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ECONOMETRIC ANALYSIS OF THE CITRUS CYCLE
IN THE UNITED STATES AND TWO SELECTED REGIONS

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

α	Probability of type I error in significance tests.
β_{ij}	The ij-th element of the matrix $\underline{B}$.
b_{ij}	The estimate of β_{ij}.
$\underline{\hat{B}}$	The matrix whose elements b_{ij} are the estimates of β_{ij} of $\underline{B}$.
γ_{ij}	The ij-th element of the matrix $\underline{\Gamma}$.
c_{ij}	The estimate of γ_{ij}.
$\gamma^{m'm}$	The element in the m'-th row and m-th column of Γ^{-1}.
$\underline{y}(t), \underline{y}'(t)$	A column vector of jointly dependent variables and its transpose, respectively.
$\underline{x}(t), \underline{x}'(t)$	A column vector of predetermined variables and its transpose, respectively.
$\sum_{i=1}^{T}$	Summation from i = 1, ..., T.
plim	Probability limit.
ton	A short ton of 2,000 pounds
R^2	Coefficient of determination
Ø	Residual variance ratio
U.S.D.A.	United States Department of Agriculture

DEDICATION

to my first child

KWEKU NYANN ERBYNN

whose birth on July 31, 1968 coincided with the completion of this dissertation. May this work serve as an inspiration to him.

I. REVIEW OF MODEL BUILDING

A. Introduction

During the nineteenth century the economic system of the West was based on the triple foundation of economic freedom, free competition and freedom of work. It was as if an invisible, omniscient official has unrestricted powers to regulate all the changes and authorize all the decisions. As the controller of prices, he authorized rises when he saw that demand exceeded supply; when supply exceeded demand he ordered a fall. And as the director of production, he built some plants and brought other firms to failure when he noticed that consumption was switching from one product to another-- and these firms became redundant. This "Omniscient" directed the economy without favor to any group and without straying from his self-appointed path. He made good his own errors and corrected by his own means the cyclical crises that were (to businessmen) the most terrible consequences of his policy.

Severe economic crises (in the form of cyclical exhilaration and depression) brought to an end this liberal epoch, and the atomic structure of small enterprises was replaced by larger firms and better organization. Government could no longer leave the economic world to weather alone the violent shocks of business cycles. The importance of economic relations and reactions has become clear not only to governments but to monopolistic organizations, firms and other producing units. This marks a new epoch in economic policy--with government intervention as the principal feature. As George Stojkovic (1963, p. 386) puts it, "the State has ceased to be simply the protective force of a certain type of economic organization; its regulating intervention has extended to all spheres; the budget and finances are no longer neutral and are henceforth utilized as a means of distributing the national income so as to obtain a better utilization of resources. Economic policy has become a recognized function of the State".

This evolution has made necessary the devising and use of simplified skeletal models to explain and predict economic phenomena. Of the two types of model, the pure mathematical ones are exact and have a theoretical construction, while the econometric models are of a stochastic nature and designed to make more systematic use of statistical data in assessing their adequacy, thus supplying more information about the real world. Consequently statistical methods are playing important role as a tool in determining economic policy: primarily to quantify and describe the relevant economic factors and also to determine the relations between them, thus facilitating the choice of action by predicting future behavior and reactions.

B. Historical Review of Model Building

A mathematical formulation of the law of supply and demand was first given by A. A. Cournot who defined demand as a function of price which is generally decreasing, i.e. $d = f(p)$, with $f'(p) < 0$. He similarly defined supply as a function of price which is usually increasing: $s = g(p)$, with $g'(p) > 0$. The price is determined by the intersection of the supply and demand curves. The two important characteristics of Cournot's model are:

1) supply and demand relations are exact without disturbances, and
2) the model is static.

Cournot's law of supply and demand for a long time appealed only to the theoretically inclined; its applicability was greatly hampered by its exact or deterministic nature. Research on determining demand and supply curves from statistical material started only in the present century. The early works in the field of econometrics are credited to H. L. Moore and H. Schultz. Moore's studies (in 1919) were concerned with the influence of the cotton price on production and demand of this commodity. Schultz concentrated his research on demand and supply curves for various agricultural products in the period between the two World Wars, employing similar methods to those used by Moore.

Since then, the statistical methods employed in determining economic laws have greatly increased. In the 1930's Jan Tinbergen ushered in a new phase of econometric model building when he formulated his pioneering multirelation models, now known as (pure) causal chain systems, or recursive systems. The approach is completely dynamic, involving no static element; also the relations of the model are not exact, involving a stochastic element. This marks the transition from deterministic to stochastic approaches in the specification of simultaneous equation models. In this "forecasting by chain principle", each forecast is generated by an extrapolation device that proceeds step by step from period to period, and from variable to variable within each period, the salient point being that the device involves a chain of iterative substitutions. Research in this field has followed three main lines of approach that represent increasing levