned in section blocks by large industrial corporations that rent to large farm operators. Second, there are substantial economies of scale on the Westside due to easy adaptability of large-scale equipment. Third, large units are more important for satisfactory earnings than on the Eastside because Westside groundwater is high in salt content, limiting the area's alternatives to reasonably tolerant and generally less profitable crops.

High water costs further limit the number of crops to those which have low water requirements, yield exceptionally high returns, or are grown for rotational purposes. Due to the water quality and cost problem, the major Westside alternative to cotton is barley, a low-value winter crop.

The RP Model of Fresno County Crop Production

It is clear from the foregoing discussion that we are interested in a linear programing model made as *predictive* as possible by additional restraints, and capable of sequentially projecting results into the future. Such a model can be constructed either on an individual "representative" farm basis, with aggregate estimates obtained by weighting individual farm results by the number of farms in each category, or on a regional or aggregate farm basis, giving aggregate results directly.

We have chosen the second or regional model, modified to distinguish between two distinct subregions, mainly for the reason that data requirements and time and cost of analysis are less than for the "representative" farm model. For example, we use as physical resource restrictions the amounts available to all farms without specifying the amounts available to each farm. Also, there are no known and usable time series data for estimating "representative" farm flexibility restraints.

The principal disadvantage of the direct aggregate approach is the problem of aggregation bias. Quantifying total physical resource restraints involves difficult problems of aggregation. Many fixed or quasi-fixed factors of production, such as tractors and irrigation wells, belong to specific farm units. Even though not used to capacity on the particular farm, these resources nonetheless may be unavailable or only partially available to the other farms in the aggregate.

Custom or contract practices for specialized machines and seasonal labor allow high resource mobility for some so-called "fixed" factors. In other cases, the degree of nonuse must be considered in setting aggregate restrictions. Specific problems of this type are discussed in the following pages and in the appendix.

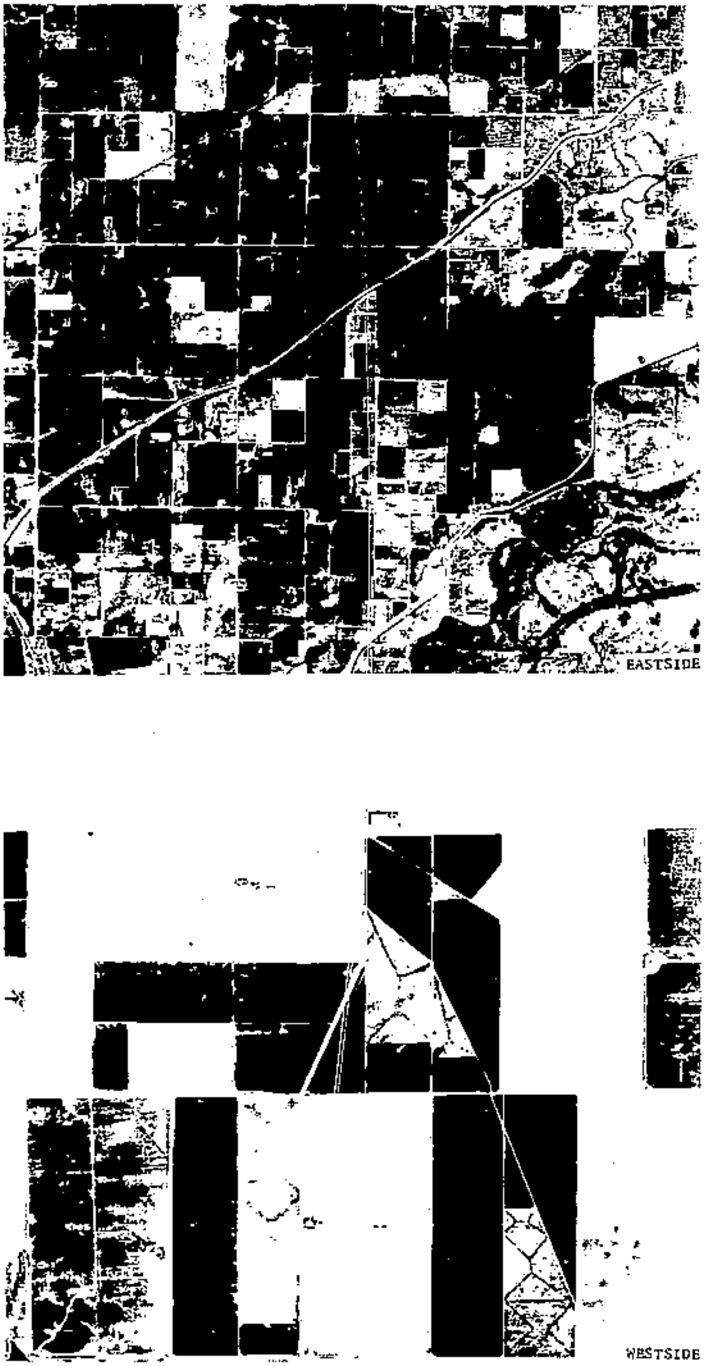

Figure 2. Land-use patterns, Fresno County, Calif. Eastside (top) is north of Sanger; Westside is about 10 miles west of Helm. These pictures were taken at the same altitude. (Courtesy Soil Conservation Service.)

To reduce aggregation problems, combinations of the representative farm and aggregate approaches are intuitively appealing. Perhaps the most obvious of these is stratifying the aggregate model into farm-type components or strata with separate, aggregate resources and possibly with all strata competing for certain other resources. In effect, our model with Eastside and Westside stratification is of this type.

The Activities

Twelve crops were defined as the basic land-use alternatives in this analysis:

Eastside	*Westside*
Cotton	Cotton
Barley	Barley
Wheat	Wheat
Alfalfa hay	Alfalfa hay
Alfalfa seed	Alfalfa seed
Sugarbeets	Sugarbeets
Grain sorghum	Grain sorghum
Rice	Melons
Field corn	
Dry beans	
Irrigated pasture	

These crops constitute the major short-run land-use alternatives directly interrelated with cotton. In 1958, the 8 Westside crop alternatives accounted for 98 percent of the Westside cropland; the 11 Eastside crops accounted for 93 percent of the total cropland on that side, excluding orchards and vineyards.[6]

Acreages in orchards and vineyards were excluded because (1) the model would be greatly complicated by their inclusion and (2) the total acreage in orchards changes slowly and would have no great effect on the short-run aggregate production responses of annual crops.[7]

Expected net returns per unit (acre) of each activity were calculated assuming that farmers' expectations of price, yield, and cost components can be approximated by simple expectation models. Expected prices for annual crops were taken to be the average prices received in the preceding year. Expected prices for the semipermanent crops, alfalfa hay and alfalfa seed, were weighted averages of prices in the past 2 years, i.e., $0.67P_{t-1}+0.33P_{t-2}$. Expected costs were set equal to actual cost estimates for the preceding year. Yield expectations were assumed to equal trend extrapolations (usually linear) of past average Fresno County data.

Production activities in the model represent unique techniques of producing each of the 12 crops. A total of 74 to 98 activities are defined,

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[6] Unpublished aerial photo survey data furnished by California State Department of Water Resources, Division of Resource Planning.

[7] For an example of how orchard crops might be handled in a linear programing model, see Dean and De Benedictis (*22*).

depending on the year tested. Alternative production techniques include:

Different Soil Types.—Activities are included for each of three types of cropland (types 1, 2, and 3 defined in the appendix), differing in yield-affecting characteristics. Expected yields and associated harvesting costs vary with each soil. Except for rice, each crop can be grown on any of the soil types. Rice, a heavy water-using crop, is limited to soil types 2 and 3 because it is commonly produced only on heavy-textured or shallow soils with high moisture-holding capacities.

Irrigated and Nonirrigated Production.—Barley and wheat are winter crops and hence usually mature with little or no irrigation. The remaining activities are summer crops, all irrigated, with one level of water application defined for each crop.

Single- and Double-Cropping Practices.—The model includes barley-sorghum double-cropped activities on each of the Eastside soil types. Since land is relatively more limited than irrigation water on the Eastside, farmers may follow winter barley with a June-planted crop that has a short growing season, such as beans, rapid-maturing varieties of corn, or sorghum. In contrast, on the Westside, water rather than land is the more restricting resource; therefore all Westside activities are single-cropped.

Different Cotton Technologies.—Cotton production alternatives include both hand and mechanical picking on both sides.

Westside cotton activities also include both solid and "skip-row" planting. Skip-row cotton was introduced by farmers as an alternative in the mid-1950's in an attempt to increase yield per unit of the most restricting factors, water and cotton acreage allotments.

The Restraints

The Fresno model includes 67 to 76 restraints, depending on the year tested. Five kinds of restraints were selected (in addition to Government programs). The criterion was to quantify as many as possible of the restrictions that actually affected the cropping pattern throughout the test period. A detailed discussion of these restraints and their derivation is found in the appendix, part B. However, a brief discussion of each should give the reader an appreciation of the procedures and difficulties encountered.

Total Land and Land in Different Soil Types.—The basic assumption used in estimating land restraints is that the actual total acreage of the 12 Fresno crops closely approximates the "supply" of land available to those crops. This assumption is probably quite valid as the crop alternative is usually more profitable than leaving land idle.

The total land restraint for years 1951–58 was set equal to the 12-crop acreage; but for years after 1958, it was derived using a Pearl-Reed growth function (appendix, page 86). In both cases, the total acreage was divided into separate soil type restraints based on available land classification data.

Acre-Feet of Irrigation Water, in Total and by Time Periods.—The assumption that resource supplies equal the quantity used or demanded was also applied to irrigation water. This is undoubtedly valid for the Westside where groundwater is the only source of supply and most farmers operate their pumps continuously during the peak season. Even on the Eastside, the supply of surface water delivered to farmers by irrigation districts or water companies is limited by entitlements which reflect actual demand.

The prevailing method used to estimate total water restraints was the least squares equation,

$$Z'_t = (1+\gamma)Z_{t-1},$$

where Z_t and Z_{t-1} are the estimated total amounts of water used by the 12 Fresno crops in years t and $t-1$, and γ is a percentage change coefficient. This total water restraint was then divided into five time-period supplies based on the historical distribution.

The Maximum Production of Cotton That Can Be Picked by Machine (capacity restraint).—Like land and water restraints, the aggregate capacity of mechanical cottonpickers was estimated from data on actual use, implicitly assuming that these data were a valid measure of farmers' willingness and ability to adopt the technology. Capacity restraints for the future were determined from the least-squares equation, $B'_t = (1+\alpha) B_{t-1}$, where $B'_t =$ the maximum number of bales that can be machine-picked in the solution in year t, and $B_{t-1} =$ the actual production machine-picked in year $t-1$.

Flexibility Restraints.—The *upper* and *lower acreage* bounds for each crop included in the model were based on regression estimates of the flexibility coefficients ($\bar{\beta}$ and $\underline{\beta}$). As explained in the appendix, the analysis was conducted in percentage terms to reflect changes in the total land base. Separate equations also were estimated for the years of increase ($\bar{\beta}$) and decrease ($\underline{\beta}$). Because they are regression estimates, the flexibility coefficients represent *average* past net changes in acreage. To be more consistent with the concept of a "bound" being a *maximum* allowable change from one year to the next, the upper bounds were increased by one standard error of the estimate, and lower bounds were decreased by one standard error.

Ideally, the flexibility coefficients ($\bar{\beta}$ and $\underline{\beta}$) are estimated from analysis of past years which are "similar" to the year to be predicted. It was necessary, therefore, to omit past years during which unique and nonrecurring forces were at work. Specifically, we omitted 1954 and 1955 as observations when estimating the upper bound coefficients for uncontrolled crops because of the substantial, but unique, acreage increases that occurred in response to the return of cotton allotments. To allow for the "pressure" to expand alternative crops *in those 2 years*, a share of the diverted acreage (based on acreage data for the preceding year) was then added to the upper bound on each of the uncontrolled crops.

A Maximum Acreage of Soil Type 1 and Minimum Acres of Types 2 and 3 in Cotton.—One of the "aggregation problems" in a regional analysis is the tendency for the model to allocate the most profitable crops, like cotton, only to the best soils, whereas in fact cotton is widely grown on farms which may have only soils of poorer quality. Hence, restrictions were included specifying (1) an agronomic maximum of no more than 50 percent of soil type 1 to cotton and (2) restrictions forcing at least a minimum of cotton onto soil types 2 and 3 equal to the actual 1958 cotton acreage on these soils (1958 cotton acreage was widespread but at a minimum due to allotments).

Representation of Government Programs

Various Government supply programs were in effect during the test period, 1951–61 (see Description of Model Tests, page 22). The activities and restraints in the model were changed or augmented to reflect these conditions so as to test the model's ability to explain or predict farmers' program response.

Price Supports and Allotments.—Cotton and wheat allotments were in effect beginning in 1954, and rice allotments were introduced in 1955. The announced allotment is the upper acreage bound on each of these crops whenever it is lower than the computed bound. The support price is used as the "expected" price whenever it is higher than the lagged price received.

The acreage of sugarbeets was under a processing "quota" throughout the test period. The quota is used as the upper bound, and a Government payment is included in the crop's net returns.

The Cotton Acreage Reserve of the Soil Bank.—This program gave each farmer the opportunity to reduce his cotton acreage below the announced allotment and to receive in return a rental payment per pound of lint that would have been produced on the "banked" acreage. Thus, for each of the soil-type activities defined for cotton, a "rental" activity was added in the problems for 1957 and 1958, the 2 years in which the program was in full operation.

One unit (acre) of this rental activity returns 15 cents per pound of lint times the average historical yield, less a nominal charge for weed control. One unit of the activity also uses 1 acre of the cotton allotment, satisfies 1 acre of the lower acreage bound on cotton, but uses none of the water or mechanical picking capacity required by production activities.

The Cotton Plan A–B Program.—Under this program, in effect for 1959–60, each farmer had a choice between *Plan A*, with the cotton price supported at not less than 80 percent of parity on production limited to the regular allotment, and *Plan B*, which permitted an expansion of acreage up to 40 percent over the allotment but involved a support that was 15 percent-of-parity less than under Plan A.

To represent this program, two sets of cotton activities are used. One set uses the "A" price and another uses the "B" price. The cotton acreage allotment remains as the upper bound, but because Plan B allowed the acreage to exceed the allotment by 40 percent, 1 acre of a B activity uses only 0.714 acres of allotment (1.0÷1.4) instead of the full acre required by each Plan A activity.

The 1961 Feed-Grain Program.—The farmer had three options under this program. If he grew an acreage of corn and sorghum larger than 80 percent of his "base" acreage (his average acreage of these crops in 1959–60), he was ineligible for price supports. If he reduced his acreage to 80 percent of the base, he was eligible for support on what he grew and, in addition, he received a payment for each diverted acre equal to 50 percent of the support price times his "normal" yield for the crop. He could further reduce his acreage by any amount down to 60 percent of the base, in which case he received the above payment plus a payment on each additional diverted acre equal to 60 percent of the support times his normal yield. Provisions for small farms were also included in the program, but these are not represented in the Fresno model.

Each of the activities for grain sorghum and corn is redefined as an option to produce the crop with no support and with no limit on acreage, other than the computed upper bound. Three additional activities are defined for each soil type to depict alternative degrees of participation in the program. The first represents the option of reducing acreage to 80 percent of feed-grain base. The returns to each of these activities are a combination of earnings from growing eight-tenths of an acre and the diversion payment for idling the remaining two-tenths of that acre. The second set of activites depicts the option of growing the crop on seven-tenths of an acre, with three-tenths idle. The third represents production on six-tenths of the acre, with four-tenths idle. Each unit of a participating activity uses 1 acre of the "feed-grain base," a new bound.

The RP Model in Matrix Form

Table 3 provides an abbreviated symbolic picture of the Fresno model. The matrix consists of two submatrices, one for the Eastside and another for the Westside, each with its own set of land, water, flexibility, and technological restraints. In addition, the two areas compete for a total Fresno County "resource," the maximum bales of cotton that may be picked by machine, because cottonpickers can and do move between the two sides.

The Eastside and the Westside are also directly competitive in the case of various "bookkeeping" restraints for 1951–58, such as the minimum total quantities of land and irrigation water that must be used on the Eastside. As explained in the appendix, part B, these restraints are

TABLE 3.—*Recursive programing matrix, Fresno County, Calif.*[1]

Westside													Eastside																Restraints	
X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	....	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{26}	....			
1	1	1	1	1	1	1	1	1	1	1	1	Soil type 2 and 3 activities																≤	Acres of soil type 1	
																												≤	Acres of soil type 2	
																												≤	Acres of soil type 3	
.92	.92	.92	.92	1.00		1.17	1.00	1.31	.58		.50																	≤	Acre feet of water, period 1	
						.58		.75	.58	.58	.75																	≤	Acre feet of water, period 2	
.67	.67	.67	.67			.67		.75	.67	.50	.83																	≤	Acre feet of water, period 3	
.67	.67	.67	.67			.75		.41	.83	.58	.33																	≤	Acre feet of water, period 4	
.75	.75	.75	.75			.83			.42	.50																		≤	Acre feet of water, period 5	
a	a	b	b																									≤	Cotton machine-picked output	
1	1	1	1																									≤	Max. soil type 1 in cotton	
																												≥	Min. soil type 2 in cotton	
																												≥	Min. soil type 3 in cotton	
	1		1																									≤	Max. soil type 1 in skip-row cotton.	
																												≤	Max. soil type 2 in skip-row cotton.	
																												≤	Max. soil type 3 in skip-row cotton.	WESTSIDE
1	1	1	1																									≤	Upper bound on cotton	
				1	1																							≤	Upper bound on barley	
						1																						≤	Upper bound on alfalfa hay	
							1																					≤	Upper bound on wheat	
								1																				≤	Upper bound on alfalfa seed	
									1																			≤	Upper bound on sugar beets	
										1																		≤	Upper bound on sorghum	
											1																	≤	Upper bound on melons	
1	1	1	1																									≥	Lower bound on cotton	
				1	1																							≥	Lower bound on barley	
						1																						≥	Lower bound on alfalfa hay	
							1																					≥	Lower bound on wheat	
								1																				≥	Lower bound on alfalfa seed	
									1																			≥	Lower bound on sugar beets	
										1																		≥	Lower bound on sorghum	
											1																	≥	Lower bound on melons	

																											Soil type 2 and 3 activities			
													1	1	1	1	1	1	1	1	1	1	1	1	1	1		≤	Acres of soil type 1	EASTSIDE
																												≤	Acres of soil type 2	
																												≤	Acres of soil type 3	
													.83	.83	.75		1.17	.75		1.31	.58		.75	.42	.50	.42		≤	Acre feet of water, period 1	
																	.58			.67	.50	.58		.58	.33	.58		≤	Acre feet of water, period 2	
													.67	.67			.67			.67	.67	.42	.75	.33	.33	.83		≤	Acre feet of water, period 3	
													.58	.58			.67			.33	.75	.50	.50	.83	.50	1.00		≤	Acre feet of water, period 4	
													.67	.67			.75				.33	.42	.42		.50	1.00		≤	Acre feet of water, period 5	
													a	b														≤	Cotton machine-picked output	
													1	1														≤	Max. soil type 1 in cotton	
																												≥	Min. soil type 2 in cotton	
																												≥	Min. soil type 3 in cotton	
													1	1														≤	Upper bound on cotton	
															1	1							1					≤	Upper bound on barley	
																	1											≤	Upper bound on alfalfa hay	
																		1	1									≤	Upper bound on wheat	
																				1								≤	Upper bound on alfalfa seed	
																					1							≤	Upper bound on sugar beets	
																						1	1					≤	Upper bound on sorghum	
																								1				≤	Upper bound on field corn	
																												≤	Upper bound on rice	
																									1			≤	Upper bound on dry beans	
																										1		≤	Upper bound on irrigated pasture.	
													1	1														≥	Lower bound on cotton	
															1	1							1					≥	Lower bound on barley	
																	1											≥	Lower bound on alfalfa hay	
																		1	1									≥	Lower bound on wheat	
																				1								≥	Lower bound on alfalfa seed	
																					1							≥	Lower bound on sugar beets	
																						1	1					≥	Lower bound on sorghum	
																								1				≥	Lower bound on field corn	
																												≥	Lower bound on rice	
																									1			≥	Lower bound on dry beans	
																										1		≥	Lower bound on irrigated pasture.	
	c	c											c															≤	Cotton machine-picked output (total).	COUNTY & "BOOK-KEEPING"
	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1		≤	Total County acreage [2]	
	3.26	3.26	3.26	3.26	1.50		4.42	1.50	3.22	3.50	2.16	2.41		3.00	3.00	1.00		4.17	1.00		2.98	3.25	1.92	2.67	2.16	2.16	4.75		≤	Total County water supply (ac. ft.).[2]	
													1	1	1	1	1	1	1	1	1	1	1	1	1	1		≥	Minimum total Eastside acreage.[2]	
													3.00	3.00	1.00		4.17	1.00		2.98	3.25	1.92	2.67	2.16	2.16	4.75		≥	Minimum Eastside water use (ac. ft.).[2]	

See footnotes on next page.

Footnotes for pages 18 and 19

[1] Only soil type 1 activities are shown. These are denoted by subscripts 1–26, as follows:

Subscript	*Activity*
	Westside
1	Cotton, machine-picked, solid-planted
2	Cotton, machine-picked, skip row
3	Cotton, hand-picked, solid-planted
4	Cotton, hand-picked, skip row
5	Barley, irrigated
6	Barley, dry
7	Alfalfa hay
8	Wheat, irrigated
9	Alfalfa seed
10	Sugarbeets
11	Grain sorghum
12	Melons
	Eastside
13	Cotton, machine-picked, solid-planted
14	Cotton, hand-picked, solid-planted
15	Barley, irrigated
16	Barley, dry
17	Alfalfa hay
18	Wheat, irrigated
19	Wheat, dry
20	Alfalfa seed
21	Sugarbeets
22	Grain sorghum, single-cropped
23	Barley-sorghum, double-cropped
24	Field corn
25	Dry beans
26	Irrigated pasture

Matrix coefficients *a*, *b*, and *c* (associated with restraints on machine-picking of cotton) differ for each activity and each year.

[2] Rows used only in the Explanatory Test, 1951–58. However, the "Total county water supply" is converted to separate Westside and Eastside restraints after 1958

required because of insufficient data concerning the breakdown of actual crop acreages between the two sides prior to 1958. Such restraints are omitted after 1958.

The Regression Models of Fresno County Crop Production

As mentioned earlier, the major purpose of the analysis is to test the RP model against conventional regression analysis of time series data. We have chosen to specify only three single-equation, least-squares models fitted independently to Fresno crops. The equations specified are quite representative of regression models, although better "fits" (higher R^2) might have been obtained by more exhaustive examination of alternative regression models.

For comparison with RP results, we select for each crop the regression model which gives the "best fit" (highest R^2). This is more rigorous than testing the RP results against those of a "naive" model as is sometimes proposed in testing econometric models, such as predicted output in year t=actual output in year $t-1$, or letting predicted output be a function of time only.

The following single-equation, least-squares models were applied independently to each of the 12 Fresno crops except sugarbeets and irrigated pasture:[8]

$$(1)\ X_t = a + bX_{t-1} + c\overset{*}{P}_t + dT + e_t$$

$$(2)\ X_t = a' + b'X_{t-1} + c'\overset{*}{R}_t + d'A_t + e'_t$$

$$(3)\ X_t = a'' + b''X_{t-1} + c''\overset{*}{R}_t + d''G_t + e''_t,$$

where the variables are defined as follows:

X_t=actual planted acreage of a given crop in year t (or harvested acreage if planted data are not available, 1,000 acres).

X_{t-1}=acreage planted (or harvested) in year $t-1$ (1,000 acres).

$\overset{*}{R}_t$="expected" gross per acre returns, year t (dollars)=$\overset{*}{P}_t$ times actual yield per harvested acre, year $t-1$.

$\overset{*}{P}_t$="expected" price per unit of output, year t (dollars)=P_{t-1}, the price actually received in year $t-1$, or the support price for year t, whichever is higher.

A_t=total Fresno County acreage available to "included" crops, year t (1,000 acres)=the RP model's total land restraint.

[8] Sugarbeets are omitted from the comparison because this crop has no recent and continuing history of uncontrolled acreage. Pasture is omitted because there are no published market price data.

G_t=a shift variable representing acreage controls on other crops, or the diverted acreage effect. $G_t=0$ for $t=1951$–53; $G_t=1$ for $t=1954$–58.

T=a trend or time variable representing the effects of changes in technology and nonprice variables; 1946=1.

Like the RP model, these equations express the hypothesis that the acreage of a crop depends on its acreage in the preceding year and on other variables such as expected price, expected gross returns, the total land resource, and the presence of Government programs. Both the RP and regression models are recursive, meaning that acreage in year t can be predicted in year $t-1$ from "known" values.

In the RP model the historical relation between X_t and X_{t-1} is used to estimate crop bounds, and $\overset{*}{P}_t$ or $\overset{*}{R}_t$ are used to compute expected net returns. The variable, A_t, is broken down into subregion and soil-type acreages that serve as restraints. The Government allotment variable is also handled on the restraint side of the RP model. In contrast, these same variables are combined into a simplified model of statistical association in equations 1–3.

To obtain estimates of crop output, as well as acreage, from regression analysis, the acreage estimates from the most acceptable of equations 1–3 were multiplied by lagged actual yields per harvested acre, as follows:

$$O'_t=\left(\frac{Y_{t-1}+Y_{t-2}+Y_{t-3}}{3}\right)X'_t,$$

where O'_t=predicted output of a given crop in year t; Y_t=actual yield per harvested acre in year t; and X'_t=acreage predicted from regression model (1), (2), or (3). Again, this comparison is a meaningful one. In the RP model, acreage and yields are predicted simultaneously, whereas in regression analysis, as used here, the yields are predetermined. The comparison of output results should, therefore, provide insight into the effect of treating the two components of output endogenously.

Description of Model Tests

Three different kinds of tests are included in this analysis: An *explanatory* test covering the period 1951–58, a *predictive* test applied to 1959–61, and a *projection* test for 1960–65.

The Explanatory Test (1951–58)

Changes occurring in the 1951–58 period were great enough to provide a challenging test of the explanatory ability of the alternative models. A variety of Government programs were in force during the period. Between 1951 and 1953, cotton accounted for almost one-half of Fresno County's acreage in included crops. When cotton allotments were reintroduced in 1954, this share declined to 31 percent, and it was further reduced to 27 percent in 1955. Substitute crops increased in relative importance, as farmers found alternative uses for diverted acres. Irrigation development continued to increase despite acreage controls on cotton, wheat, and rice; and this development provided additional land for alternative crops.

Changes in costs and technology also occcurred rapidly during the period. The cost of pumping irrigation water on the Westside increased from an estimated $3.85 per acre foot in 1950 to $6.70 in 1958, due to a lowering of the water table associated with increasing use.[9] On the technological side, the proportion of Fresno's cotton production picked by machine increased from 25 to 96 percent between 1950 and 1961.[10]

The explanatory models, as the name implies, simply try to "explain" *ex post* why changes have taken place in the past. Thus, it is considered legitimate to use data for the entire period in "explaining" output in a particular year. For example, the regression equations are fitted to data for the entire period (actually 1946–58), and the predicted value of the dependent variable for each year compared with the actual value in that year. Likewise, the RP model uses "advance" information in this period; resource and flexibility restraints for a particular year are estimated from data for the entire 1951–58 period. The "test" of the RP model will be whether or not its "explained" acreage and output of the various crops over the time period approximate actual values more closely than similar "explanations" from the regression models.

The Predictive Test (1959–61)

This test uses no advance information except what is known *ex ante* each year about Government programs. RP and regression predictions are based only on preceding information. Here the problem for both models is to predict 1 year ahead for the years 1959, 1960, and 1961 based on data for years 1958, 1959, and 1960, respectively. This provides a more rigorous test than the Explanatory Test and more nearly represents the setting in which "real" problems of prediction are confronted by decision-makers.

The Projection Test (1960–65)[11]

This test is included in the analysis to evaluate the intermediate-run nature of RP results. Specifically we want to answer the following types of questions: What happens to predictive reliability over time when the data are *not* corrected annually for the actual outcome in the preceding

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[9] Unpublished data furnished by Pacific Gas & Electric Co., Fresno, Calif.

[10] Estimates in Hedges and Bailey (*32*) or derived from unpublished U.S. Department of Agriculture data and from unpublished records of the California Department of Employment, Farm Labor Office, Fresno.

[11] The term "projection" is used instead of "long-run prediction" because in a projection certain data are assumed rather than predicted.

year? From a policy standpoint, what kinds of adjustments would be expected over a period of years in a western irrigated region such as Fresno, under assumed program conditions?

Two series of projections are included. In the first series, it is assumed that the base year is 1958, and estimates of cotton production response are desired for each year through 1965. Thus, a series of year-to-year solutions from the RP model and regression analysis are computed to 1965 based on data through 1958. The second series in the test consists of the same sequential procedure, but uses 1959 as the base year instead of 1958. Again, solutions are computed through 1965 based on those for the preceding year.

Results of Explanatory Test (1951–58)

The results of the Explanatory Test (in which we use data for the entire period to "explain" changes in each year) are illustrated crop-by-crop in figure 3. Table 4 shows the percentage deviation of "explained" from "actual" acreage and production for the RP and regression models for each crop in the period 1951–58. Table 5 gives the outcome of the regression analysis in more detail. The results are discussed crop by crop, and then summarized.

Cotton

Changes in the acreage of cotton are explained by the RP model with an average error of about 6 percent (table 4). The model has a strong tendency to overestimate this crop (fig. 3) because of its high relative profitability, particularly in 1953 when the error was 21 percent.

The discrepancy in 1952 and 1953 would have been even greater if the upper bounds on cotton had been reached. Instead, the estimated acreage in these years was limited by supplies of irrigation water and the degree to which farmers were willing to reduce their acreages of alternative crops (depicted by lower bounds). Also, limits on the production of machine-picked cotton and on the acreage of soil type I that could go to cotton have important effects on the solutions for 1952–53. As these limits are reached, the only opportunity to increase cotton is by the hand-picked activities on the poorer soils; and these activities are less profitable for cotton than for crops like melons and rice.

The RP estimates for 1954–56 are without error. The model correctly explains farmers' full use of cotton allotments. In 1957–58, the model includes Cotton Acreage Reserve Activities on each soil type.[12] These represent the option of *not* producing a portion of the allotment in return for a rental payment. In 1957, the model places in Reserve 3,275 acres on the Westside and 5,080 on the Eastside, or a total of 8,355. This

[12] Because the Soil Bank Act was passed too late in 1956 for most farmers to consider it an alternative, it was excluded from the model until 1957.

compares with an estimated 24,430 acres actually "banked."[13] In 1958, the model places only 3,082 Westside acres in the Reserve, compared with an actual estimate of 17,540 acres.

The discrepancy occurs because the model does not reflect many of the differences between farms, and among fields within each farm, which account for the decision to participate in a voluntary-type program. A breakdown of the region into farm type aggregates could result in more accurate estimates of participation, but even a model with such intra-regional detail would not reflect all the reasons behind farmers' decisions, particularly those of a noneconomic nature.

The RP solutions place all of the Reserve acreage on soil type 3. This is probably a fair approximation of actual participation for farms having soil of this type. Although the per acre payment rates varied directly with cotton yields, costs of production *per bale* were higher on soil type 3 than on the better quality land because of the lower yields on type 3. Therefore, the net returns from the Reserve activities were relatively more attractive than the cotton producing activities on soil type 3. In actual applications of the model, the returns could be varied to estimate participation associated with alternative payment rates and other program conditions.

Table 4 shows that the regression model, despite its relative simplicity, explains the 1952–53 acreage more accurately than the RP model. The RP model estimate, however, is more accurate for 1951, a year in which cotton increased from an allotted acreage of only 159,000 to 342,000 acres after controls were removed. This result supports the hypothesis that regression analysis provides better estimates during periods of smaller changes and relatively stable structure, while the RP model is better able to predict under situations of sharp changes in structure.

The use of regression alone presents a problem in the period of cotton allotments from 1954–58. The time series estimates apply only to an unrestricted decision environment for the crop in question and thus cannot be used directly to explain or predict in years of cotton allotments. Of course, if by substituting the support price in the regression equation, the predicted acreage is well above the total allotment, one would have strong grounds for concluding that farmers will fully plant their allotments. Still, it must be conceded that RP has a substantial advantage as an analytical tool to approximate new structural conditions such as would accompany Government programs.

As was shown in figure 3, the RP model overestimates cotton production with a larger average error than for acreage (17 percent versus 6 percent), because yields tend to be overestimated (table 6). One reason for the model's slight overestimation of cotton yields is its tendency to place as much cotton as possible on the better soils, because of the crop's high relative profitability. This occurs despite the agronomic restriction

[13] County total provided by the Fresno Agricultural Stabilization and Conservation (ASC) Office.

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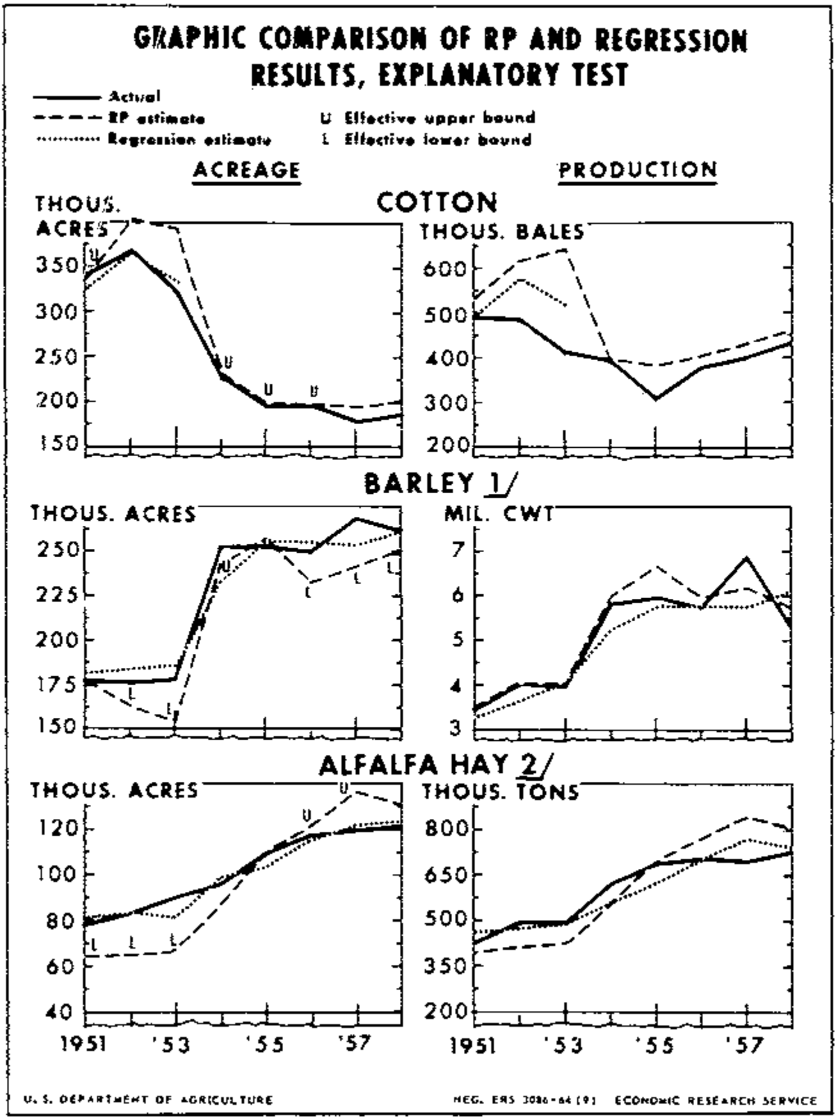

Figure 3, Part 1

[1] Production estimates = predicted acres, adjusted for average abandonment, times expected yields per harvested acre.

[2] Expected yields used to compute RP production estimates = (0.25) (first year yield) + (0.75) (mature yield).

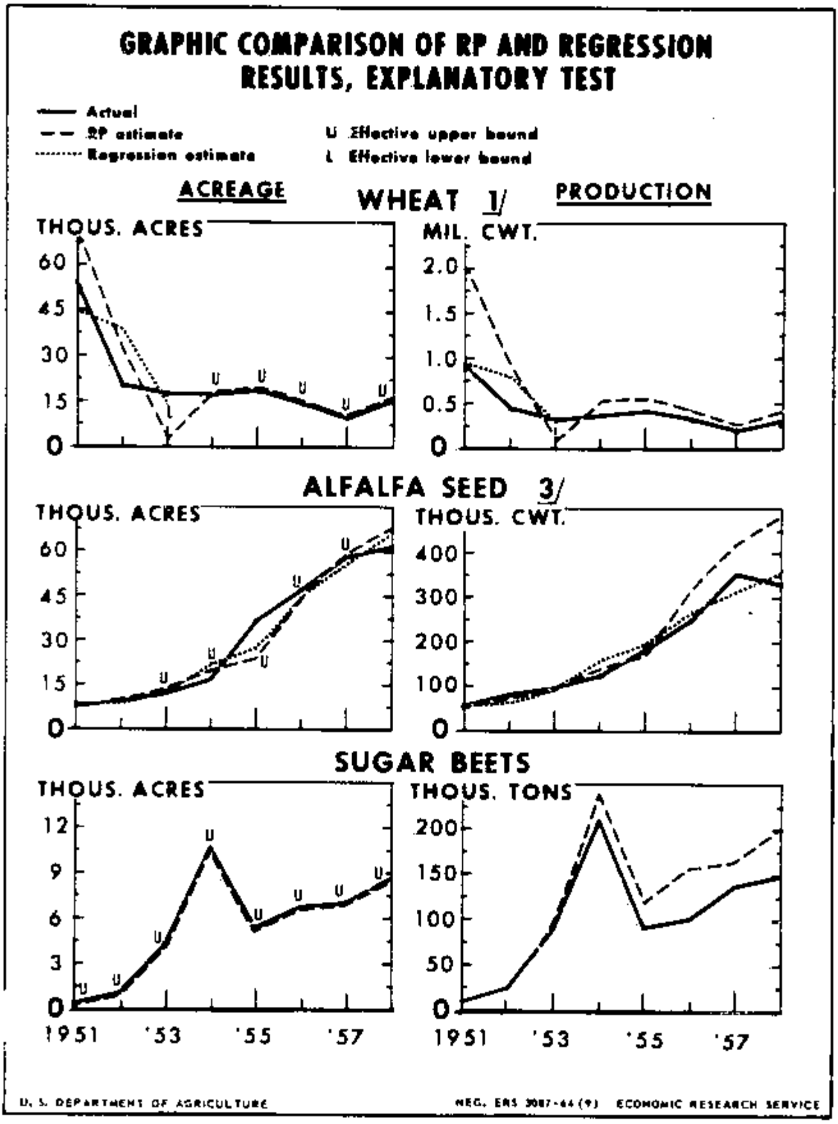

Figure 3, Part 2

[1] Production estimates = predicted acres, adjusted for average abandonment, times expected yields per harvested acre.

[3] Expected yields used to compute RP production estimates = (0.33) (first year yield) + (0.67) (mature yield).

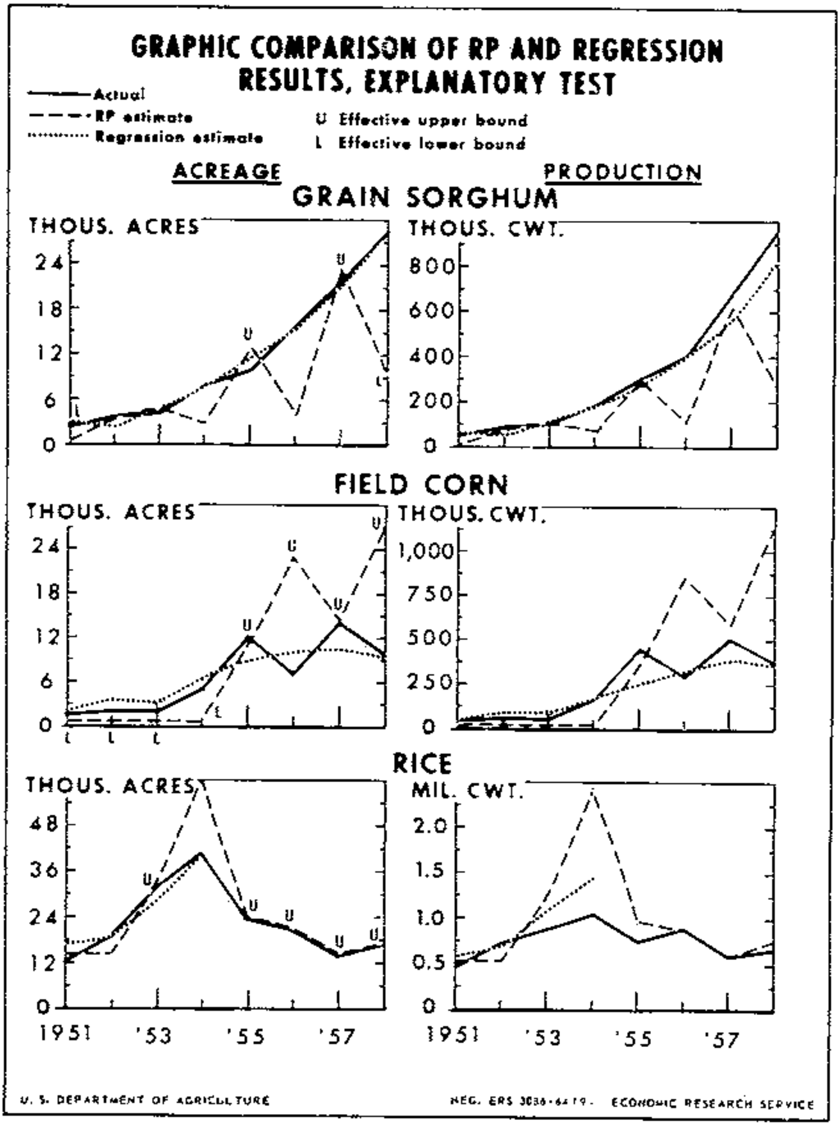

Figure 3, Part 3

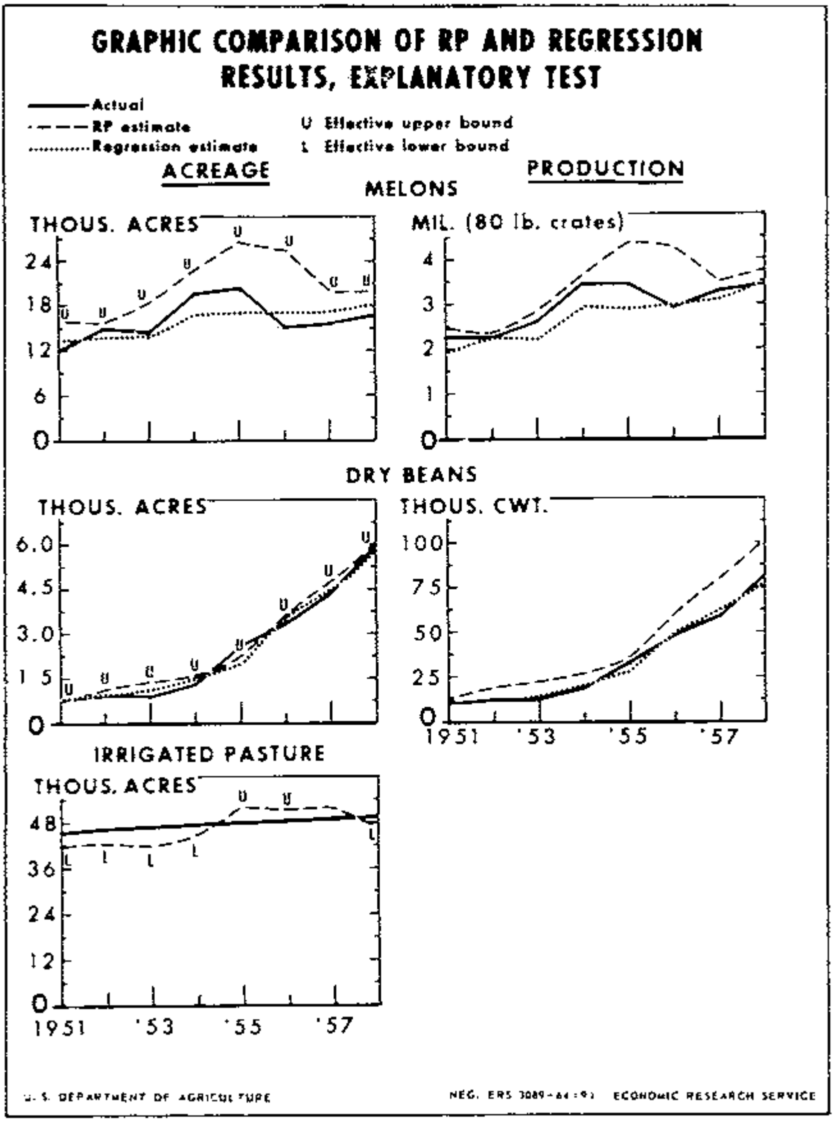

Figure 3, Part 4

TABLE 4.—*Percentage deviation of "explained" from "actual" crop acreage and production, Fresno County, 1951–58* [1]

[ACREAGE]

Year	Cotton		Barley		Alfalfa hay		Wheat		Alfalfa seed		Sugarbeets	
	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression
1951	1. 1	4. 7	0. 6	2. 4	17. 6	4. 5	32. 2	16. 3	2. 5	16. 7	0	....
1952	9. 0	1. 0	7. 9	4. 4	22. 6	. 6	57. 8	94. 1	6. 4	2. 7	0	....
1953	21. 3	3. 1	13. 6	4. 2	27. 1	9. 6	87. 2	20. 9	10. 3	4. 3	0	....
1954	0	....	4. 0	7. 7	10. 5	2. 8	0	....	17. 8	32. 2	0	....
1955	0	....	1. 6	1. 2	. 8	5. 4	0	....	35. 1	26. 3	0	....
1956	0	....	6. 6	2. 4	3. 3	2. 2	0	....	4. 6	4. 9	0	....
1957	9. 8	....	10. 1	5. 6	13. 7	1. 5	0	....	1. 9	4. 9	0	....
1958	7. 8	....	4. 1	0	7. 9	1. 8	0	....	10. 0	7. 8	0	....
Average 1951–58	6. 1	....	6. 1	3. 5	12. 9	3. 4	22. 2	....	11. 1	12. 5	0	....
Average 1951–53	10. 5	2. 9	....	....	....	....	59. 1	43. 8	....	....	....	....
Average 1951–54	....	....	....	....	....	....	....	....	....	....	....	....

Year	Grain sorghum		Field corn		Rice		Melons		Dry beans		Irrigated pasture		Average of 7 crops [2]	
	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression
1951	79.0	16.7	65.3	24.5	17.9	43.0	33.1	12.1	3.4	10.7	8.3	....	28.8	12.5
1952	8.8	39.3	80.9	80.9	24.9	2.8	3.7	7.3	23.8	4.9	8.2	....	22.0	20.0
1953	14.2	13.8	67.0	57.1	.1	11.1	26.4	5.3	53.2	25.8	11.4	....	30.3	17.2
1954	63.0	2.4	87.8	30.5	46.6	2.5	16.5	13.4	22.8	13.1	6.5	....	31.8	14.6
1955	26.9	16.5	11.8	26.5	0	....	30.3	15.7	22.9	24.0	8.8	....	18.5	16.5
1956	73.9	4.1	225.2	44.1	0	....	67.2	13.1	7.7	8.7	5.3	....	55.5	11.4
1957	6.2	3.7	2.2	24.4	0	....	27.4	10.3	8.6	3.1	6.4	....	10.0	7.6
1958	68.4	12.5	175.3	4.2	0	....	18.1	8.7	.3	3.2	6.5	....	40.6	5.5
Average 1951–58	42.6	13.6	89.4	36.5	11.2	....	27.8	10.7	17.8	11.7	7.7	....	29.7	13.1
Average 1951–53	......	....	......	....	......	....	......	....	......	....	......	....	......	....
Average 1951–54	......	....	......	....	22.4	14.8	......	....	......	....	......	....	......	....

See footnotes at end of table.

TABLE 4.—*Percentage deviation of "explained" from "actual" crop acreage and production, Fresno County, 1951–58* [1]—Con.

[PRODUCTION]

Year	Cotton		Barley		Alfalfa hay		Wheat		Alfalfa seed		Sugarbeets	
	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression
1951	8.0	0.2	1.5	4.6	7.3	8.3	119.3	2.2	6.0	0.5	3.4	....
1952	27.1	18.3	1.2	9.8	16.2	4.4	108.6	81.7	13.1	26.6	2.0	....
1953	55.7	25.3	1.5	2.7	13.8	1.3	78.3	10.4	2.1	6.5	5.0	....
1954	.9	....	3.2	9.8	10.6	9.8	43.2	....	14.4	30.3	12.8	....
1955	23.4	....	11.8	3.6	1.4	9.9	35.9	....	6.8	4.8	30.3	....
1956	7.1	....	3.9	.1	9.1	.6	25.2	....	29.0	8.3	55.2	....
1957	7.4	....	10.2	16.6	21.2	10.3	34.6	....	20.4	10.9	18.8	....
1958	6.6	....	7.9	15.9	10.6	1.8	39.3	....	48.4	10.2	35.1	....
Average 1951–58	17.0	....	5.2	7.9	11.3	5.8	60.6	....	17.5	12.3	20.3	....
Average 1951–53	30.3	14.6	....	....	....	....	102.1	31.4	....	....	....	....
Average 1951–54	....	....	....	....	....	....	....	....	....	....	....	....

Year	Grain sorghum		Field corn		Rice		Melons		Dry beans		Irrigated pasture		Average of 7 crops [2]	
	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression
1951	79.6	14.1	69.6	5.6	15.4	28.8	9.7	14.8	22.3	9.6	...	...	28.0	8.2
1952	18.3	46.0	86.4	63.4	26.1	6.0	3.7	.5	59.8	4.3	...	...	28.4	22.1
1953	2.8	1.7	74.4	57.0	40.8	23.2	8.3	15.8	84.2	18.3	...	...	26.7	14.8
1954	63.1	6.8	88.8	7.6	131.8	38.0	5.9	14.9	44.0	6.0	...	...	32.9	12.2
1955	1.6	11.7	21.3	43.9	29.8	...	27.2	15.7	3.0	16.8	...	...	10.4	15.2
1956	74.3	2.8	190.4	9.7	1.8	...	46.5	2.0	25.7	2.7	...	...	54.1	3.7
1957	9.0	18.3	16.8	22.5	2.3	...	5.2	6.3	36.1	5.9	...	...	17.0	13.0
1958	73.3	14.3	210.4	4.0	13.4	...	8.9	1.3	23.5	4.0	...	...	54.7	7.4
Average 1951–58	40.2	14.4	94.8	26.7	26.8	...	14.4	8.9	37.3	8.4	...	...	31.5	12.1
Average 1951–53	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Average 1951–54	...	...	...	...	53.5	24.0	...	...	...	...	...	...	...	...

[1] The difference between the model estimate and the actual value, expressed as a percent of the actual.
[2] Seven crops estimated by both models for the entire period (barley, alfalfa hay, alfalfa seed, grain sorghum, field corn, melons, and dry beans).

TABLE 5.—*Regression equations used for Explanatory Test, 1951–58* [1]

Crop	Equation	$\bar{R}^2$	Standard error of X'_t (1,000 acres)
Cotton	$X'_t = -189.519 + 0.400X_{t-1} + 0.522\overset{*}{R}_t + 0.372A_t$ (2.857) (2.330) (1.942)	0.99	15.280
Barley	$X'_t = 88.861 + 0.337X_{t-1} + 0.458\overset{*}{R}_t + 54.903G_t$ (2.228) (1.398) (4.492)	0.91	14.536
Alfalfa hay	$X'_t = 10.790 + 0.834X_{t-1} + 0.008\overset{*}{R}_t + 11.770G_t$ (7.517) (1.338) (3.303)	0.95	4.594
Wheat	$X'_t = -4.360 + 0.592X_{t-1} + 12.906\overset{*}{P}_t - 5.321T$ (1.562) (0.810) (−1.875)	0.68	13.908
Alfalfa seed	$X'_t = -6.318 + 0.987X_{t-1} + 0.033\overset{*}{R}_t + 10.051G_t$ (10.011) (0.830) (2.802)	0.97	4.640
Grain sorghum	$X'_t = -6.995 + 1.147X_{t-1} + 0.099\overset{*}{R}_t + 3.410G_t$ (12.104) (2.187) (3.217)	0.97	1.554
Melons	$X'_t = 9.875 + 0.091X_{t-1} + 0.005\overset{*}{R}_t + 3.088G_t$ (0.399) (0.759) (2.140)	0.59	1.943
Field corn	$X'_t = -5.217 + 0.198X_{t-1} + 0.083\overset{*}{R}_t + 4.366G_t$ (0.898) (2.215) (2.435)	0.78	2.442
Rice	$X'_t = -10.140 + 0.967X_{t-1} + 1.838\overset{*}{P}_t + 1.070T$ (2.419) (0.944) (0.944)	0.88	4.884
Dry beans	$X'_t = 0.102 + 1.231X_{t-1} - 0.001\overset{*}{R}_t + 0.421G_t$ (15.307) (−0.267) (2.007)	0.98	0.284

[1] Variables are explained on page 21. Each equation selected on basis of highest $\bar{R}^2$ from among three alternatives. 1946–58 data used for all crops except cotton (1946–53, omitting 1950 due to allotments), wheat (1946–53), and rice (1946–54). Numbers in parentheses are *t*-ratios. Tabled *t*-values for 2-tail test, 5 percent level are: 3.182 for cotton, 2.776 for wheat, 2.571 for rice, and 2.262 for all other crops.

that no more than 50 percent of soil type 1 can be planted to cotton. However, the RP model does approximate the actual reduction in yield that occurred when cotton acreage was expanded in 1952.

This reduction was due primarily to the fact that a larger acreage of poorer-quality soil was necessarily brought into production as the total acreage increased. Of course, errors in yield estimates also occur because of weather variations. Like other predictive techniques, the RP model does not attempt to account for these factors.

TABLE 6.—*Actual cotton yields per acre compared with RP model estimates, 1951–58*

Year	Actual yields	RP yields	Year	Actual yields	RP yields
	Lbs. of lint	*Lbs. of lint*		*Lbs. of lint*	*Lbs. of lint*
1951	688	745	1955	777	932
1952	626	728	1956	955	989
1953	609	777	1957	1,107	1,062
1954	838	829	1958	1,147	1,105

Barley

The barley acreage is explained by the RP model with the same degree of accuracy as cotton; the average error is 6 percent. However, the circumstances are quite different. Barley is a relatively unprofitable crop grown in rotation and frequently on land that is unsuitable for high-value row crops.

Because of the low returns on barley, the RP estimates equal the crop's lower bounds in all but the 3 years, 1951, 1954, and 1955 (fig. 3). The low estimates in 1952 and 1953 are associated with the already mentioned overestimation of cotton acreage.

The barley acreage for 1954 deserves special comment. The actual acreage increased from 178,000 to 253,000 between 1953 and 1954, due chiefly to the restoration of cotton allotments in 1954. Farmers, faced with the problem of how to use land formerly in cotton, had several alternatives; but the expansion of most other crops was limited by such things as know-how, specialized equipment, and the uncertainty attached to abrupt changes in the cropping plan.

Barley, though not the most profitable alternative, was a long-established crop of sizable acreage which could be expanded rapidly onto diverted land. The RP model shows an increase in the barley acreage from 154,000 to 243,000. The 1954 estimate was 79,000 acres above the crop's lower bound; it differed from the actual acreage by only 10,000. In contrast, the regression estimate in 1954 was only 233,000 acres. Thus the RP model results add support to the hypothesis that under conditions of radical change, the RP approach is more appropriate than regression.

In the next few years, as farmers adjusted to allotments by expanding the acreage of alternatives with higher returns, the difference between the estimated and minimum acreage of barley narrowed. In 1956, the lower bound was again effective. Thus, the RP model explains reasonably well the region's actual pattern of crop adjustments in response to cotton allotments.

Despite the advantage of the RP model in a few selected years, the regression model is clearly superior on an average over the 8-year test period—3.5 percent average "error" versus 6.1 percent for the RP model (table 4).

Again, the regression model provides a rigorous test criterion with an $\overline{R}^2$ of 0.91 (table 5). The most significant independent variable in the equation is G_t, which represents the diverted acreage effect of controls on other crops. This is probably quite realistic. The barley acreage seems to be determined to a large exent by the cotton acreage, while the converse is not true. The one-way relationship is particularly rele ant on the Westside, where there are relatively few alternative crops.

Table 4 shows that the RP model explains changes in production more accurately than the regression model (5.2 and 7.9 percent average error, respectively). Although the RP model underestimates acreage in all but two years, these errors are offset somewhat by a slight overestimation of average yields.

Alfalfa Hay

The RP acreage path estimated for alfalfa hay follows a pattern similar to the one estimated for barley. The county estimate is at the crop's lower bound in 1951–53; somewhere between the two bounds in 1954–55; at the upper bound in 1956–57; and between the two again in 1958. This pattern, as with barley, is due to production on diverted acres following the reintroduction of allotments on cotton, wheat, and rice.

Again, the regression analysis provides a very good fit to the data for the period as a whole with $\overline{R}^2=0.95$ (table 5), and gives an average error of estimate of only 3.4 percent as compared to 12.9 percent for the RP model. The RP model improves its relative position somewhat in the production comparison but is still decidedly inferior to the regression model.

The remaining nine crops are far less important than cotton, barley, and alfalfa hay in terms of acreage. Nevertheless, the results for these other crops are discussed briefly, since they do provide further evidence of the relative reliability of the RP and regression models and illustrate differences not yet discussed.

Wheat

The RP estimates of wheat acreage follow the actual downward trend, but they badly overestimated the actual in both 1951 and 1952 and underestimated it in 1953. The regression model also has sizable errors ($\overline{R}^2=0.68$, table 5). After 1953, wheat allotments were in effect, and the RP model correctly specifies that the full allotment was planted. For the reasons explained for cotton, the regression model is inappropriate for direct estimates of acreage under allotments.

Table 4 shows that the RP model overestimates total production during the allotment years. The reason is apparently that high returns on wheat cause more acreage to be planted on soil type 1 than seems likely, another example of one of the aggregation problems which are not solved in the RP model.

Alfalfa Seed

This crop expanded from 7,000 to 62,000 acres during the test period. Both the RP and regression estimates parallel this growth with reasonable accuracy. The average errors are 11.1 and 12.5 percent, respectively (table 4). The upper bounds in the RP model are effective in 5 of the 8 years.

The year 1955 is an interesting one in that the actual acreage more than doubled between 1954 and 1955. This sharp increase exceeded the average rate of change by a substantial margin. The upper bound, though it permits a high degree of flexibility, could not allow for this actual change. One reason is that 1954 and 1955 were not included as observations when estimating the upper bound coefficients for uncontrolled crops because of the unique adjustments to cotton allotments. As explained earlier, a "diverted acreage share" was added to the upper bounds in those years, a procedure that obviously underestimates the actual diversion to alfalfa seed in 1955.

Contrary to the earlier hypothesis, 1955 was a year in which the regression equation for alfalfa seed provides a better estimate under conditions of sharp structural change. But the relative accuracy of regression is due partly to the fact that 1954 and 1955 were included as observations, and their uniqueness accounted for by the variable, G_t. As a consequence, the regression estimates reflect actual diversion in those years.

Alfalfa seed is a relatively profitable crop, and for this reason it is placed largely on soil type 1 in the RP solutions. This allocation explains the model's tendency to overestimate seed production, except for years when the acreage is sufficiently below the actual to offset the error.

Sugarbeets

The beet acreage was under quotas, or otherwise restricted by processing limits, throughout the test period. The RP model correctly allocates acreage to this crop up to the maximum allowed. Production is overestimated because the model places this relatively profitable crop entirely on soil type 1 in every solution. Obviously, some restrictions were needed to account for the fact that all quotas were not on soil 1; unfortunately, no data were available and any restriction would have been extremely subjective. A comparative sugarbeet regression model could not be fitted due to the historical limits on free movement of the beet acreage.

Grain Sorghum

Like alfalfa seed, this crop expanded considerably between 1951 and 1958 due to allotments on other crops and the profitable adoption of hybrid sorghum. Because of the strong time trend, the regression model has a very good fit ($\overline{R}^2=0.97$, table 5). However, the crop acreage fluctuates widely in the RP solutions, with large underestimations of acreage in 1954, 1956, and 1958. As pointed out in the next section, these errors appear closely related to overestimation of field corn acreage.

Production estimated by the RP model is consistently below the actual, not only because of low acreage estimates but also because sorghum is placed chiefly on soil types 2 and 3. When this crop appears on soil type 1, it is double-cropped with barley, resulting in sorghum yields less than those for single-cropped grain sorghum.

Field Corn

The RP estimates of corn acreage also fluctuate considerably. The estimates for 1951–54 equal the crop's lower bound, while those for the remaining years equal the upper bound. The acreage errors for corn and grain sorghum appear to be closely related. For example, sorghum is underestimated in 1956 and 1958, while the model's corn acreage in these years is substantially above the actual data. When sorghum acreage is slightly overestimated in 1955, the corn estimate for 1955 also is below the actual. These relationships attest to the fact that grain sorghum and corn are close substitutes.

The RP model is very sensitive to slight changes in net return ratios between these two crops in the 1954–58 period. Thus, despite the large individual errors in annual acreage estimates of corn and grain sorghum by the RP model, the *total* acreage estimates of the two crops closely approximate the actual:

	1955	*1956*	*1958*
	Acres of corn plus grain sorghum		
Total actual	22,000	23,000	38,180
Total RP	23,273	26,941	35,661
Deviation	−1,273	−3,941	2,519

The regression equation for field corn, although a better predictor than the RP acreage estimate for corn, just shown, was also not particularly successful in predicting the sharp actual acreage changes between 1954 and 1958.

Rice

Acreage allotments on rice were instituted in 1955. The RP and regression estimates follow the actual growth through 1953 quite closely, although the 1954 RP estimate exceeds the actual by 19,000 acres (fig. 3). The 1954 error is largely due to an overestimation of the extent to which cotton allotments induce increased rice production. The model specifies rice as one of the most profitable alternatives to cotton in the use of soil type 2 and irrigation water. Again, the regression model is inappropriate after rice allotments were imposed.

Melons

Melons are a profitable specialty crop on the Westside, produced for eastern markets in a semi-institutional arrangement. That is, the total acreage is informally restricted by the growers to maintain price and market conditions. Such factors are accounted for by upper bounds. But in this case the bounds, which are effective every year, apparently overestimate the institutional limits on change.

The regression equation is again more accurate (table 4), although it fails to explain as much of the variation in acreage ($\bar{R}^2=0.59$, table 5) as the equations for other crops.

Dry Beans

Both models explain the upward trend in the bean acreage. Upper bounds are effective for the RP model throughout the test, as the crop has fairly high returns.

Although the RP estimates show a sizable percentage error in 1952–55, perhaps it is unwise to take this error too seriously due to the small acreage involved. For example, a deviation of only 212 acres in 1952 yields a 24-percent error, whereas the deviation of 254 acres in 1956 is only 8 percent in error. Measures of accuracy, like the percentage deviation, tell only a part of the story.

Despite the close fit ($\bar{R}^2=0.98$), the strongest association in the regression model is between X_t and X_{t-1}, because of the strong time trend. The gross-returns coefficient is negative for the first time, contrary to expectation. The RP model would seem to be structually superior to the simplified bean equation because it recognizes the interrelation of crop profitabilities and restraints such that an increase in acreage can be consistent with a decline in price or returns.

Irrigated Pasture

The RP acreage path for this crop further illustrates the effects of allotments on alternative crops. The pasture estimate equals the crop's lower bound in 1951–54, increases to the upper bound in 1955 and 1956, falls between the two bounds in 1957, and declines to the lower bound in 1958. This adjustment corresponds to changes in the acreage of barley and alfalfa hay that occurred when cotton was cut back and further time was needed to expand more profitable alternatives.

Production estimates are derived from the RP model, but due to the absence of published yield data, the accuracy of the model cannot be tested. Production is therefore disregarded. Similarly, the regression model could not be used to estimate pasture acreage and production because of the absence of actual price data.

Conclusions Based on the Explanatory Test

The Explanatory Test shows that the RP model can lead to sizable errors when actual crop acreages do not change radically from one year to the next. Regression seems more appropriate under these conditions because of a continuation of previous conditions. There is some indication that the RP model may be more effective when sharp changes occur. The most obvious examples are the estimates for cotton in 1951 and barley in 1954. Their relative accuracy is especially significant because critical policy questions more often than not are concerned with the response of *major* crops under *new* structural conditions.

Still, the acreage results in table 4 are not at first sight particularly encouraging for the RP model. The average regression error for the 8-year period is less than the RP error for six of the seven crops estimated by both models. A year-by-year comparison shows that the average crop error is less for the regression model in every one of the 8 years.

Despite these results, the RP model does have important advantages. Perhaps most obvious is that it estimates the production of a crop regardless of whether that crop is controlled by legislation or operates in a free market, whereas regression is suitable only for uncontrolled crops. Also, the RP model can be used to estimate changes in a crop like irrigated pasture where much of the data guiding farmers' decisions are unpublished.

Undoubtedly the main advantage of the RP model is that it provides some idea as to *why* certain changes occur, going back to the basic production relationships and interplay of competitive crops and resource and behavioral restrictions. Farmers' response to the reintroduction of cotton allotments in 1954 and the resultant shift to other crops nicely illustrates this point.

The question arises as to the importance of the flexibility restraints in the RP model. If these upper and lower bounds were always effective, the upper bounds would always be the predicted acreages of the most profitable crops and the lower bounds the predicted acreages of the least profitable.

Empirically, does the model in fact amount to more than this simple idea? Table 7 shows when the specified bounds were effective. For 22

TABLE 7.—*Effective Fresno County acreage bounds, Explanatory Test* [1]

Crop	1951	1952	1953	1954	1955	1956	1957	1958
Cotton	U	......	......	U	U	U	......	......
Barley	......	L	L	U	......	L	L	L
Alfalfa hay	L	L	L	......	......	U	U	......
Wheat	......	......	L	U	U	U	U	U
Alfalfa seed	......	......	U	U	U	U	U	......
Sugarbeets	U	U	U	U	U	U	U	U
Grain sorghum	L	......	......	......	U	......	U	L
Field corn	L	L	L	L	U	U	U	U
Rice	......	......	U	......	U	U	U	U
Melons	U	U	U	U	U	U	U	U
Dry beans	U	U	U	U	U	U	U	U
Irrigated pasture	L	L	L	L	U	U	......	L

[1] U denotes upper bound effective. L denotes lower bound effective.

of the 96 solutions for Fresno County as a whole (8 years x 12 crops), neither bound is effective. The same bound is effective throughout the period for only three crops—beets, melons, and beans.

These figures indicate that the RP model is more than a set of bounds on each crop, even though the number of resource and other restraints is still quite small. Additional restraints, if they could be formulated, would further reduce the model's reliance on upper and lower bounds.

The Explanatory Test strongly suggests that future attempts to predict farmers' response should consider the complementary or supplementary roles of programing and regression. This might take one of two forms:

1. *A more refined use of regression for estimating components of the RP model, especially the flexibility restraints.* The RP model would remain the basic framework, but an attempt would be made to reduce the excessive flexibility or the range of likely response by refined adjustment of upper and lower bounds.

2. *The use of programing to provide data for regression analysis.* As the latter technique is frequently ill-suited for prediction when important changes in structure occur, it might be possible to estimate the effects of those changes by programing and then adjust the independent variables or their historical coefficients before deriving a statistical estimate.

Perhaps two qualifications to the Explanatory Test should be added. First, the actual published and unpublished data used are themselves subject to some unknown error. Thus, error deviations in prediction might be quite different from those summarized above if the true data were known.

Second, a qualification should be mentioned concerning the nature of the test itself. Predictive properties of a model are not easily inferred from the results of a test in which "advance information" is used. In other words, the *explanations* of change are equivalent to *predictions* only under the assumption that subsequent experience was known before the start of each year, or that this experience was guessed (estimated) correctly. Both the RP and the regression models use data through 1958 to explain changes that occurred in each of the years 1951–58.

Results of the Predictive Test (1959–61)

The Predictive Test applied to 1959–61 uses no advance information other than announced Government program data. That is, the estimates from both the RP and regression models are based solely on data through the immediately preceding year. Thus the Predictive Test gives us a truer measure of model reliability than the Explanatory Test previously discussed. In fact, the results can be regarded as 1-year *forecasts* or *predictions* of the kind that might well have been made at the time.

As farmers made plans in the 1959–61 period, they again had to consider several kinds of Government programs. Allotments on wheat and rice

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and quotas on sugarbeets were in effect for the entire period. Cotton controls were altered by the introduction of the "Plan A–B" program for 1959 and 1960. This program allowed each farmer to increase his acreage of cotton 40 percent over his allotment. If he stayed within the allotment (Plan A), he qualified for price supports at about 85 percent of parity. If he grew more than his allotment (Plan B), he was entitled to a support of roughly 15 percent of parity below the Plan A price. In 1961, the cotton program returned to a standard price-support and allotment basis. Also in 1961, the current feed-grain program was introduced, affecting corn and grain sorghum (barley was not included until 1962).

The results of this test are presented graphically in figure 4, and in tabular form in table 8. A reasonable expectation is that the truly *predictive* models would give larger errors of estimate than the *explanatory* models. However, a comparison of table 8 (Predictive Test) with table 4 (Explanatory Test) shows that this decrease in accuracy is not marked. Overall, for the seven crops estimated by both models in both periods, the error in predicted acreage increased from 30 percent to 37 percent for the RP model and from 13 percent to 28 percent for the regression model.

On this overall comparison, the RP model has decidedly improved its position. The two models are quite comparable in 1959 and 1961 (table 8); the regression model has a decided advantage only in 1960. Also, in terms of individual crops, the RP model predicts more accurately than the regression model for three of seven crops in 1959–61, compared with only one of seven crops in the 1951–58 period.

To obtain the regression estimates for this test, the following procedures were used. To predict for 1959, regression model (3), $X_t = a + bX_{t-1} + c\overset{*}{R}_t + dG_t + e_t$, was fitted to each of the crops through 1958. These equations have been summarized already in table 5 for the Explanatory Test. Tables 9 and 10 show the regression equations fitted to data through 1959 and 1960 and used to predict for 1960 and 1961. Again, high $\bar{R}^2$ values are generally obtained, but a comparison of the $\bar{R}^2$ values with the errors of prediction in table 8 serves as a good reminder that a high $\bar{R}^2$ may be primarily a "test of the investigator's patience" rather than a reliable indicator of future predictive power.

Participation in the Cotton Plan A–B Program

Some of the large errors in prediction by the RP model trace to the substantial underestimate of farmers' participation in Plan B of the cotton program. One possible reason for the underestimate is that noneconomic factors may have been important—such as the hope that the expanded acreage might be used in computing future base acreages. Perhaps a second major reason is that there is no guarantee that the expected prices used in the model approximate farmers' true expectations under a radically different program.

The expected model price for Plan A cotton in 1959 was 34.1 cents per pound of lint. This is the actual price received in 1958, used instead of the announced loan rate (33.3 cents) on the assumption that farmers expect higher returns in the market.[14] The Plan B expected price used in the model is 28.2 cents, which bears the same relation to the expected A price as the ratio of B to A loan rates.[15]

An investigation of the relative net returns per acre from Plan A and Plan B activities shows that a very slight price increase for Plan B relative to Plan A would have improved the estimates. In 1959, for instance, only 2 of the 18 Plan B activities show higher returns *per unit of allotment* than the corresponding Plan A activities. But if the expected Plan B price were increased by only 1 cent, from 28.2 to 29.2 cents per pound, nine of the Plan B activities would have been more profitable per unit of allotment than the corresponding Plan A activities. In 1960, a 1-cent increase in the Plan B price would have shifted the number of more profitable B activities from zero to five.

To investigate the effect that higher price expectations for *both* Plans A and B may have had on the results, cotton prices in 1959 were varied upward using parametric programing to see what changes occurred in the acreage and production forecast by the RP model. The same A–B price differential of 5.8 cents was used throughout, although this implies that as the expected price level rises, Plan B becomes relatively more attractive (table 11), and the proportion of total acreage in Plan B cotton as well as total acreage expands.

Figure 5 and table 11 show that the RP model acreage forecast for cotton passes the actual figure in 1959 only when the A price is 41.8 cents and the B price is 36.0 cents, and in 1960 when the A price is 43.3 cents and the B price is 37.4 cents. But even though these are well above previous prices, they may approximate the relative value farmers attached to cotton under a completely different program. Also, it is likely that economies of scale in operating a larger cotton acreage would encourage expansion.

As the price and acreage of cotton increased, the acres of other crops also changed. The question is: Did the higher cotton prices improve the model's estimates of alternative crops? For 1959, only the sorghum and rice estimates were more accurate. The new solution includes 11,736 acres of sorghum, slightly less than the actual 13,000 acres but closer than the original estimate of 16,242. The rice estimate declined to 18,849, compared to 19,978 initially predicted and an actual acreage of 18,000.

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[14] Between 1950 and 1959, the average price received did in fact exceed the loan rate in every year except 1953, 1957, and 1958.

[15] The Plan B price is derived from the equation, $\frac{33.31}{27.61} = \frac{34.06}{\text{B price}}$, where 33.31 and 27.61 are the 1959 loan rates on Plans A and B cotton and 34.06 is the expected A price.

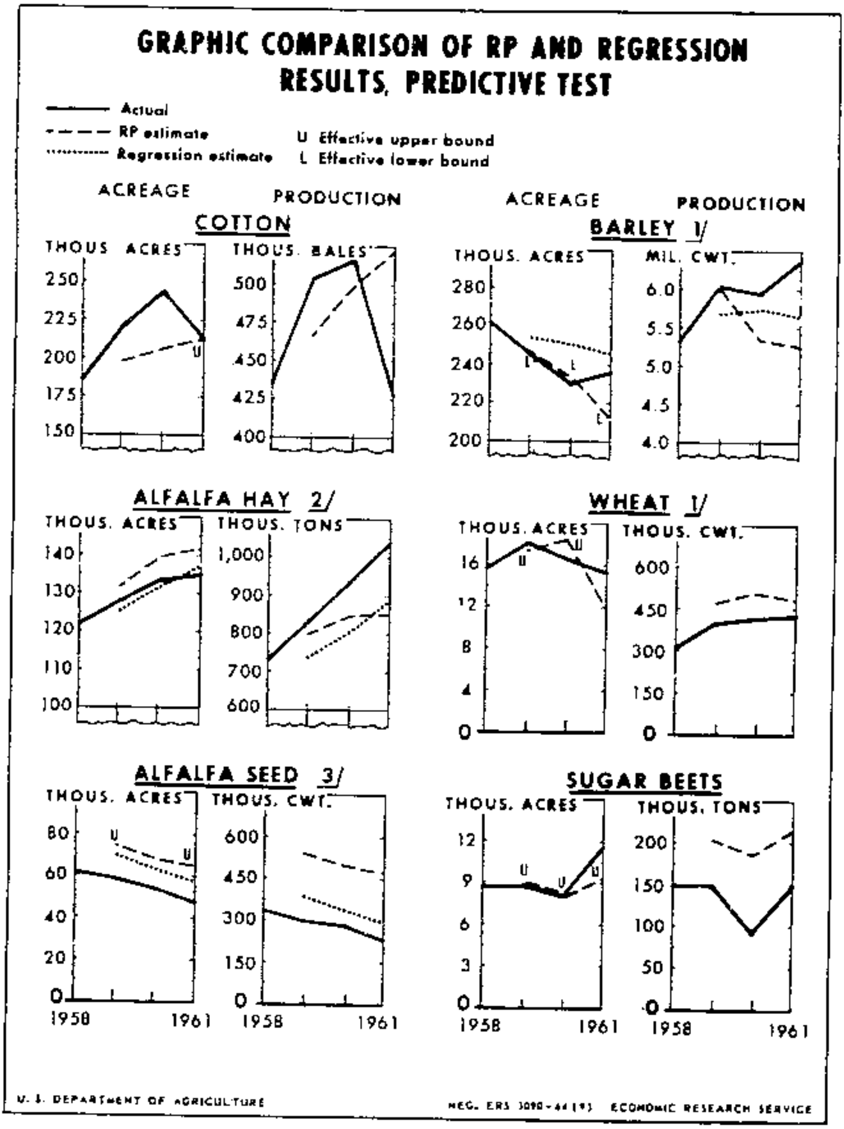

Figure 4, Part 1

[1] Production estimates = predicted acres, adjusted for average past abandonment, times expected yields per harvested acre.

[2] Expected yields used to compute RP production estimates = (0.25) (first year yield) + (0.75) (mature yield).

[3] Expected yields used to compute RP production estimates = (0.33) (first year yield) + (0.67) (mature yield).

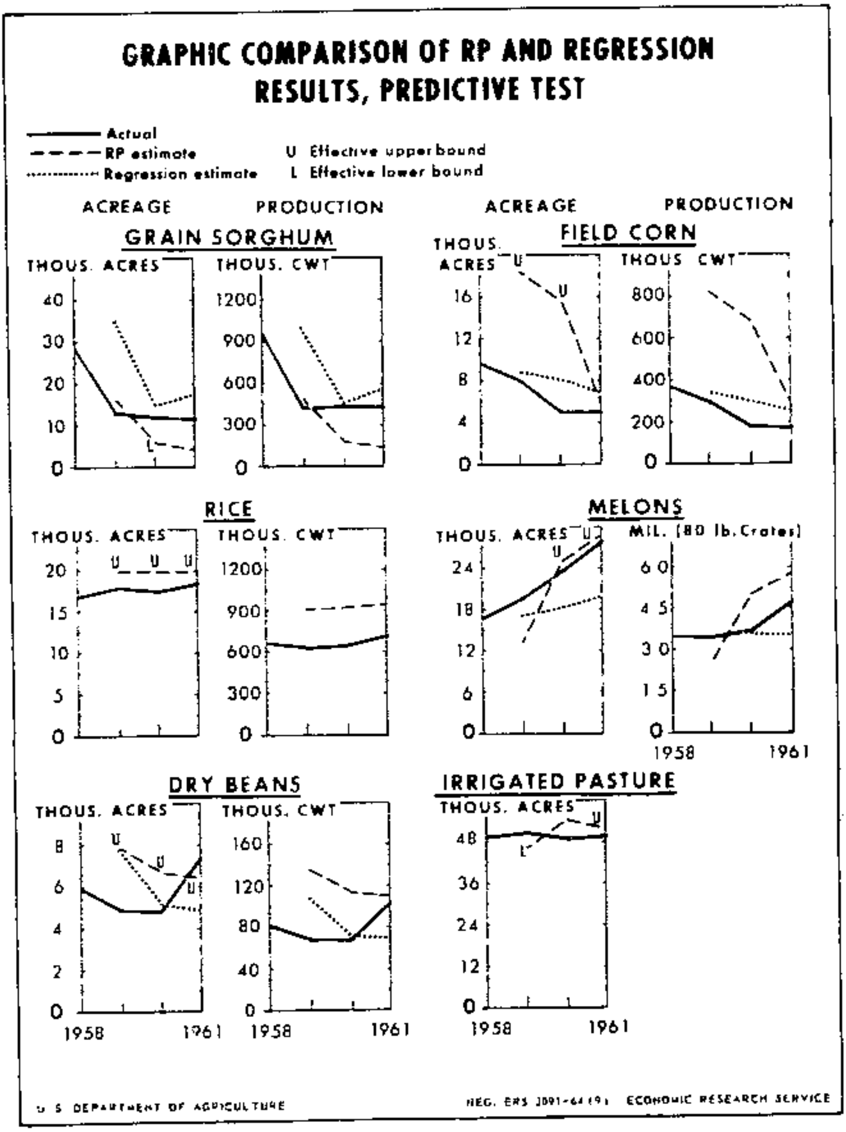

Figure 4, Part 2

TABLE 8.—*Percentage deviation of "predicted" from "actual" crop acreage and production, Fresno County, 1959–61*[1]

[ACREAGE]

Year	Cotton		Barley		Alfalfa hay		Wheat		Alfalfa seed		Sugarbeets	
	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression
1959	10.6	....	0.4	3.7	3.1	2.0	4.3	....	27.5	19.1	0	....
1960	15.5	....	1.4	8.8	4.5	1.5	11.4	....	26.0	16.5	0	....
1961	0	....	10.6	3.8	5.0	1.6	24.8	....	35.8	19.6	19.9	....
Average	8.7	....	4.1	5.4	4.2	1.7	13.5	....	29.8	18.4	6.6	....

Year	Grain sorghum		Field corn		Rice		Melons		Dry beans		Irrigated pasture		Average of 7 crops[2]	
	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression
1959	24.9	170.4	131.5	1.2	11.0	....	32.6	12.7	63.0	58.1	8.8	....	40.0	38.0
1960	52.0	24.7	214.2	62.3	13.7	....	6.2	22.7	39.6	8.1	11.1	....	49.0	21.0
1961	64.1	51.6	20.2	37.1	7.8	....	3.3	28.5	13.1	33.4	4.1	....	22.0	25.0
Average	47.0	82.3	122.0	33.5	10.8	....	14.0	21.3	38.6	33.2	8.0	....	37.1	28.0

[PRODUCTION]

Year	Cotton		Barley		Alfalfa hay		Wheat		Alfalfa seed		Sugarbeets	
	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression
1959	7.4	....	0.8	6.0	3.8	11.0	18.4	....	84.7	30.9	37.0	....
1960	3.3	....	10.2	3.5	9.5	14.2	22.4	....	77.8	21.3	102.8	....
1961	21.7	....	17.6	11.6	17.9	14.3	12.8	....	107.5	29.5	45.3	....
Average	10.8	....	9.5	7.0	10.4	13.2	17.9	....	90.0	27.2	61.7	....

Year	Grain sorghum		Field corn		Rice		Melons		Dry beans		Irrigated pasture		Average of 7 crops [2]	
	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression	RP	Regression
1959	16.5	136.7	181.6	17.8	44.0	....	24.9	0.8	98.8	58.3	......	....	58.7	37.4
1960	58.5	4.5	291.9	69.0	43.3	....	36.2	2.9	69.0	5.8	......	....	79.0	17.3
1961	69.2	32.8	64.6	49.2	32.3	....	22.3	25.1	6.0	33.6	......	....	43.6	28.0
Average	48.1	58.0	179.4	45.3	39.9	....	27.8	9.6	57.9	32.6	......	....	60.4	27.6

[1] The difference between the model estimate and the actual value, expressed as a percent of the actual.
[2] Seven crops estimated by both models (barley, alfalfa hay, alfalfa seed, grain sorghum, field corn, melons, and dry beans).

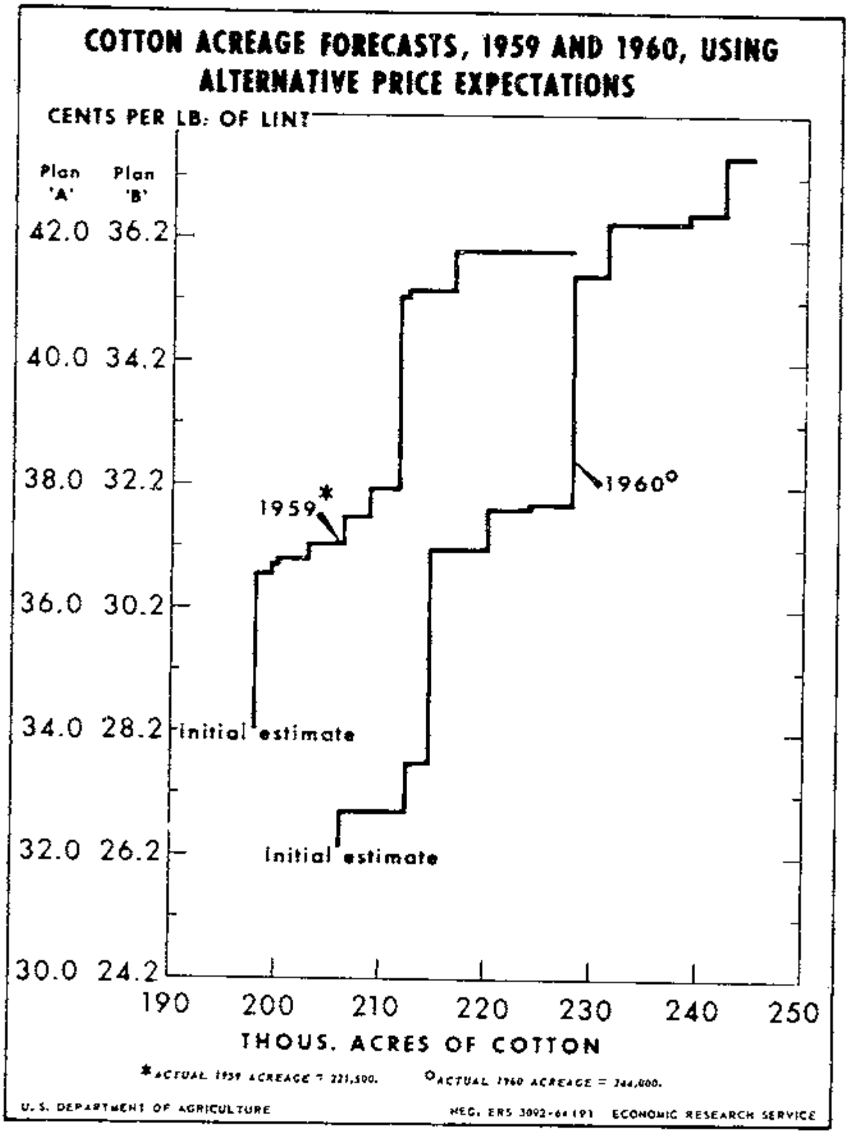

Figure 5

In 1960, the increased cotton price substantially improved the estimates for corn, beans, and pasture and only slightly worsened the estimate for wheat; all other crop estimates remained unchanged. Overall, the change in cotton price brought the percent forecasting error equal to that of the regression analysis in 1959 (38 percent) and slightly less than for the regression analysis in 1960—16 percent versus 21 percent (table 12). Of course, this is more an illustration of why the errors occurred in the RP model than a true test of its performance relative to regression analysis.

TABLE 9.—*Regression equations used to forecast 1960 acres* [1]

Crop	Equation	$\bar{R}^2$	Standard error of X'_t
			(1,000 acres)
Barley	$X'_t = 90.873+0.310X_{t-1}+0.504\overset{*}{R}_t+55.448G_t$ (2.257) (1.655) (4.724)	0.92	14.008
Alfalfa hay	$X'_t = 9.075+0.856X_{t-1}+0.008\overset{*}{R}_t+11.612G_t$ (8.833) (1.400) (3.411)	0.96	4.410
Alfalfa seed	$X'_t = -5.403+0.890X_{t-1}+0.031\overset{*}{R}_t+11.180G_t$ (9.374) (0.692) (2.813)	0.96	5.214
Grain sorghum	$X'_t = -10.366+0.524X_{t-1}+0.192\overset{*}{R}_t+5.782G_t$ (2.624) (1.427) (1.858)	0.74	4.722
Melons	$X'_t = 9.783+0.106X_{t-1}+0.005\overset{*}{R}_t+3.420G_t$ (0.458) (0.708) (2.369)	0.61	1.982
Field corn	$X'_t = -5.247+0.181X_{t-1}+0.083\overset{*}{R}_t+4.320G_t$ (0.883) (2.343) (2.530)	0.79	2.332
Dry beans	$X'_t = 0.367+0.858X_{t-1}-0.002\overset{*}{R}_t+0.829G_t$ (6.642) (−0.206) (1.817)	0.92	0.647

[1] Variables are explained on pages 21–22. Data used: 1946 through 1959. Numbers in parentheses are t-ratios. Tabled t-value (2-tail test, 5-percent level)=2.228.

Participation in the Feed Grain Program

It is interesting to see how well the RP model predicted the response of farmers to the voluntary Feed Grain Program in 1961. As mentioned earlier, the program gave each farmer the option of reducing his acreage of sorghum or corn down to 60 percent of his historical base acreage in return for diversion payments on the idle land. This program is represented in the RP model by additional activities for possible combinations of produced and idle acres, and by base acreage restraints on each side of Fresno County.

Fresno acreage participation in the 1961 program was relatively minor. ASCS data show 5,968 acres "participating"—or idled as a result of the program (table 13). The RP model forecasts 6,735 idle acres—or only 767 acres more than the actual. However, this occurs because of offsetting errors in the forecasts for corn and grain sorghum separately.

All of the participating acreage forecast by the model is of soil type 3. This would be in line with adjustments that farmers would be expected to make, although the actual diversion undoubtedly involved all types of soil. The model shows that other crops out-compete sorghum

TABLE 10.—*Regression equations used to forecast 1961 acres* [1]

Crop	Equation	$\bar{R}^2$	Standard error of X_t'
			(1,000 acres)
Barley	$X_t' = 93.173 + 0.293X_{t-1} + 0.513\overset{*}{R}_t + 54.049G_t$ (2.068) (1.629) (4.461)	0.90	14.515
Alfalfa hay	$X_t' = 7.775 + 0.872X_{t-1} + 0.008\overset{*}{R}_t + 11.430G_t$ (10.410) (1.473) (3.531)	0.97	4.235
Alfalfa seed	$X_t' = -4.778 + 0.838X_{t-1} + 0.029\overset{*}{R}_t + 11.664G_t$ (9.009) (0.620) (2.794)	0.96	5.494
Grain sorghum	$X_t' = -10.131 + 0.525X_{t-1} + 0.188\overset{*}{R}_t + 5.417G_t$ (2.710) (1.444) (1.833)	0.73	4.578
Melons	$X_t' = 5.089 + 0.308X_{t-1} + 0.009\overset{*}{R}_t + 3.005G_t$ (1.225) (1.195) (1.785)	0.63	2.330
Field corn	$X_t' = -5.441 + 0.163X_{t-1} + 0.086\overset{*}{R}_t + 3.992G_t$ (0.778) (2.368) (2.310)	0.76	2.389
Dry beans	$X_t' = 0.434 + 0.832X_{t-1} - 0.002\overset{*}{R}_t + 0.840G_t$ (7.232) (−0.268) (1.907)	0.92	0.626

[1] Variables are explained on pages 21–22. Data used: 1946–60. Numbers in parentheses are t-ratios. Tabled t-value (2-tail test, 5-percent level)=2.201.

and corn on the higher quality soils and, because of the relatively lower yields and higher unit costs of producing sorghum and corn on soil type 3, the net returns from participation are apt to exceed those from nonparticipation. In addition, when a portion of soil type 3 is idled, irrigation water is released to more profitable crops on the better land.

Conclusions Based on the Predictive Test

An important cause of forecasting error in the RP model again traces to the interrelation of crop returns in an optimizing framework restrained by reasonably wide upper and lower bounds and a limited number of resources. The result is particularly evident in the problems for 1959 and 1960, where the model underestimates cotton acreage under the Plan A–B program. The model's overall accuracy is improved somewhat by raising the prices of A and B cotton and by giving Plan B an increasing relative advantage in the process. This suggests the critical importance of learning more about how farmer expectations are formulated.

While each of the single regression equations used in the analysis are independent of errors in the estimates of other crops, they need to be

TABLE 11.—*Cotton acreage and production forecasts for 1959 and 1960 using alternative cotton price expectations* [1]

RP model data		Forecasts			
Plan A price per pound	Plan B price per pound	Plan A acres	Plan B acres	Total acres	Total production
1959 *Cents*	*Cents*				*1,000 bales*
34.06	28.23	160,227	37,839	198,066	466.4
36.55	30.72	156,507	43,046	199,553	470.0
36.71	30.88	154,815	45,414	200,229	471.7
36.80	30.97	147,574	55,553	203,127	479.1
37.04	31.21	139,055	67,480	206,535	487.8
37.48	31.65	132,932	76,050	208,982	493.8
37.94	32.11	126,177	85,509	211,686	500.4
41.04	35.21	124,131	88,374	212,505	502.5
41.16	35.33	113,126	103,780	216,906	513.7
41.80	35.97	85,500	142,457	227,957	541.9
1960					
32.16	26.27	138,349	67,932	206,281	499.0
32.70	26.81	122,891	89,573	212,464	514.5
33.49	27.60	117,342	97,342	214,684	520.0
36.96	31.07	103,621	116,551	220,172	534.3
37.61	31.72	93,852	130,227	224,079	544.1
37.69	31.80	83,560	144,636	228,196	554.8
41.40	35.51	75,859	155,417	231,276	562.8
42.25	36.36	56,443	182,599	239,042	582.2
42.40	36.51	48,253	194,065	242,318	590.4
43.32	37.43	41,773	203,137	244,910	596.9

[1] Actual *acres* in cultivation, July 1, were 221,500 (1959) and 244,000 (1960). Actual *production* was 503,400 bales (1959) and 515,800 bales (1960).

TABLE 12.—*Changes in model accuracy using higher cotton prices*

Crops	1959			1960		
	Initial RP solution	Final RP solution [1]	Regression	Initial RP solution	Final RP solution [1]	Regression
	Deviation from actual acreage (percent)					
All crops	26	24	....	33	13	....
7 crops	40	38	38	49	16	21

[1] Solution where the cotton forecast passes actual acreage.

qualified by their statistical reliability. Sixty-three regression coefficients were estimated in the test (7 crops ×3 years ×3 variables). Only 28 of these—less than half—are "significant" at the 5 percent level of confidence, according to the *t*-test (2-tail). All but 2 of the 28 are the coefficients for X_{t-1} (hence, usually related to time trends) and G_t. The

TABLE 13.—*Actual and RP model forecasts of participation in the 1961 Feed Grain Program*

Item	Sorghum	Corn	Total
Actual:	*Acres*	*Acres*	*Acres*
Participation [1]	4,238	1,730	5,968
Produced	11,400	5,000	16,400
Total	15,638	6,730	22,368
RP model:			
Participation	2,727	4,008	6,735
Produced	4,090	6,011	10,101
Total	6,817	10,019	16,836

[1] Total county data, courtesy Fresno ASCS office.

$\overset{*}{R}_t$ coefficients are generally nonsignificant statistically. Alternative equations—curvilinear or with different variables—might have yielded coefficients having a higher degree of confidence, but this is no guarantee of greater predictive power.

In short, neither model does a particularly outstanding job of *real* prediction, as opposed to explanation. The regression analysis is still slightly superior, but the RP model has probably improved its relative position. Again, it should be noted that the RP model provides at least some estimate of controlled crops, whereas the regression model is inapplicable in these circumstances.

Results of the Projection Test (1960–65)

So far in this analysis we have applied the RP and regression models to the problem of explaining historical changes from one year to the next (the Explanatory Test for 1951–58) and to the problem of forecasting or predicting one year ahead (the Predictive Test for 1959–61). Explanations of past response and 1-year forecasts, though they fill a pressing need, are not nearly as critical for certain policy problems as estimates of intermediate or longer-run response. For example, there is a continuing need for time-dated estimates of the longer-run effects of a particular program or the readjustments to removal of a Government program. Further projections may anticipate areas in which a problem requiring policy might develop—such as a prospective surplus or shortage of certain commodities.

At the present time, 5-year projections are made annually by the Economic Research Service of the U.S. Department of Agriculture. These are made on the basis of several techniques of analysis including judgments of informed commodity specialists. The purpose of the Projection Test, therefore, is to see if RP models might be a useful addition to the current set of longer-run estimating tools.

The Projection Test involves making a series of forecasts recursively year-by-year to 1965 for both the RP and regression models. Obviously, this is not a test in the strict sense of the term because the solutions cannot be compared with actual data for the latest years. However, something can be learned in general about the characteristics of the models from inspection and comparison of the results over time.

Two sets of projections are made: (1) By solving a series of year-to-year problems through 1965, based on data through 1958 (called Series 1); and (2) repeating the process based on data through 1959 (Series 2). The results for both models for 1959 (the first year of Series 1) are the same as the forecasts that year described under the Predictive Test. Likewise, the estimates for the first year of Series 2 are the forecasts for 1960. RP solutions for each of the subsequent years use projected data and are based on the *solution* for the preceding year, rather than *actual* data.

Upper and lower bounds are computed recursively, applying the original set of flexibility coefficients to the solution acreages. Other restraints are assumed or projected from the base years, 1958 and 1959, as explained in the appendix. Allotments on wheat and rice are equal to those for the first year of each series. The maximum acreage of sugarbeets is the computed bound, or the highest preceding acreage since 1951, whichever is lower. The melon acreage cannot exceed 25,000, or the computed bound, whichever is lower. The model assumes no allotments on cotton after 1960, the last year of the Plan A–B program, although computed bounds are included. Thus, the results might be taken as an estimate of the effects of removing cotton allotments in Fresno County.

Inputs, costs, and yields are projected data which change from one year to the next. The expected prices for each series remain the same. Except for cotton, these are the average prices received in the 4-year period, 1955–58, for Series 1 and 1956–59 for Series 2. The price of cotton lint is 80 percent of the 4-year average—26.1 cents per pound for Series 1 and 25.9 cents for Series 2. The lower price level represents either the price expectations that would have accompanied an end to allotments, or a support level that might be applied, despite the lack of acreage control, in order to ease transition to a freer market.

Year-by-year projections to 1965 from the regression analysis were made as follows: The original equations fitted to data through 1958 and refitted to data through 1959 were used as the basic equations for Series 1 and Series 2, respectively. Price and yield projections (hence gross returns) are the same as those used in the RP model. The predicted acreage value for each year becomes the independent variable in the regression equation for the next year. This procedure is essentially the same as using the RP results in year t as data for year $t+1$; thus the two models are comparable techniques of projection. The absence of cotton controls is treated in each regression equation by setting $G_t=0$ (G_t is the 0–1 shift variable denoting the effects of acreage allotments).

Results of the Projection Test, limited in the discussion to acreage, are summarized for 7 of the 12 crops in figures 6 and 7. A more detailed graphic presentation for each of the 12 crops appears in figure 8. Corresponding production figures are available on request.

Projections Made Using the RP Model

Results of the RP model show cotton acreage increasing sharply after controls were removed in 1961, but the upper bounds are not effective

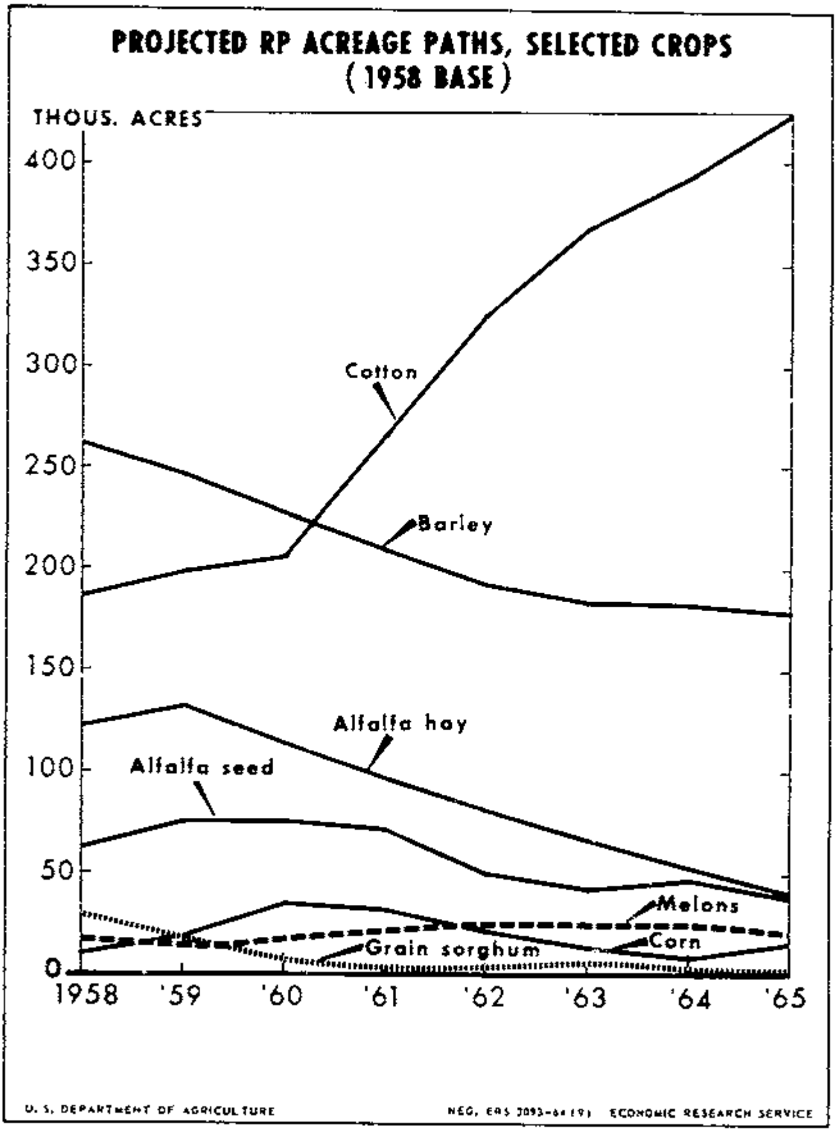

Figure 6

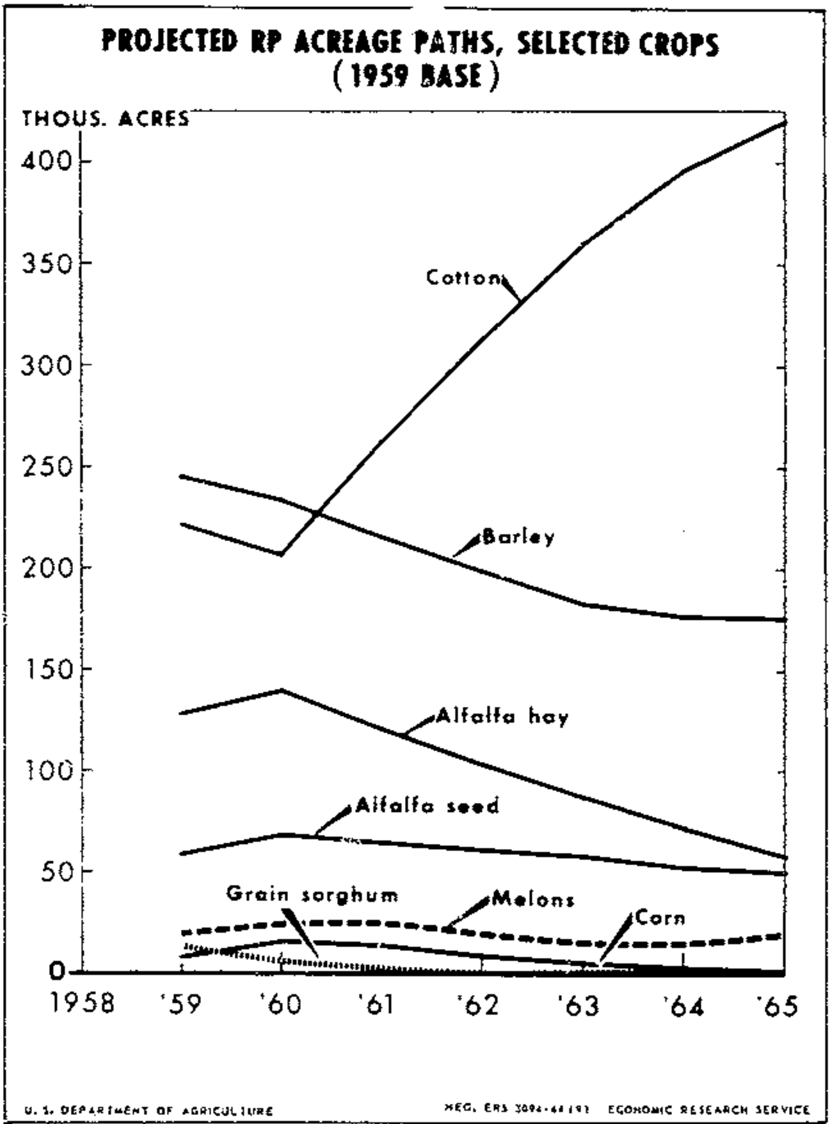

Figure 7

except at the start of each series. In fact, the discrepancy between the bounds and the projected cotton path increases each year.

In terms of the programing mechanism, there are two important reasons for the increased discrepancies. First, the lower bounds on alternative crops do not decline fast enough to allow cotton to expand at a higher rate. Second, effective limits on the production of cotton that can be harvested mechanically force hand-picked cotton to compete with other crops; and as noted in the Explanatory Test, some of these alternatives are quite competitive on the poorer soils.

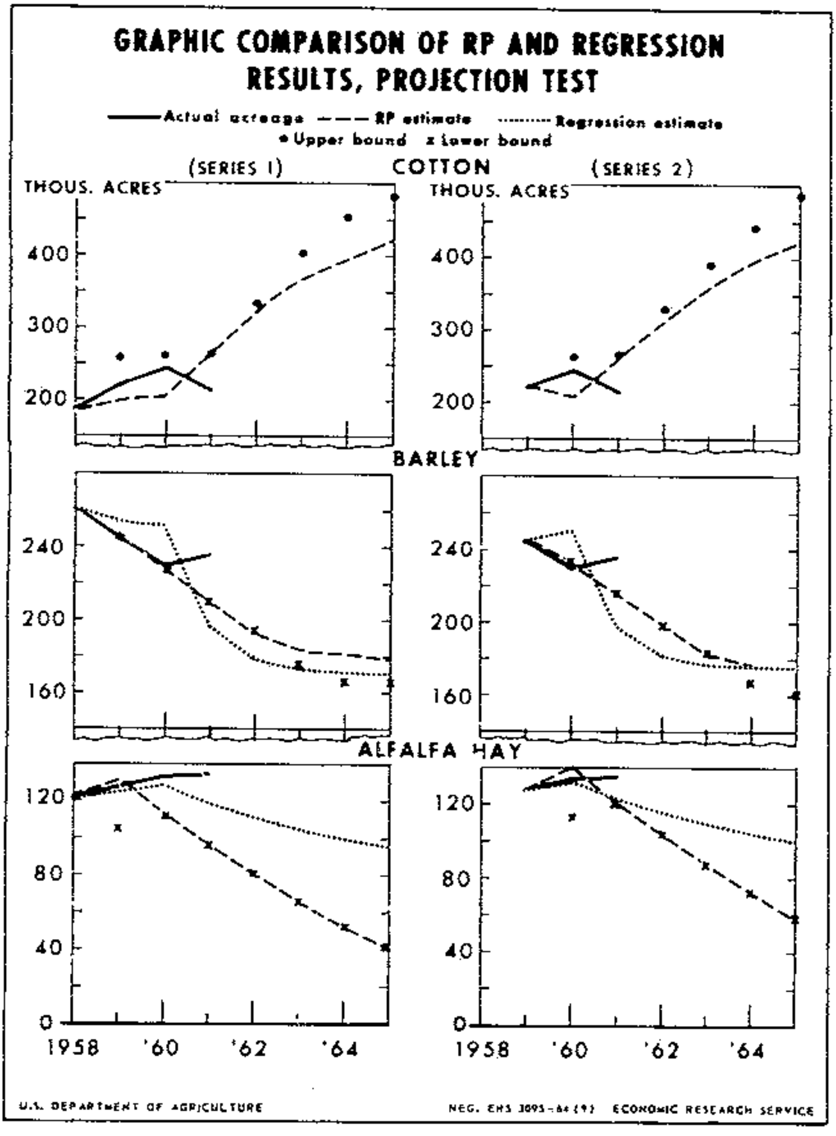

Figure 8, Part 1

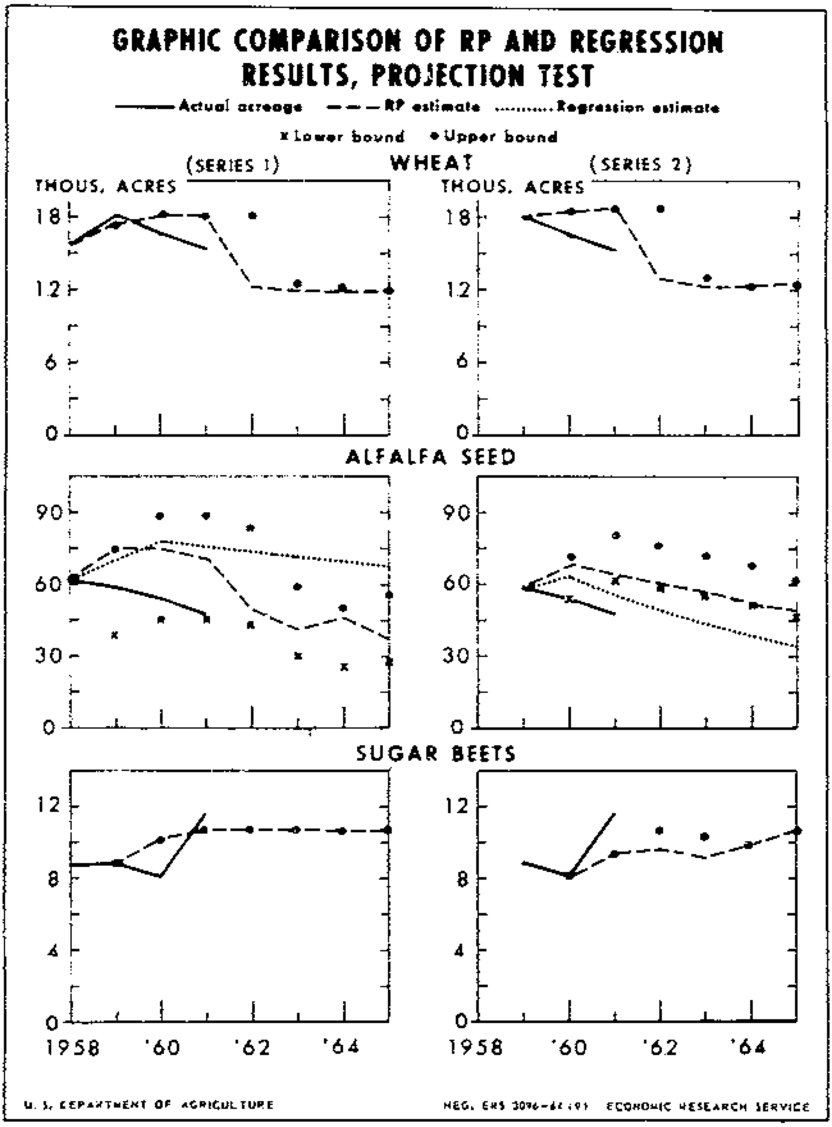

Figure 8, Part 2

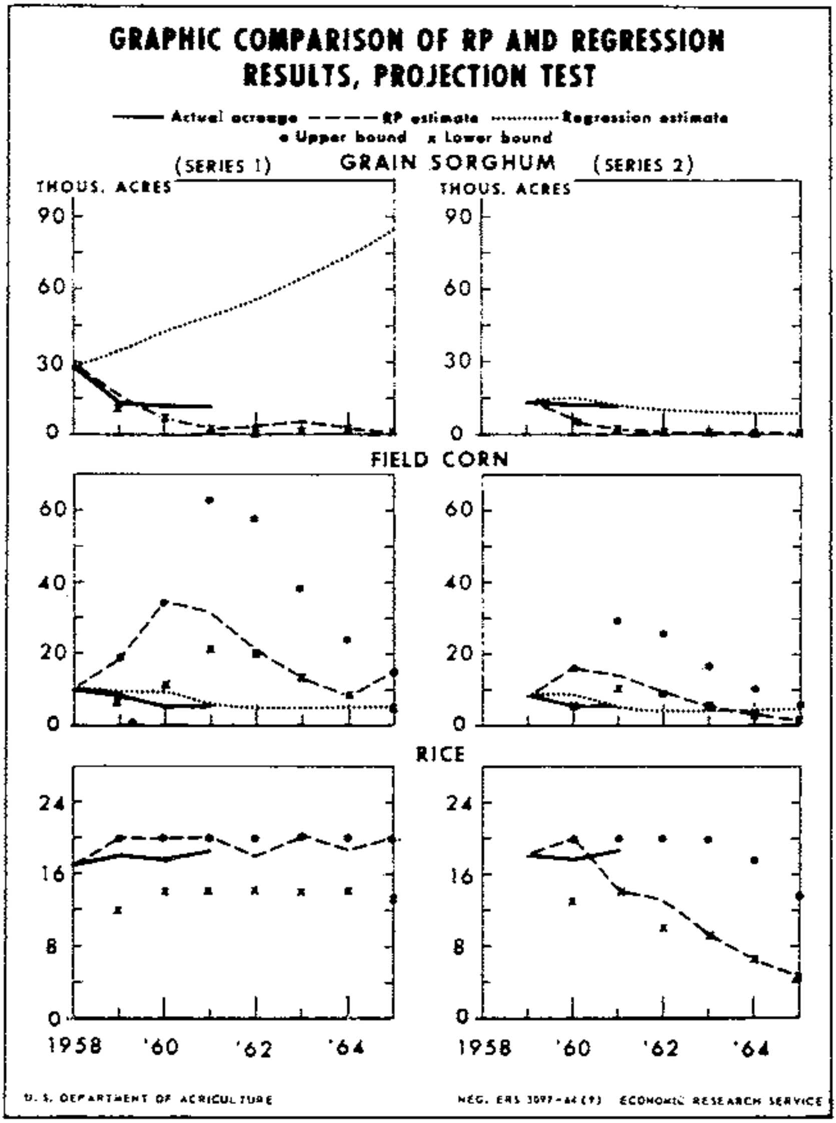

Figure 8, Part 3

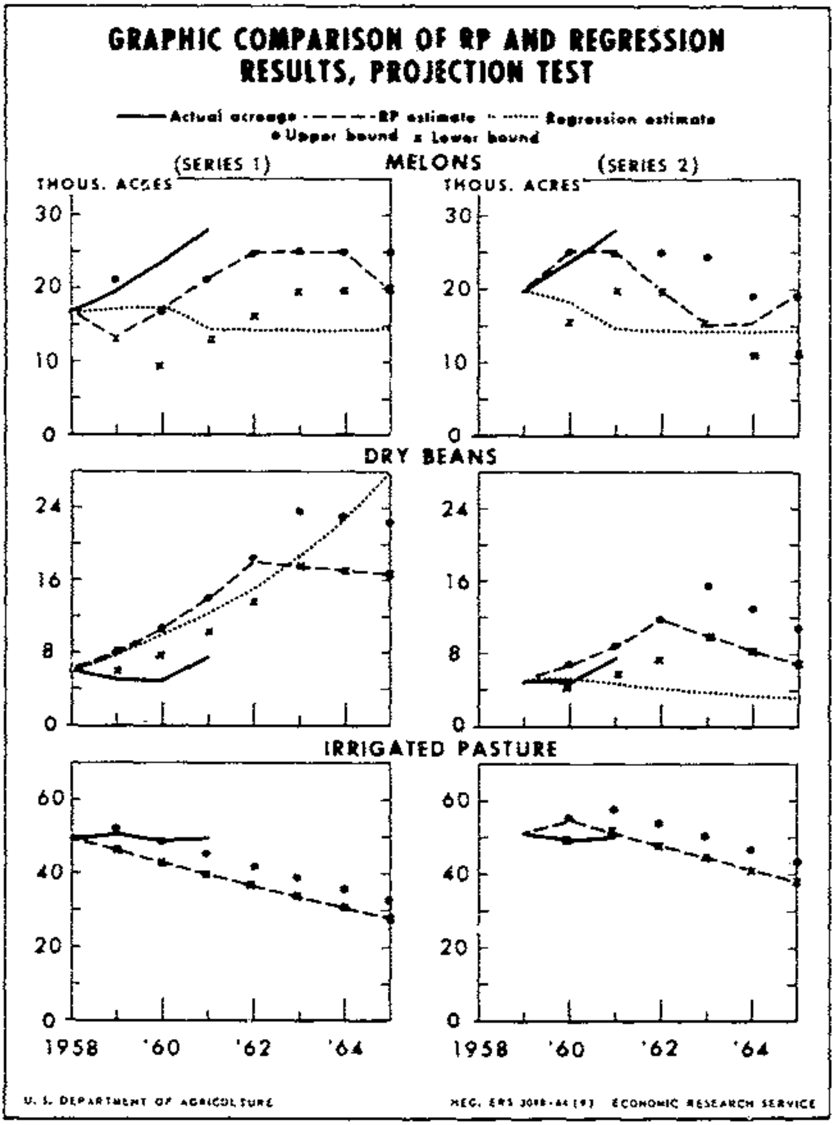

Figure 8, Part 4

The projected cotton paths suggest important policy implications. Suppose, for example, that in 1958 or 1959 there was some concern as to how fast cotton might expand with no controls after 1960 and what effect this expansion would have on alternative crops. Figures 6 and 7 show that cotton does indeed expand but probably not as much, or as fast, as might be expected. The projected rates of increase are as follows:

Between—	*Series 1*	*Series 2*
	Percent	
1960 and 1961	29	27
1961 and 1962	23	19
1962 and 1963	13	15
1963 and 1964	7	10
1964 and 1965	8	6

Cotton allotments prevailed from 1954 through 1960, according to test assumptions. During that period a number of alternative crops were expanded to offset the reduction in cotton acreage. The expansion of cotton without controls would logically depend on how fast farmers would shift out of alternatives. By 1961, many of the alternatives had become well established. Farmer skills in producing them had undoubtedly increased, as did the yields, particularly of crops like sorghum. The RP acreage paths are quite in accord with these developments.

Crops like alfalfa seed, corn, melons, and beans do not always follow their lower bounds, especially in Series 1. Instead, they show periods of increasing acreage. Only three crops remain at the same bound throughout the period. Alfalfa hay and pasture are at their lower bounds throughout; sugarbeets remain at the upper bound, in every year except one. Corn and beans begin each series at their upper bounds but decline to the lower limits by 1965.

Other crops do not follow any particular pattern. Barley begins at its lower bound but ends the series above the minimum. Sorghum begins and ends at its lower bound but shows 1 or 2 years between bounds in the middle of the series. These shifting acreage paths could be extremely important for policy purposes. They indicate clearly that expansion or contraction of individual crops affect, and are affected by, the responses of all other crops.

Comparative Regression Results

Although a direct comparison is not made graphically, it is interesting to compare the RP estimates for cotton with those derived using three regression equations fitted to preallotment data (1946–53):

$$(1)\quad X_t = -128.403 + \underset{(0.267)}{0.176}X_{t-1} + \underset{(2.141)}{7.924}\overset{*}{P}_t + \underset{(0.617)}{19.278}T$$

$$(2)\quad X_t = -246.729 + \underset{(1.591)}{0.277}X_{t-1} + \underset{(1.079)}{3.650}\overset{*}{P}_t + \underset{(2.089)}{0.523}A_t$$

$$(3)\quad X_t = -189.519 + \underset{(2.857)}{0.400}X_{t-1} + \underset{(2.330)}{0.522}\overset{*}{R}_t + \underset{(1.942)}{0.372}A_t$$

These equations are used to estimate year-to-year changes in the cotton acreage, *starting with 1961*, using the 1960 acres estimated by the RP model as the first value of X_{t-1} for Series 1 and 2, and using the Series 1 and 2 prices, projected yields, and land areas. The resulting estimates are compared with the RP series in table 14. Equations 1 and 3 result in acreage paths above those projected by the RP model, while equation 2 provides a somewhat lower path.

TABLE 14.—*RP and regression estimates of cotton acreage, 1961–65*

Year	Series 1				Series 2			
	RP	Equation			RP	Equation		
		1	2	3		1	2	3
		1,000 acres				*1,000 acres*		
1961	265	423	324	361	262	422	321	355
1962	325	481	361	427	313	479	357	418
1963	368	510	375	456	360	508	371	446
1964	393	534	382	470	396	533	378	461
1965	423	558	386	478	420	556	383	469

The actual cotton acreage increased dramatically during the observation period 1946–53, when allotments were not in effect, except in 1950. In a problem requiring the estimation of acreage *after* allotments, historical preallotment observations may be the only appropriate regression data. However, the time elapsed between the preallotment and post-allotment periods would reduce the confidence one could place in the results of all three equations. As it is difficult to select any one set of regression estimates as the most reasonable, and there are no actual data for comparison, the "test" is inconclusive.

Additional comparisons for all crops illustrate several points worth mentioning even though a final "test" is also impossible here. In general, the regression paths are relatively smooth in a given direction after 1960. Many of the regression estimates decline in 1961 when G_t changes from 1 to 0. They then follow a path with no change in direction because the regression results are independent of the acres projected for every other crop. The comparison shows that the interrelation between crop returns and restraints must be recognized to predict changes in direction, like those illustrated by a few of the RP paths.

In a number of cases (barley, alfalfa hay, alfalfa seed, and field corn), the general trend of results is the same for both the RP and regression models. However, the 1965 "end point" projections for each crop, except rice, seem to be more variable for the regression analysis; that is, more sensitive to whether the projections are made from data through 1958 or through 1959. This is particularly noticeable for alfalfa seed, grain sorghum, and dry beans. For the latter two, the long-run trend is even different for the two series. Thus, the RP results appear to be a bit more stable, undoubtedly due to the flexibility restraints. There would appear to be an advantage to a long-run predicting technique which is not quite so sensitive to the addition of 1 year's data.

Comparative Accuracy of Estimates for 1960

A question concerning any recursive technique is how much accuracy is lost as the system is regenerated over a series of years. Because each new problem is not adjusted for the actual outcome in year $t-1$, but is based on the preceding solution, errors for each crop may accumulate. The longer the series, the greater is the potential decline in accuracy.

The question of relative accuracy can be answered partially in this test by examining the results for 1960. Four different sets of estimates are compared in table 15; these are the RP and regression estimates made from base years 1958 and 1959. The table shows that the percentage deviations from actual data are substantially larger when the estimates are made 2 years ahead, instead of 1, regardless of which model is used. The average RP error for the seven crops is 49 percent, looking 1 year ahead, but 120 percent when made 2 years ahead. Corresponding average errors for the seven regression equations are 21 and 78 percent. However, if field corn is removed from the comparison (a crop for which the RP estimates are extremely poor), there appears to be little basis for selecting one technique over the other according to this test.

TABLE 15. —*The relative accuracy of 1960 acreage estimates using 1958 and 1959 as base years*

Crop	1958 base		1959 base	
	RP	Regression	RP	Regression
	Deviation from actual (percent)			
Cotton	15.8	....	15.5	....
Barley	1.3	9.3	1.4	8.8
Alfalfa hay	15.0	3.8	4.5	1.5
Wheat	9.1	....	11.4	....
Alfalfa seed	38.3	43.6	26.0	16.5
Sugarbeets	27.0	....	0	....
Grain sorghum	46.0	264.6	52.0	24.7
Melons	28.2	25.7	6.2	22.7
Rice	13.8	....	13.7	....
Field corn	588.2	88.4	214.2	62.3
Dry beans	120.9	107.2	39.6	8.1
Irrigated pasture	12.3	....	11.1	....
Average, all crops	76	....	33	....
Average, 7 crops	120	78	49	21
Average, 7 crops (omitting corn)	42	76	22	14

Cotton Supply Functions

For policy purposes we may want to know the position and elasticity of supply functions at different time periods in the future. Usually, this is done from regression equations by projecting values of the "shift" variables and then looking at the relationship between price and acreage, or quantity. In the RP model, the year-to-year solutions provide levels of the shift variables. At any point in time, supply functions can be derived by parametric programing.

In this analysis, the sequential estimating procedure for the RP model was interrupted in 1961, 1963, and 1965 to derive a set of "stepped" cotton acreage functions (fig. 9 and fig. 10). Each of these short-run functions applies only to the acreage range between the crop's upper and lower bound. In figure 9, for example, the 1961 function begins at a price of 15.6 cents, where the lower bound is effective, and ends at a price of 26.1 cents, corresponding to the upper bound of 265,000 acres.

There are several uses or interpretations of these functions. They might be used to help answer policy questions of the following type: What will be the probable acreage of cotton in 1961, after the Plan A–B program, if allotments are removed and prices supported at a given level (say 80 percent of parity)? How much cotton will be planted in 1963 if the expected (or support) price is maintained at 80 percent of the base price in 1961 and 1962, but is lowered to 60 percent of the base in 1963? How much additional cotton could be expected in 1963 and 1964, if the

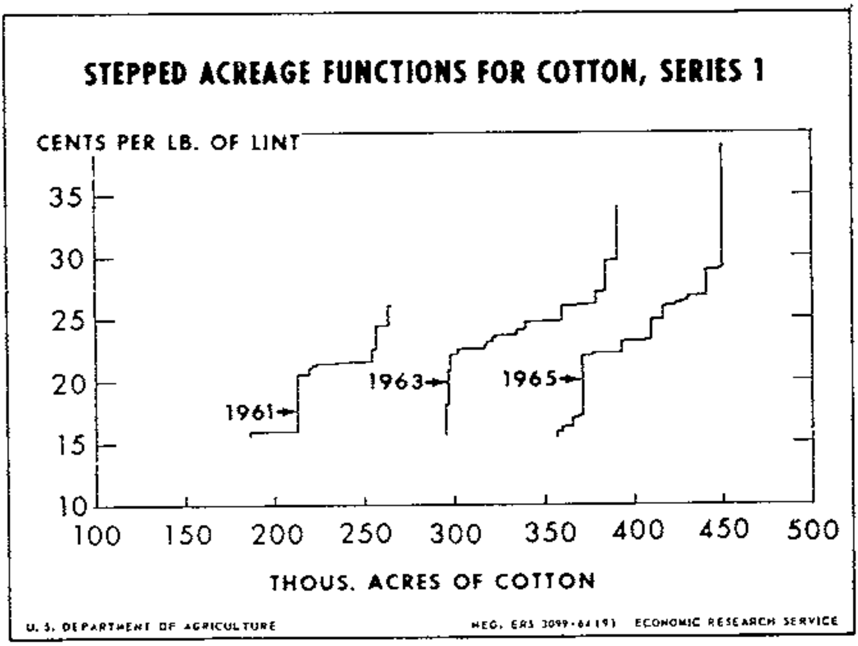

Figure 9

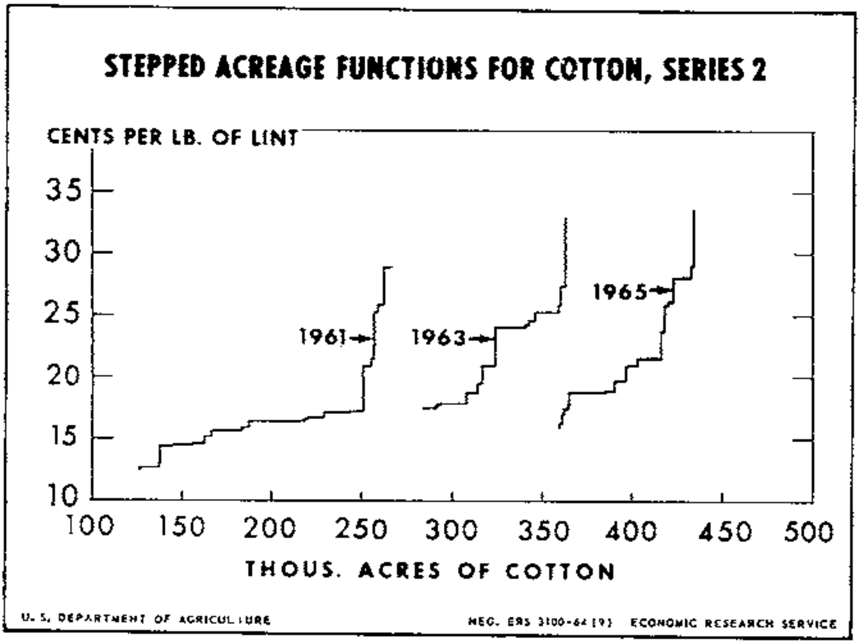

Figure 10

price is not lowered to the 60 percent level until 1965? These kinds of questions are familiar to economists engaged in current policy research.

The supply functions in figures 9 and 10 should be more "predictive" than the usual programing supply functions. In this respect, they are similar to functions derived statistically. One additional advantage is that the RP functions are defined explicitly in terms of years and differ for each year and in each series. Elasticities are not necessarily the same for a given price-acreage combination, since the response environment changes from year to year.

Changes in the acreage and production of alternative crops under different cotton prices is another important policy problem. This information is also derived in the parametric analysis, although only the cotton results are discussed.

Conclusions Based on the Projection Test

It is difficult to draw any definite conclusions from the Projection Test, since actual data are unavailable. Thus, the following comments are more in the nature of hypotheses suggested by the results. First, the RP results appear to be more stable through time and less likely to give extreme values than regression analysis. Second, the RP results appear to lose no more accuracy by being generated recursively into the future than the regression results. Third, the RP estimates for individual crops can and do change directions due to the interrelationships among crops, while the regression results tend to be monotonically increasing or decreasing.

If the region involved were larger, it would be logical to bring aggregate demand and supply into the analysis. In the Predictive Test, the solutions to the model for a single region were adjusted for the effects of aggregate product supplies on product and resource prices by reestimating these prices each year, using actual data for the preceding year. In other words, the cobweb principle was applied in a partial analysis of one region to correct for aggregate effects. When projected solutions for future years are desired, the same procedure can be followed, but only through a recursive interregional analysis.

Suppose that an RP model has been developed for each of the major producing regions of the United States. To simplify the example, assume that the expected crop prices in each region are the actual prices received in the preceding year. The sum of regional supplies predicted for year t, when superimposed on aggregate demand functions, will generate a new set of regional prices received. These prices are then used as expected prices for year $t+1$ and the model is re-solved. The new set of solutions will feed back new prices, and the process is repeated. The same recursive procedure can be used to adjust the prices of production resources for aggregate effects.

The regional price for each crop may be determined by first getting a national market price from the equilibrium of national (predicted) supply and the exogenous demand curve, and then using the historical price differential between regions to adjust for transportation costs. Another possibility is a two-stage technique whereby the predicted supplies from each region are plugged into a separate transportation model to determine product flows, and hence product prices for the following year (*19*).

The main reason why these steps are not taken here is that production of each crop in the study area is not a large share of the total supply. Therefore, it would be impossible to adjust prices and costs for aggregate effects without expanding the analysis to a larger area or without making bold assumptions as to what changes would occur in other producing areas. Still, it should be recognized that a similar model for an entire industry is a possibility that would have considerable usefulness in the policy field.

SUGGESTIONS FOR FUTURE RESEARCH

As just outlined, the integration of separate regional models into a "recursive interregional system" appears to be a logical direction for future research. But as this study is limited to the first stage of such a development, we will concentrate here on research and data requirements to improve the regional components of that system.

Improvement of Farm Type Representation

Further stratification of the region into subclasses of farms—of the kind illustrated by the division of Fresno into two parts—would not only isolate differences in input-output relations and other response determinants; it would also lead to the identification of restraints unique to farm types. For example, if Fresno farms had been grouped according to their soil type proportions, rather than on the basis of geography alone, we would not have needed minimum cotton acreage restraints on soil types 2 and 3 (the indirect restraints added to prevent all of the cotton from going onto soil type 1).

The underlying research problem, basic to virtually all micro-oriented supply analysis, is to determine the conditions associated with homogeneity of response among farms and to know something about the predictive errors or biases that accompany deviation from homogeneity in the model's grouping of farms. Based on this knowledge, we need to define criteria for grouping farms so as to minimize the aggregation bias, or at least so that we know what kinds of biases we can expect in our results.[16] Recent studies by Day *(20)*, Hartley *(28)*, and Bolton *(3)* give us considerable insight into these problems. Some emphasize that the farm resource mix, or resource ratios, are critical determinants of homogeneity in production response. Perhaps our biggest difficulty is to convert their contributions into operational criteria for stratifying subclasses.

Research on the Decision-Making Process, With Emphasis on Farmer's Expectations

The RP model attempts to "simulate" the decision problem facing individual farmers. The variables are presumed to be those guiding farmers' actual decisions (hence their plans). However, the results of this study suggest that in several instances the model data may not represent farmers' expectations properly. The model underestimates participation in Plan B of the cotton program for 1959–60; it overestimates the wheat acreage, and so on.

We could have tested any number of price expectations but chose lagged prices in the absence of a strong empirical basis for a different assumption. Thus, where the purpose of the analysis is to predict, research can be directed profitably to questions such as: How do farmers arrive at their price, yield, and other expectations under different conditions (including different kinds of Government programs)? How do they use this information to make plans?

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[16] This bias is defined as the discrepancy between (1) the aggregate response obtained when every farm is analyzed, and (2) the response estimated when we use the geographic region or representative farms as the units of analysis in an attempt to simplify the problem.

The RP model expresses a logical answer to the second question, as it assumes that restrained profit-maximizing decisions are made 1 year at a time. This simplification, though reasonably valid for annual crops, may distort the decision process when permanent crops and livestock are involved. Therefore, future research might explore combinations of the RP model and "dynamic programing" (*4*).

In dynamic programing the planning horizon is longer than 1 year, and the solution for a given year depends on the solutions for both preceding and subsequent years in that horizon. For certain purposes, one might define an RP problem involving a 5-year planning horizon. The solution for the first 5-year plan—which includes solutions for each year—would be based on data for the current year. Next year a new 5-year plan could be estimated, based on the actual outcome in the first year of the initial 5-year plan, and so on. Such a procedure would express the theory that farmers and ranchers make tentative long-run plans but continually revise them in light of new information and expectations.

Improvement of Flexibility Restraints

Flexibility restraints, though a logical addition to the linear programing model, are an extreme simplification and have obvious limitations. Improvement possibilities rest partly on greater knowledge of factors governing actual behavior, many of which are noneconomic. Certain considerations deserve comment. We would expect, for instance, that as the acreage of a crop is increased farmers will become more reluctant to expand that acreage at the same rate.[17] The flexibility coefficients formulated in the Fresno analysis do not directly account for this kind of response. A constant percentage growth, say $1.15X_{t-1}$, assumes that the larger the initial acreage the greater is the potential for absolute expansion. This ignores the uncertainty attached to specialization.

Another consideration is that farmers may be willing to increase the rate of expansion of a crop when Government supports are introduced because supports reduce price risk, one of the factors accounted for by flexibility restraints. An upper bound coefficient estimated from presupport data could easily underestimate this response.

Lack of change is often due to farmers' personal preferences. Some farmers may prefer not to produce a commodity, despite its profitability, perhaps because it requires "stoop" labor. The restriction in this case is really on the *absolute* level of production, not on the *rate of change* (although

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[17] Henderson took this into account by stratifying historical acreage data into classes according to the "percent of base acreage" occupied by the crop. He estimated different bound coefficients for these classes and found that "Several of the crops showed the anticipated inverse relationship between the levels of the proportionate change and the percentage of base-year acreages devoted to the crops" (*33*, p. 250). This procedure was not used in the Fresno study due to a limited number of observations.

a history of no change would yield flexibility coefficients of comparable magnitude).

Farmers may be willing to enter the production of a commodity only at a minimum level and change their plans only if the profitability of doing so exceeds their current earnings by a specified amount. True, many individual considerations of this kind may average out in the aggregate, but a further understanding of such phenomena should improve the theoretical basis for estimating flexibility restraints.

The main problem is to make the flexibility coefficients or the resulting bounds more adaptable to the conditions for each new year. The Fresno study shows that the bounds often allow too much flexibility in the solution, causing an overestimation of relatively small changes. On the other hand, the model would probably underestimate many changes if the bounds are made too narrow (for example, by omitting the standard errors used in this study). Thus, we may need to "adjust" the bounds using more information than just the preceding year's acreage and a historical change coefficient.

Several ways to improve the estimation of flexibility restraints warrant attention. First, we might consider estimating flexibility coefficients from more sophisticated crop regression equations, with additional independent variables, like the equations tested as alternative models in this study. The regression coefficient for the lagged acreage variable (X_{t-1}) would then reflect the historical effects of price, yield, and other factors.

Second, a regression equation for each crop could be used to make a conditional point acreage estimate for the year ahead. The R^2 for each equation indicates how completely the included independent variables (such as the crop's own price, other prices, land area, and so on) explain changes in acreage. Thus the unexplained deviations ($X_t - X_t'$) are presumably due to omitted variables such as risk and uncertainty—the unknowns taken account of by flexibility restraints. Perhaps the maximum or average of these absolute deviations (much narrower than the usual flexibility restraints) could then be placed as upper and lower bounds on the conditional point estimate forecast by regression analysis.

After establishing the bounds in this way, the programing would be carried out as usual. The advantage of this method is that it makes greater use of the estimates provided by regression analysis and then attempts to refine these estimates through programing. The method differs from the previous refinement, and the method used in the Fresno study, in that we would be defining an allowable acreage range above and below the *regression forecast* rather than placing limits around the preceding year's acreage.

Third, the estimation of flexibility restraints might well be based on an analysis of the discrepancy between *actual* response and the relatively unrestrained or *profit-maximizing* response. For example, we might determine for each crop the statistical association over a period of years between the most profitable acreage (derived from an RP model without flexibility restraints) and the actual acreage. The bounds for future years could then be expressed as a function of this discrepancy as well as the acreage in the preceding year. This kind of approach may appeal to those who favor getting the most profitable solution initially and then adding bounds for a second round of computations.

A closely related procedure would be to base the flexibility restraints on their "shadow prices."[18] These prices represent the increment in total net returns which would accompany a unit change in the bound. The higher the shadow price the greater would be the pressure to increase the upper bound (or decrease the lower bound). Possibly one could examine the past relationship between these prices and the deviation between actual and programing solution acreages to derive a procedure for adjusting bounds. An initial set of bounds might be obtained from a simple equation of the kind used in this study, i.e., $X_t = f(X_{t-1})$. The fully restrained RP model would be solved and shadow prices computed. The initial bounds would then be revised and the problem re-solved.

Finally, recognizing that the bound-estimating procedure can become a complex problem in itself, we hasten to suggest a far less sophisticated approach. It is simply to formulate two sets of bounds, one assuming a *liberal* rate of change and the other assuming a relatively *conservative* response. The resulting RP solutions would serve to "bracket" the likely aggregate response.

Research to improve flexibility restraints should not ignore the advantages of building a more direct representation of the decision problem into the model, *in lieu of upper and lower bounds*. Stratification of the region into more homogeneous farm types and additional resource restraints should remove much of the burden now placed on flexibility restraints. Various forms of stochastic or risk programing would incorporate the risk factor directly in the model.

Data Requirements

Questions of data availability pervade this entire discussion. Stratification of the region into farm types and other refinements already described will depend on the availability of data in addition to those required in the Fresno study. Expansion of the analysis to an interregional level would further multiply these requirements. Thus the data implications of this study and of possible directions for future research might be summarized as follows:

First, if we are to provide predictive answers for aggregate levels (major regions and the United States as a whole), we must face up to the need for *time series* data describing changes in the opportunities, the resources, and operator characteristics for different *types of farms*. Such data are

[18] This idea is taken from a suggestion by Melvin D. Skold, ERS, stationed at the University of Nebraska.

necessary not only to delineate farm subclasses but also to estimate rates of expansion and contraction for flexibility, capacity, and other changing restraints. Data on changes in the numbers of farms in each class will be needed to revise the "farm weights" within each region. Ideally, these data would describe the *process* of change in the farm-size or farm-type distribution.

Secondly, if the regional RP models are to be linked together in an interregional system, we will need the best possible data on product demands and resource supplies, preferably at the regional level.

Widespread application of RP models for supply analysis appears to be technically feasible due largely to the "component" approach; that is, the idea of computing separate results for regions and bringing these together in another step. This means that we can no longer ignore data requirements on the grounds that computer capacity would prevent us from solving the model *even if* we had all the data.

Consequently, serious thought must be given to the problems not only of obtaining the right kinds of data but also of devising automatic data processing aids to organize and keep these data in a state of readiness. The latter point is often neglected in methodological research. Model results, to be useful, must be *timely* as well as *reliable*. We must be able to produce answers quickly, not 2 or 3 years after the problem has been raised, at which time the answers are chiefly of historical interest.

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APPENDIX

Part A: Estimation of Input-Output Coefficients and Activity Returns

Inputs and Costs

Irrigation water, irrigator labor, and fertilizer inputs were estimated first in physical terms (per-acre labor hours, pounds of fertilizer, etc.), and these quantities then multiplied by unit costs to determine per-acre variable costs (tables 16 and 17). All other variable costs were estimated directly in dollars because of a lack of consistent annual data isolating physical inputs and unit costs and also because of the large number of activity returns required in the study. The cost in any one year was taken as an "expected" cost for the subsequent year.

In the Projection Test, per-acre costs of preharvest operations, irrigation water, and ginning of cotton were extrapolated, assuming a linear trend. Irrigator labor costs were projected to $1.25 per hour in 1975, and costs for in-between years obtained by linear interpolation. Similarly, the costs of picking cotton by hand were assumed to increase by 25 percent between 1958 and 1975.

Fertilizer inputs were assumed to increase in the same proportion as expected yields (see below), except that base year inputs were used for barley, wheat, and pasture because of insignificant projected changes in their yields. All other costs were held constant at the values estimated for the first year of the series. Total per-acre costs for all activities and years will be provided on request.

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Expected Yields

A freehand trend of county yields was drawn for each crop to establish an expected yield path. The breakdown of this trend yield into subregion and soil-type yields was based largely on judgment guided by previous studies of the San Joaquin Valley and information provided by Fresno farm advisors (table 18).

TABLE 16.—*Irrigation water: Inputs per acre used in RP model*

Crop	Total (acre-feet)	Time periods[1] (acre-feet)					
		1	2	3	4	5	Other
Eastside							
Cotton	3.00	0.83	......	0.67	0.58	0.67	0.25
Barley	1.00	.75	......	......	......	......	.25
Wheat	1.00	.75	......	......	......	......	.25
Sugarbeets	3.25	.58	0.50	.67	.75	.33	.42
Alfalfa hay, first year	4.67	1.67	.58	.67	.67	.75	.33
Alfalfa hay, mature	4.00	1.00	.58	.67	.67	.75	.33
Alfalfa seed, first year	3.25	1.58	.67	.67	.33	......	......
Alfalfa seed, mature	2.84	1.17	.67	.67	.33	......	......
Grain sorghum, single-cropped	1.92	......	.58	.42	.50	.42	......
Barley sorghum, double-cropped	2.67	.75	......	.75	.50	.42	.25
Rice	6.75	1.67	1.00	1.25	1.42	1.42	......
Corn	2.16	.42	.58	.33	.83	......	......
Dry beans	2.16	.50	.33	.33	.50	.50	......
Irrigated pasture, first year	5.33	.42	.58	.83	1.00	1.00	1.50
Irrigated pasture, mature	4.66	.42	.58	.83	1.00	1.00	.83
Westside							
Cotton	3.26	.92	......	.67	.67	.75	.25
Barley	1.50	1.00	......	......	......	......	.50
Wheat	1.50	1.00	......	......	......	......	.50
Sugarbeets	3.50	.58	.58	.67	.83	.42	.42
Alfalfa hay, first year	4.92	1.67	.58	.67	.75	.83	.42
Alfalfa hay, mature	4.25	1.00	.58	.67	.75	.83	.42
Alfalfa seed, first year	3.49	1.58	.75	.75	.41	......	......
Alfalfa seed, mature	3.08	1.17	.75	.75	.41	......	......
Grain sorghum, single-cropped	2.16	......	.58	.50	.58	.50	......
Melons	2.41	.50	.75	.83	.33	......	......

[1] *Period* — *Months*
1 .... February, March, and April
2 .... May
3 .... June
4 .... July
5 .... August
Other .... September through January

In the Projection Test, expected yields were linear extrapolations from the base year based on 1975 yield indexes developed by Dean and McCorkle (*23*). The 1975 index was first applied to the average 1954–57 expected yields on soil-type 1 to determine a 1975 "expectation." The soil-type 1 yields for in-between years were interpolated, and all other soil-type yields then calculated, assuming the same yield differential as was used for the Explanatory and Predictive Tests.

Expected Prices and Net Returns

In the absence of data on prices actually received in Fresno County, the expected price for each crop in year t is the "average price received by California farmers" in year $t-1$ or the announced county price support, whenever the latter exceeds the price in year $t-1$ (table 19). One exception, however, is the use of a weighted average price for alfalfa hay and alfalfa seed $0.67P_{t-1}+0.33P_{t-1}$. This price is based on the assumption that producers consider more than 1 year of price experience when judging the expected returns of a semipermanent crop.

Prices used in the Projection Test are the average of expected prices for 1955 58 (Series 1), and for 1956 59 (Series 2). The only exception is the use of a lower cotton price, 80 percent of the previous 4-year average, as explained in the text.

The computation of net returns is straightforward for all annual crops. For the three semipermanent crops alfalfa hay, alfalfa seed, and irrigated pasture average annual returns were used. The expected returns in the first and mature years were summed, and this total divided by an assumed typical life of the stand—4 years for alfalfa hay, 3 years for alfalfa seed, and 7 years for irrigated pasture.

Part B: Estimation of Restraints

A practical advantage of the regional model over the farm model for predicting aggregate response is its time-saving use of aggregative or secondary data. Problems of measurement nevertheless arise when available resource data consist only of data on total *resources actually used* by "included" crops or of data on *gross supplies available* to all users of the resource in addition to those defined endogenously. Use of the first type of data, as the restraint itself, assumes that the quantity actually used and the quantity available are identical—that demand equals supply. This is the basic assumption used to estimate restraints on *soil types* and *irrigation water* in the Fresno model.

If gross supplies are used as restraint data, the resources allocated to exogenous activities must be subtracted from the gross quantity to obtain a net supply available to included crops. These data present no problem if the resource is specific to only one of the included crops, such as a cotton allotment; but they are a problem if the resource is required by both included and excluded activities, such as water. Only one restraint other than allotments a maximum total Eastside acreage for 1951 58 is derived in this manner.

Finally, there is the problem of a limitational resource which cannot be quantified in either of the ways already discussed because of a complete lack of data. Examples are the aggregate capacities of certain

TABLE 17.—*Fertilizer: Inputs per acre used in RP model*

1. Explanatory and Predictive Test data

Crop	Kind	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
Westside		*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Cotton	N	100	110	120	130	130	140	150	150	155	155	160
Barley, irrigated	N	60	60	60	60	60	60	60	60	60	60	60
Wheat, irrigated	N	60	60	60	60	60	60	60	60	60	60	60
Grain sorghum	N	50	60	70	80	100	110	120	125	125	125	125
Sugarbeets	N	100	100	110	120	130	150	160	160	160	160	160
Melons	N	60	70	70	80	80	90	100	100	100	100	100
Melons	P_2O_5	60	70	70	70	75	75	80	80	80	80	80
Alfalfa hay	P_2O_5	50	50	50	50	50	50	50	50	55	55	55
Eastside												
Cotton	N	90	100	100	105	110	110	120	120	125	125	130
Barley, irrigated	N	50	50	50	50	50	50	50	50	55	55	60
Wheat, irrigated	N	50	50	50	50	50	50	50	50	55	55	60
Grain sorghum	N	50	60	70	80	100	110	120	125	125	125	125
Sugarbeets	N	100	100	110	120	130	150	160	160	160	160	160
Rice	N	50	50	50	50	50	50	50	50	55	60	65
Field corn	N	80	80	80	100	120	130	140	150	150	155	155
Alfalfa hay	P_2O_5	50	50	50	50	50	50	50	50	55	55	55
Irrigated pasture	P_2O_5	50	50	50	50	50	50	50	50	55	55	55

2. Projection Test data [1]

Crop	Kind	1958 base [2]						1959 base [3]				
		1960	1961	1962	1963	1964	1965	1961	1962	1963	1964	1965
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Westside												
Cotton	N	157	159	161	163	165	167	157	159	161	163	165
Grain sorghum	N	126	127	128	129	130	131	126	127	128	129	130
Sugarbeets	N	161	162	163	164	165	166	162	164	166	168	170
Melons	N	101	102	103	104	105	106	101	102	103	104	105
Melons	P_2O_5	81	82	83	84	85	86	81	82	83	84	85
Eastside												
Cotton	N	127	129	131	133	135	137	127	129	131	133	135
Grain sorghum	N	126	127	128	129	130	131	126	127	128	129	130
Sugarbeets	N	161	162	163	164	165	166	162	164	166	168	170
Rice	N	56	57	58	59	60	61	61	62	63	64	65
Field corn	N	152	154	156	158	160	162	156	157	158	159	160

[1] For 1958 base, these inputs are computed as follows: (1965 expected yield ÷ 1959 expected yield) × (1959 fertilizer input/acre) − (1959 fertilizer input/acre) ÷ 6 yrs. For 1959 base, same formula is used, but 1960 is substituted for 1959. Barley, wheat, and pasture are excluded as no change from base year is assumed. Yield increases are assumed to be due to improved variety and practices. Alfalfa hay is excluded as projected inputs are not significantly different from those of base year.

[2] 1959 inputs are same as under Part 1.

[3] 1960 inputs are same as under Part 1.

TABLE 18.—*Expected yields per acre, selected years, used in both models*

Activity	Unit	Explanatory Test				Predictive Test			Projected 1965 (1959 base) [1]
		1951	1953	1955	1957	1959	1960	1961	
1. Westside									
Soil type 1:									
Cotton, solid-planted, lint	bale	1.9	2.0	2.2	2.4	2.55	2.60	2.65	2.75
Cotton, solid-planted, seed [2]	ton	.694	.730	.803	.876	.931	.949	.967	1.004
Cotton, skip-row, lint [3]	bale	....	....	2.86	3.12	3.32	3.38	3.44	3.58
Cotton, skip-row, seed [2]	ton	....	....	1.044	1.139	1.212	1.234	1.256	1.307
Barley, irrigated	cwt.	33	33	33	33	33	33	33	34.6
Barley, dry	cwt.	15	15	15	15	15	15	15	15.2
Wheat, irrigated	cwt.	30	32	32	32	32	32	32	32
Alfalfa hay, first year	ton	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.15
Alfalfa hay, mature	ton	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.15
Alfalfa seed, first year	cwt.	6.5	6.5	6.5	6.5	6.5	6.5	6.5	7.15
Alfalfa seed, mature	cwt.	7.5	7.5	7.5	7.5	7.5	7.5	7.5	6.7
Sorghum, single-crop	cwt.	29	31	35	39	43	44	45	7.7
Sugarbeets	ton	22	22	22	23	23	23	23	46
Melons	80-lb. crate	155	165	175	185	195	200	200	24.2
									210
Soil type 2:									
Cotton, solid-planted, lint	bale	1.4	1.5	1.7	1.9	2.05	2.10	2.15	2.25
Cotton, solid-planted, seed [2]	ton	.511	.548	.620	.694	.748	.765	.785	.821
Cotton, skip-row, lint [3]	bale	....	....	2.21	2.47	2.66	2.73	2.80	2.92
Cotton, skip-row, seed [2]	ton	....	....	.807	.902	.971	.996	1.022	1.066
Barley, irrigated	cwt.	27	27	27	27	27	27	27	28.6
Barley, dry	cwt.	10	10	10	10	10	10	10	10.2
Wheat, irrigated	cwt.	24	26	26	26	26	26	26	26
Alfalfa hay, first year	ton	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.9
Alfalfa hay, mature	ton	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.9
Alfalfa seed, first year	cwt.	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.7
Alfalfa seed, mature	cwt.	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.7
Sorghum, single-crop	cwt.	25	27	31	35	39	40	41	42
Sugarbeets	ton	17	17	17	18	18	18	18	19.2
Melons	80-lb. crate	145	155	165	175	185	190	190	200

Soil type 3:									
Cotton, solid-planted, lint	bale	.9	1.0	1.2	1.4	1.55	1.60	1.65	1.75
Cotton, solid-planted, seed [2]	ton	.328	.365	.438	.511	.566	.584	.602	.639
Cotton, skip-row, lint [3]	bale	....	....	1.56	1.82	2.02	2.08	2.14	2.28
Cotton, skip-row, seed [2]	ton	....	....	.569	.664	.737	.759	.781	.832
Barley, irrigated	cwt.	20	20	20	20	20	20	20	21.6
Barley, dry	cwt.	5	5	5	5	5	5	5	5.2
Wheat, irrigated	cwt.	17	19	19	19	19	19	19	19
Alfalfa hay, first year	ton	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.9
Alfalfa hay, mature	ton	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.9
Alfalfa seed, first year	cwt.	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.2
Alfalfa seed, mature	cwt.	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.2
Sorghum, single-crop	cwt.	21	23	27	31	35	36	37	38
Sugarbeets	ton	15	15	15	16	16	16	16	17.2
Melons	80-lb. crate	120	130	140	150	160	165	165	175
2. Eastside									
Soil type 1:									
Cotton, solid-planted, lint	bale	1.8	1.9	2.1	2.3	2.45	2.50	2.55	2.65
Cotton, solid-planted, seed [2]	ton	.657	.694	.766	.840	.894	.912	.931	.967
Barley, irrigated	cwt.	28	28	28	28	28	28	28	29.6
Barley, dry	cwt.	15	15	15	15	15	15	15	15.2
Wheat, irrigated	cwt.	25	27	27	27	27	27	27	27
Wheat, dry	cwt.	13	14	14	14	14	14	14	14
Alfalfa hay, first year	ton	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.15
Alfalfa hay, mature	ton	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.15
Alfalfa seed, first year	cwt.	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.7
Alfalfa seed, mature	cwt.	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.7
Sorghum, single-crop	cwt.	23	25	29	33	37	38	39	40
Sorghum, double-crop	cwt.	19	21	25	29	33	34	35	36
Sugarbeets	ton	22	22	22	23	23	23	23	24.2
Field corn	cwt.	28	30	38	46	52	54	56	56
Dry beans	cwt.	17	17	17	17	17	17	17	17.4
Irrigated pasture, first year	AUM [4]	11	11	11	11	11	11	11	11.2
Irrigated pasture, mature	AUM	14	14	14	14	14	14	14	14.2

See footnotes at end of table.

TABLE 18.—*Expected yields per acre, selected years, used in both models*—Continued

Activity	Unit	Explanatory Test				Predictive Test			Projected 1965 (1959 base) [1]
		1951	1953	1955	1957	1959	1960	1961	
Soil type 2:									
Cotton, solid-planted, lint	bale	1.3	1.4	1.6	1.8	1.95	2.00	2.05	2.15
Cotton, solid-planted, seed[2]	ton	.474	.54	.584	.657	.712	.730	.748	.785
Barley, irrigated	cwt.	22	22	22	22	22	22	22	23.6
Barley, dry	cwt.	10	10	10	10	10	10	10	10.2
Wheat, irrigated	cwt.	19	21	21	21	21	21	21	21
Wheat, dry	cwt.	8	9	9	9	9	9	9	9
Alfalfa hay, first year	ton	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.9
Alfalfa hay, mature	ton	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.9
Alfalfa seed, first year	cwt.	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.7
Alfalfa seed, mature	cwt.	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.7
Sorghum, single-crop	cwt.	19	21	25	29	33	34	35	36
Sorghum, double-crop	cwt.	15	17	21	25	29	30	31	32
Sugarbeets	ton	17	17	17	18	18	18	18	19.2
Field corn	cwt.	23	25	33	41	47	49	51	51
Dry beans	cwt.	12	12	12	12	12	12	12	12.4
Irrigated pasture, first year	AUM	9	9	9	9	9	9	9	9.2
Irrigated pasture, mature	AUM	12	12	12	12	12	12	12	12.2
Rice	cwt.	38	40	42	44	46	47	48	51.2

Soil type 3:									
Cotton, solid-planted, lint	bale	.8	.9	1.1	1.3	1.45	1.50	1.55	1.65
Cotton, solid-planted, seed [2]	ton	.292	.328	.402	.474	.529	.548	.566	.602
Barley, irrigated	cwt.	15	15	15	15	15	15	15	16.6
Barley, dry	cwt.	5	5	5	5	5	5	5	5.2
Wheat, irrigated	cwt.	12	14	14	14	14	14	14	14
Wheat, dry	cwt.	4	5	5	5	5	5	5	5
Alfalfa hay, first year	ton	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.9
Alfalfa hay, mature	ton	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.9
Alfalfa seed, first year	cwt.	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.2
Alfalfa seed, mature	cwt.	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.2
Sorghum, single-crop	cwt.	15	17	21	25	29	30	31	32
Sorghum, double-crop	cwt.	11	13	17	21	25	26	27	28
Sugarbeets	ton	15	15	15	16	16	16	16	17.2
Field corn	cwt.	18	20	28	36	42	44	46	46
Dry beans	cwt.	7	7	7	7	7	7	7	7.4
Irrigated pasture, first year	AUM	7	7	7	7	7	7	7	7.2
Irrigated pasture, mature	AUM	10	10	10	10	10	10	10	10.2
Rice	cwt.	25	27	29	31	33	34	35	38.2

[1] For other years in series, yields are interpolated between base year and 1965 yields.

[2] Cottonseed yield of 730 lb. per bale of lint, based on assumption of 36 percent turnout, 55 percent seed, and 9 percent trash, as follows:

$$\frac{478 \text{ (lb. lint per bale)}}{0.36 \text{ (turnout)}} = 1{,}328 \text{ lb. seed cotton needed to yield one bale.}$$

$$1{,}328 \text{ lb. seed cotton} \times 0.55 \text{ (seed proportion)} = 730 \text{ lb. seed.}$$

[3] Skip-row lint yield is 30 percent over solid-planted yield.

[4] Animal unit month.

TABLE 19.—*Expected prices used in both models*[1]

Year	Cotton lint	Cotton seed	Barley	Wheat	Alfalfa hay [2]	Alfalfa seed [2]	Grain sorghum	Sugar-beets [3]	Melons	Field corn	Dry beans	Irrigated pasture [4]	Rice
	Cents per lb.	*Per ton*	*Per cwt.*	*Per cwt.*	*Per ton*	*Cents per cwt.*	*Per cwt.*	*Per ton*	*Per 80-lb. crate*	*Per cwt.*	*Per cwt.*	*Per AUM*	*Per cwt.*
1951	[5] 34.71	$74.00	$2.54	$3.78	$20.62	2.61	$2.64	$12.95	$3.00	$3.34	$8.90	$5.00	$4.54
1952	39.25	71.90	3.15	3.77	26.87	3.52	3.30	13.95	3.15	3.88	9.00	5.00	4.95
1953	32.21	66.70	3.21	3.78	31.00	3.76	3.36	14.45	3.30	3.48	10.10	5.00	6.25
1954	32.48	54.00	2.71	3.90	24.80	2.89	2.80	13.95	3.05	3.29	9.70	5.00	5.38
1955	33.32	59.20	2.42	3.65	21.33	3.18	2.66	13.15	2.85	3.29	8.90	5.00	4.61
1956	33.08	48.00	2.31	3.52	24.68	2.70	2.49	13.15	2.70	2.80	8.20	5.00	4.31
1957	32.65	62.10	2.31	3.52	24.46	3.02	2.57	13.65	3.00	2.93	8.00	5.00	4.44
1958	34.27	52.80	2.19	3.52	23.43	2.92	2.26	13.25	3.68	2.48	8.40	5.00	4.48
1959	[6] 34.06	43.00	2.23	3.22	23.80	2.99	2.14	13.85	2.72	2.50	8.40	5.00	3.85
1960	[6] 32.16	44.40	2.15	3.17	25.54	3.25	2.04	13.75	3.60	2.50	8.90	5.00	4.19
1961	32.24	51.50	2.17	3.17	25.09	3.21	[7] 2.30	13.05	3.32	[8] 2.46	10.30	5.00	4.43
Projection data: [9]													
1958 base	[10] 26.08	51.00	2.18	3.33	24.32	2.88	2.32	13.48	3.02	2.68	8.25	5.00	4.26
1959 base	[10] 25.90	50.58	2.18	3.22	24.30	3.13	2.24	13.62	3.25	2.60	8.42	5.00	4.23

[1] Actual prices received by California farmers in preceding year, or announced county price supports if higher, unless otherwise noted.

[2] $0.67P_{t-1}+0.33P_{t-2}$.

[3] Includes average sugar payment of $2.25 per ton.

[4] Assumed rental value.

[5] Average of prices received in 1949 and 1950. Latter price (41.25¢) assumed to be too high for expected price in 1951 due to allotments and large demand in 1950.

[6] Price shown is for *Plan A* cotton. Prices used for *Plan B* cotton are: 28.23 cents (1959) and 26.27 cents (1960).

[7] Actual price lagged 1 year used for supported and unsupported output in connection with Feed Grain Program.

[8] Support price used for participation in Feed Grain Program. Unsupported price (actual price lagged 1 year) is $2.14/cwt.

[9] Average of expected prices in 1955–58 for 1958 base and average of 1956–59 for 1959 base.

[10] Eighty percent of preceding 4-year average.

equipment and the capital of individual farmers. When this problem arises, one can handle the need for a restraint only indirectly by placing limits on the acreage or output of the crop(s) using that resource. This approach is taken to estimate *flexibility restraints* and the restraints on *mechanical cotton picking*.

Aggregate Land and Soil Type Restraints

The "supply" of land has increased substantially in Fresno County, due to continuing irrigation development. No attempt was made to explain this development, or to predict changes in supply, until after 1958.

Explanatory Test.—Eight land restraints were defined for 1951–58 based primarily on land use and land classification data provided by the California Department of Water Resources (table 20).

Westside and Eastside acreage restraints were developed indirectly because separate acreage data were available only for 1958. In 1958, the Westside had 53 percent of the total included crop acreage and the Eastside had 47 percent. As irrigation development on the Westside has occurred more recently than on the Eastside, it was assumed (1) that the Westside's share in years prior to 1958 was *less* than, or equal to, its share in 1958 and (2) that the Eastside's share in years prior to 1958 was *greater* than, or equal to, its share in 1958. These two assumptions were expressed by the following conditions:

$$X_{1t} \leq 0.53 X'_t$$

and

$$X_{2t} \geq 0.47 X'_t,$$

where X_{1t} = the aggregate solution acreage on the Westside in year t, X_{2t} = the Eastside solution acreage, and X'_t = the maximum total Fresno County acreage, or in this test the actual total acreage of the 12 crops.

Under these conditions the total Eastside acreage in the solution could conceivably equal the total county acreage available to included crops. Thus, an additional condition was added, namely, $X_{2t} \leq K_2$, which specifies that the total Eastside solution acreage could not exceed a constant. K_2, equal to 390,303 acres. This is the area suitable for crop production on the Eastside (910,563 acres) less an estimated acreage of "excluded" crops, fallow land, farmsteads, etc. (520,260 acres).

The county acreage actually devoted to included crops was also defined as a separate restraint to ensure that the sum of Eastside and Westside solution acres would not exceed this limit.

Maximum Eastside and Westside acres were divided into soil types 1, 2, and 3 using the proportions of *total* Fresno County land in each type (table 20). These "types" combine a large number of soils, identified by the Department of Water Resources, into manageable groups having

TABLE 20.—*Land and soil type restraints (acres)*

Year	Maximum county acreage [1]	Westside restraints				Eastside restraints				
		Maximum total [2]	Soil 1 (0.564) × col. 3	Soil 2 (0.278) × col. 3	Soil 3 (0.158) × col. 3	Maximum total [3]	Soil 1 (0.361) × col. 7	Soil 2 (0.360) × col. 7	Soil 3 (0.279) × col. 7	Minimum total (0.467) × col. 2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Explanatory Test:										
1951	733, 960	390, 907	220, 472	108, 672	61, 763	390, 303	140, 899	140, 509	108, 895	343, 053
1952	746, 520	397, 597	224, 245	110, 532	62, 820	390, 303	140, 899	140, 509	108, 895	348, 923
1953	726, 290	386, 822	218, 168	107, 536	61, 118	390, 303	140, 899	140, 509	108, 895	339, 468
1954	744, 410	396, 473	223, 611	110, 219	62, 643	390, 303	140, 899	140, 509	108, 895	347, 937
1955	735, 810	391, 892	221, 027	108, 946	61, 919	390, 303	140, 899	140, 509	108, 895	343, 918
1956	743, 110	395, 780	223, 220	110, 027	62, 533	390, 303	140, 899	140, 509	108, 895	347, 330
1957	785, 730	418, 480	236, 023	116, 337	66, 120	390, 303	140, 899	140, 509	108, 895	367, 250
1958	801, 500	426, 879	240, 760	118, 672	67, 447	390, 303	140, 899	140, 509	108, 895	374, 621
Predictive Test:										
1959	....	439, 462	247, 857	122, 170	69, 435	377, 617	136, 320	135, 942	105, 355	....
1960	....	443, 303	250, 023	123, 238	70, 042	378, 709	136, 714	136, 335	105, 660	....
1961	....	445, 109	251, 041	123, 740	70, 327	380, 641	137, 411	137, 031	106, 199	....

Projection Test:										
1958 base:										
1959	....	439, 462	247, 857	122, 170	69, 435	377, 617	136, 320	135, 942	105, 355	....
1960	....	446, 808	252, 000	124, 212	70, 596	380, 218	137, 259	136, 878	106, 081	....
1961	....	453, 432	255, 736	126, 054	71, 642	382, 298	138, 010	137, 627	106, 661	....
1962	....	459, 384	259, 092	127, 709	72, 583	383, 955	138, 608	138, 224	107, 123	....
1963	....	464, 716	262, 100	129, 191	73, 425	385, 275	139, 084	138, 699	107, 492	....
1964	....	469, 477	264, 785	130, 5[illegible]5	74, 177	386, 322	139, 462	139, 076	107, 784	....
1965	....	473, 719	267, 177	131, 694	74, 848	387, 154	139, 763	139, 375	108, 016	....
1959 base:										
1960	....	443, 303	250, 023	123, 238	70, 042	378, 709	136, 714	136, 335	105, 660	....
1961	....	449, 950	253, 772	125, 086	71, 092	380, 962	137, 527	137, 146	106, 289	....
1962	....	455, 964	257, 164	126, 758	72, 042	382, 786	138, 186	137, 803	106, 797	....
1963	....	461, 389	260, 224	128, 266	72, 899	384, 259	138, 718	138, 333	107, 208	....
1964	....	466, 270	262, 976	129, 623	73, 671	385, 448	139, 147	138, 761	107, 540	....
1965	....	470, 651	265, 447	130, 841	74, 363	386, 405	139, 492	139, 106	107, 807	....

[1] Actual acres devoted to included crops.

[2] For Explanatory Test, col. 3=0.533×col. 2. For other tests, col. 3 is predicted by Pearl-Reed growth function (see text).

[3] For Explanatory Test, col. 7=K_2 (see text). For other tests, col. 7 is predicted by Pearl-Reed growth function.

comparable yield-affecting characteristics. Soil type 1 includes smooth-lying land free of salinity with medium-to-deep root zones. Soil 3, the least productive group, includes land that is suitable for production but severely limited by characteristics such as slope, an excess of salts, or shallow depth.

Predictive Test.—Maximum Westside and Eastside acres were "predicted" separately, using the Pearl-Reed function,

$$X'_t = \frac{\gamma}{1+\beta e^{-\alpha t}},$$

where X'_t=the supply of land available to included crops in year t; γ=an upper asymptote; and t=time (1945=1). In the Eastside equation, $\gamma = K_2$, or 390,303 acres. The counterpart acreage suitable for included crops on the Westside (K_1) is 505,370 acres.

These equations were fitted to data through 1958, 1959, and 1960 to predict for 1959–61, respectively. The included crop-acreage data used for this purpose were derived from total county data, assuming that the percentage distribution of each crop grown on both the Eastside and the Westside in years other than 1958 was the same as that in 1958. Soil type percentages were multiplied by these maximum acreages to obtain soil type restraints (table 20).

Projection Test.—The Pearl-Reed functions were extended to 1965 to provide maximum acreage data for each year in Series 1 and 2, using data through 1958 and 1959, respectively.

Irrigation Water Restraints

The growing seas n was divided into five time periods, and the supply of water in each period treated as a different input:

Period	*Months*
1	February, March, and April
2	May
3	June
4	July
5	August

Separate restraints were included for time-period supplies on each side of the county, assuming that the quantity available in one period is independent of the quantity available or used in the preceding period of the same year.

The estimation of water restraints was based on the assumption that historical water use or demand particularly in July and August, the peak summer months, is a close approximation of the actual supply of water. This assumption is undoubtedly quite valid for the Westside, where groundwater is the only source and farmers are known to operate their pumps continuously during the peak season. Although the Eastside uses surface water as well as groundwater, arrangements for obtaining additional surface water are limited by dam and diversion capacities which, like pump capacity, are relatively fixed in the short run.

Explanatory Test.—A restraint was placed first on the county's total annual supply of irrigation water, obtained recursively from the least-squares equation, $Y'_t = 1.068 Y_{t-1}$, where Y'_t = the total acre-feet available in year t, Y_{t-1} = the estimated acre-feet used in the county for included crops in year t–1, and t=1946–58 (omitting 1950 and 1953–55 when water use declined, presumably because of cotton allotments).

As in the case of land input, a set of conditions was defined to bracket the model's allocation of water between the two sides. In 1958, it was estimated that 44 percent of the water required by included crops in the county was used on the Westside and 56 percent on the Eastside. Based on knowledge of historical development, it was assumed (1) that in each year prior to 1958 the quantity available on the Westside was *less* than or equal to 44 percent of the county supply, and (2) that the Eastside supply was *greater* than or equal to 56 percent of the total, i.e.,

$$Y_{1t} \leq 0.44\, Y'_t$$

and

$$Y_{2t} \geq 0.56\, Y'_t.$$

where Y_{1t} and Y_{2t} = total acre-feet available on the Westside and the Eastside, respectively, and Y'_t = acre-feet available to the county, derived above. To ensure that the model would not allocate an unrealistic share to the Eastside, we added the condition, $Y_{2t} \leq K_2 A_2$, where K_2 = the *maximum* Eastside acreage and A_2 = the estimated average input to included crops on the Eastside in 1951–58 (3.38 acre-feet per acre).

The maximum subregion supplies (0.44 Y'_t on the Westside and K_2A_2 on the Eastside) were divided into time-period restraints based on estimates of the maximum relative use in each period (table 21). The county supply, Y'_t, was also included as a separate restraint because the above procedure might have allowed the model to use more than that total.

Predictive Test.—For this test, maximum water supplies on the Westside and the Eastside were estimated separately at the outset, rather than derived as shares of the county supply. Using the crop distribution based on 1958 data, equations of the form, $Y'_t = (1+\gamma) Y_{t-1}$, were applied separately to the subregion data through 1958, 1959, and 1960 to obtain predicted supplies for 1959–61. The values of $(1+\gamma)$ are as follows:

	Using data through:		
	1958	*1959*	*1960*
Westside [1]	1.044	1.045	1.041
Eastside [2]	1.078	1.074	1.067

[1] 1948, 1953, and 1954 omitted as observations due to an extreme increase or a decline in water use.

[2] 1954, 1955, and 1957 omitted due to a decline in use.

TABLE 21.—*Irrigation water restraints*

1. Total supplies (1,000 acre-feet)

Year	Maximum county supply [1]	Maximum Westside supply [2]	Maximum Eastside supply [3]	Minimum Eastside use [4]
(1)	(2)	(3)	(4)	(5)
Explanatory Test:				
1951	1,962	857	1,319	1,068
1952	2,181	953	1,319	1,187
1953	2,324	1,016	1,319	1,265
1954	2,319	1,013	1,319	1,262
1955	2,278	995	1,319	1,240
1956	2,184	955	1,319	1,189
1957	2,228	974	1,319	1,213
1958	2,230	975	1,319	1,214
Predictive Test:				
1959	....	984	1,309	....
1960	....	1,030	1,365	....
1961	....	1,038	1,387	....
Projection Test:				
1958 base:				
1959	....	984	1,309	....
1960	....	987	1,288	....
1961	....	1,001	1,295	....
1962	....	1,014	1,300	....
1963	....	1,026	1,305	....
1964	....	1,037	1,308	....
1965	....	1,046	1,311	....
1959 base:				
1960	....	1,030	1,365	....
1961	....	1,003	1,279	....
1962	....	1,017	1,285	....
1963	....	1,029	1,290	....
1964	....	1,040	1,294	....
1965	....	1,050	1,298	....

2. Time-period supplies [5]

Year	Percent of total quantity used in specified time periods									
	Eastside					Westside				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
1951	*(24.8)*	7.3	19.0	18.6	20.3	39.0	2.1	15.0	14.2	15.1
1952	24.7	7.5	*(19.1)*	18.8	*(20.4)*	37.1	2.5	*(16.2)*	*(15.2)*	*(15.9)*
1953	24.5	8.6	18.8	*(18.9)*	20.2	37.7	3.0	15.8	14.7	15.2
1954	24.4	10.1	18.3	18.9	19.7	42.2	4.2	13.6	12.1	11.5
1955	24.4	10.6	18.0	18.8	19.1	43.1	5.8	13.8	11.5	10.0
1956	24.4	10.6	18.0	18.5	19.2	42.9	6.2	13.9	11.7	10.0
1957	24.1	*(11.1)*	17.8	18.7	18.7	*(43.6)*	6.9	13.8	11.2	9.0
1958	24.0	11.1	17.9	18.7	18.9	42.7	*(7.3)*	14.3	11.6	9.3
1959	24.5	10.4	18.0	18.5	19.1	41.8	6.8	14.8	12.2	10.1
1960	24.7	10.0	18.1	18.4	19.3	40.6	6.7	15.4	12.8	10.9

[1] Equals Y_t' where $Y_t' = 1.068\ Y_{t-1}$ (fitted to data for 1946–58, omitting 1950 and 1953–55 when actual use declined). (Footnotes 2–5 are on facing page.)

Time-period restraints were derived as explained above, using the maximum percentage data for 1951 through the year immediately preceding the one to be predicted.

Projection Test.—We did not want to assume that Fresno water supplies would continue to increase according to the formula $Y_t = (1+\alpha)Y_{t-1}$. The product of average applications per acre and projected land restraints provided more reasonable estimates because the latter restraints, taken from the Pearl-Reed growth curve, increase at a decreasing rate. The per acre water inputs used for this purpose were the averages of 1954–58 data for Series 1 and the averages of 1955–59 data for Series 2:

	For Series 1	*For Series 2*
	Acre-feet	
Westside	2.21	2.23
Eastside	3.39	3.36

Time-period restraints were again derived using the maximum percentage data for years preceding the projection series.

Cotton Machine-Picking Capacity

Like water restraints, the aggregate capacity of cotton pickers was estimated from data on actual use, the assumption being that these data provide a reasonable measure of farmers' willingness and ability to adopt the technology.

Explanatory Test.—A total county capacity was estimated by the least squares equation, $B'_t = (1.182)B_{t-1}$, where $B'_t =$ the number of bales that can be machine-picked in the solution for year t, $B_{t-1} =$ the actual production machine-picked in year $t-1$, and $t = 1947$–1958 (omitting 1953 and 1955 when machine-picked output declined).

As the expected returns to machine-picked activities differ between the two sides of Fresno County, this single restraint might have allowed a disproportionate use of the resource on one side. Thus, additional restraints were placed on the *percent* of cotton production on each side that could be harvested mechanically, derived from the least-squares equation, $P'_t = 1.103P_{t-1}$, where $P'_t =$ the maximum allowable percent for year t, $P_{t-1} =$ the actual percent in year $t-1$, and $t = 1947$–58. This restraint is the same for both sides as available data apply only to the county and because there is no empirical basis for assuming different expansion rates (table 22).

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[2] For Explanatory Test, col. 3 = 0.137 Y'_t. For Predictive Test, col. 3 = $Y'_{1t} = (1+\alpha_1)Y_{1,t-1}$, where $(1+\alpha_1)$ values differ each year (see text). For Projection Test, col. 3 = (average acre-feet used per acre in preceding 4-year period) × (maximum Westside land restraint, table 20).

[3] For Explanatory Test, col. 4 = (average acre-feet used per acre, 1951–58) × K_2 (see text). For predictive test, col. 4 = $Y'_{2t} = (1+\alpha_2)Y_{2,t-1}$, where $(1+\alpha_2)$ values differ each year (see text). For Projection Test, col. 4 = (average acre-feet used per acre in preceding 4-year period) × (maximum Eastside land restraint, table 20).

[4] 0.563 Y'_t. This figure was reduced by 4 percent to ensure that minimum use would not exceed actual use.

[5] Maximum absolute time-period supplies = maximum percentages (shown in parentheses) × maximum total acre-feet in part 1 of this table.

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TABLE 22.—*Restraints on mechanical cotton picking*

Year	Actual data					Restraints			
	Harvested cotton acres [1]	Average yield per acre (bales) [1]	Total production (bales)	Percent machine picked [2]	Production machine picked col. 4×5	Maximum county bales [3]	Maximum percent [4]	Maximum Westside bales [5]	Maximum Eastside bales [6]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Explanatory Test:									
1951	339, 000	1. 439	487, 821	41	200, 007	87, 401	27. 6	...	...
1952	369, 000	1. 310	483, 390	48	232, 027	236, 358	45. 2	...	...
1953	322, 500	1. 274	410, 865	51	209, 541	274, 198	52. 9	...	...
1954	223, 500	1. 753	391, 796	55	215, 488	247, 625	56. 2	...	...
1955	189, 730	1. 626	308, 501	63	194, 356	254, 653	60. 6	...	...
1956	189, 100	1. 998	377, 822	67	253, 141	229, 680	69. 5	...	...
1957	173, 000	2. 316	400, 668	71	284, 474	299, 150	73. 9	...	...
1958	181, 000	2. 400	434, 400	75	325, 800	336, 177	78. 3	...	...
Predictive Test:									
1959	215, 000	2. 343	503, 745	85	428, 183	383, 363	82. 2	...	...
1960	238, 000	2. 167	515, 746	89	459, 014	520, 363	93. 8	...	...
1961	208, 000	2. 061	428, 688	96	411, 540	536, 363	97. 2	...	...

Projection Test:									
1958 base:									
1959	......	......	......	......	......	383, 363	82. 2	......	......
1960	......	......	......	......	......	451, 096	90. 1	......	......
1961	......	......	......	......	......	530, 797	98. 8	......	......
1962	......	......	......	......	......	624, 579	100. 0	351, 013	273, 566
1963	......	......	......	......	......	734, 931	100. 0	413, 031	321, 900
1964	......	......	......	......	......	864, 780	100. 0	486, 006	378, 774
1965	......	......	......	......	......	1, 017, 571	100. 0	571, 875	445, 696
1959 base:									
1960	......	......	......	......	......	520, 363	93. 8	......	......
1961	......	......	......	......	......	632, 387	100. 0	355, 401	276, 986
1962	......	......	......	......	......	768, 528	100. 0	431, 913	336, 615
1963	......	......	......	......	......	933, 977	100. 0	524, 895	409, 082
1964	......	......	......	......	......	1, 135, 045	100. 0	637, 895	497, 150
1965	......	......	......	......	......	1, 379, 399	100. 0	775, 222	604, 177

[1] California Crop and Livestock Reporting Service. "California Cotton: Acreage, Yield Per Acre, and Production" (annual reports).

[2] Estimated from Hedges and Bailey, "Economics of Mechanical Cotton Harvesting," Calif. Agric. Expt. Sta. Bull. 743, April 1954; USDA, AMS estimates for California, 1949–61; and unpublished data obtained from Fresno Farm Labor Office, U.S. Employment Service.

[3] Predicted by equation, $B_t' = (1+\alpha)B_{t-1}$ (see text).

[4] Predicted by equation, $P_t' = (1+\alpha)P_{t-1}$ (see text).

[5] 0.562×col. 7.

[6] 0.438×col. 7.

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Predictive Test.—The same estimating procedure was used for the Predictive Test, although the coefficients, $1+\alpha$, were obtained by refitting the above equations to data through the immediately preceding year. These coefficients are:

	Using data through—		
	1958	*1959*	*1960*
Total county bales	1.177	1.215	1.169
Percentage equation	1.096	1.103	1.092

Projection Test.—The estimating procedure remained the same except that when the maximum percentage restraint (P_t') reached 100, the maximum county restraint on production (B_t'), derived from data through the base year, was divided into separate Westside and Eastside restraints. This breakdown was based on the cotton acreage distribution in 1958 and the average yield differential between the two sides.

Flexibility Restraints

Year-to-year changes in the acreage of each included crop are the *effects* of three phenomena: (1) Normal substitution of one included crop for another, as well as supplementary changes tied to rotation; (2) changes in the land base such that as new land is developed or bid away from "excluded" enterprises, increases are expected in the acreages of some or all of the included crops; and (3) Government programs and other institutional factors.

All of these phenomena apply to acreage changes in the Fresno test. Yet the concept of a flexibility restraint, as explained in the text, is related only to enterprise substitution, the first phenomenon. Consequently, two adjustments were made in the historical data to isolate these effects.

1. The upper and lower bound inequations were expressed in *percentage* rather than *absolute* acreage terms. The equation actually fitted to obtain values of $(1+\bar{\beta}_i)$ and $(1-\underline{\beta}_i)$ was

$$X_{it}=(1+\beta_i)\left(\frac{\sum_{i=1}^{12} X_{it}}{\sum_{i=1}^{12} X_{i,\,t-1}}\right)X_{i,\,t-1}.$$

In other words, the effects of a changing land base are isolated by multiplying $X_{i,\,t-1}$ by an adjustment factor before fitting the equation.[1] The historical observations were stratified into increasing and decreasing data, and the equation just shown was fitted separately to each data set so that $(1+\beta_i)$ is the estimate of $(1+\bar{\beta}_i)$ or $(1-\underline{\beta}_i)$ depending on the set used.

[1] This equation is $X_{it}/\Sigma X_{it}=(1+\beta_i)X_{i,\,t-1}/\Sigma X_{i,\,t-1}$ with both sides multiplied by ΣX_{it}. Notice that if the total acreage were constant, the denominators would cancel, leaving $X_{it}=(1+\beta_i)X_{i,\,t-1}$.

2. 1954 and 1955 were omitted as observations because of pronounced changes in acreage associated with the reintroduction of allotments on cotton, wheat, and rice. If these years had not been removed, the upper bound coefficients for alternative crops would have overestimated the maximum rates of change in years when the diverted acreage effect was not important. To account for the pressure to expand alternative crops on diverted acres in 1954 and 1955, a share of the total diverted acreage was added to each of the upper bounds. This share was the crop's acreage in year $t-1$ expressed as a percent of the total acreage of alternative crops in year $t-1$.

The upper and lower bounds obtained in this manner represent *average net* changes in acreage. To be more consistent with the concept of a *maximum* allowable change from one year to the next, these bounds were further adjusted as follows: The "standard error of estimate" associated with the equation fitted to increasing acreage data was *added* to each of the upper bounds. The standard error associated with the lower bound equation was *subtracted* from each of the lower bounds.

Explanatory Test.—This procedure was applied to county acreage data. Adjusted county bounds were divided into Eastside and Westside bounds, using the 1958 crop acreage data estimated by the California Department of Water Resources (table 23).

Predictive Test.—County bound coefficients were estimated using data only through the year immediately preceding the one predicted. In addition, the county acreage of each crop in year $t-1$ was first separated into Eastside and Westside acres, based on the 1958 distribution, and these multiplied by the land adjustment factors *for each subregion*, $\sum_i X_{ijt}/\sum_i X_{ij,t-1}$. In this case, $\sum_i X_{ijt}$ is the maximum restraint acreage for the jth subregion derived from the Pearl-Reed functions described on page 86. The adjusted acres in year $t-1$ were then multiplied by the county flexibility coefficients. Standard errors were also separated into Eastside and Westside acres based on the 1958 acreage distribution.

Projection Test.—Only one set of land adjustment factors was used for each subregion in each of the projection series to minimize computing time. These factors were the averages of the ratios, $\sum_i X_{ij}/\sum_i X_{ij,t-1}$, for the entire series.

Special Cotton Acreage Restraints

Two additional kinds of restraints were applied specifically to cotton. First, restraints were imposed on the acres of each of the soil types 1–3 that could be allocated to skip-row cotton on the Westside. Skip-row activities have higher yields and higher per acre returns than those of solid-planted cotton. To ensure that the model results reflect the use of both practices, it was assumed that the acreage of fallow land provides a reasonable estimate of the limit on skip row cotton. According to the California Department of Water Resources, 14.6 percent of the Westside

TABLE 23.—*Flexibility restraints* [1]

1. Explanatory Test data (1951–58)

Crop	Upper bound		Diverted acreage share		Lower bound	
	$1+\bar{\beta}$	Standard error of estimate	1954	1955	$1-\underline{\beta}$	Standard error of estimate
		Acres	*Acres*	*Acres*		*Acres*
Cotton	1.151	26,521	....	....	0.901	[2] 0
Barley	1.026	2,406	53,398	36,101	.945	8,022
Wheat	1.122	382	....	....	.727	12,174
Alfalfa hay	1.074	2,878	18,953	9,616	.924	8,917
Alfalfa seed	1.132	3,121	2,853	1,915	.611	281
Grain sorghum	1.311	1,179	1,276	1,143	.424	492
Sugarbeets [3]	1.151	0	....	....	.901	0
Melons	1.150	1,517	5,342	2,804	.856	1,993
Rice	1.518	3,848	9,419	....	.711	215
Field corn	1.797	989	551	712	.642	607
Dry beans	1.300	176	251	182	.968	16
Irrigated pasture	1.023	1,479	5,657	2,727	.962	1,777

2. Predictive Test data [4]

Crop	1960				1961			
	Upper bound		Lower bound		Upper bound		Lower bound	
	$1+\bar{\beta}$	Standard error of estimate	$1-\underline{\beta}$	Standard error of estimate	$1+\bar{\beta}$	Standard error of estimate	$1-\underline{\beta}$	Standard error of estimate
Cotton	1.151	26,521	0.901	[2] 0	1.151	26,521	0.901	[2] 0
Barley	1.026	2,406	.945	7,430	1.026	2,406	.944	7,000
Wheat	1.122	382	.727	12,174	1.122	382	.727	12,174
Alfalfa hay	1.068	2,509	.924	8,917	1.059	2,701	.924	8,917
Alfalfa seed	1.132	3,121	.945	2,975	1.132	3,121	.932	2,527
Grain sorghum	1.311	1,179	.457	399	1.311	1,179	.532	3,144
Sugarbeets [3]	1.151	0	.901	0	1.151	0	.901	0
Melons	1.161	1,264	.856	1,993	1.172	1,128	.856	1,993
Rice	1.518	3,848	.711	215	1.518	3,848	.711	215
Field corn	1.797	989	.681	912	1.797	989	.674	852
Dry beans	1.300	176	.834	75	1.300	176	.890	250
Irrigated pasture	1.025	1,377	.962	1,777	1.025	1,377	.962	1,589

[1] The coefficients, $(1+\bar{\beta})$ and $(1-\underline{\beta})$, describe the average *net* relation between X_{it} and $X_{i,t-1}$ (see text).

[2] The estimate of $(1-\underline{\beta})$ is based on only one observation.

[3] Bound coefficients could not be estimated for this crop as it has no history of unrestricted acreage. The coefficients for cotton were used for beets, due to the similarity of earnings on the two crops. The standard error for cotton was not used for the upper bounds on beets because the actual acreages of the two crops are quite different.

[4] Data for 1959 are the same as for 1951–58. Projection Test data for the series with a 1958 base are the same as for 1951–58; and for the 1959 base they are the same as for 1960 (the Predictive Test).

cropland was fallowed in 1958. This percentage was multiplied by the "maximum" soil-type acreages to obtain estimates of the maximum *additional* acreage of each type available for skip-row cotton. One unit of each skip-row activity therefore uses one acre of the particular soil type *plus* 1 acre of fallow land.

Other special restraints included in the model specify (1) that a maximum of 50 percent of soil type 1 on each side can be allocated to cotton and (2) that minimum acres of soil types 2 and 3 must be used for cotton. Cotton is grown on a large number of farms, many of which have little, if any, soil type 1. Cotton allotments are allocated to individual farmers according to acreage histories, rather than their soil resources. Rotation practices also preclude continuous use of soil type 1 for the same crop.

Minimum soil type 2 and 3 restraints were taken from the following data on the 1958 cotton acreage distribution (provided by the California Department of Water Resources):

Soil type	*Westside*	*Eastside*
	Acres of Cotton	
2	30,998	31,649
3	12,929	27,770

These data were believed to be reasonable estimates of the minimum acres in other years because the 1958 acreage was at a minimum due to allotments.

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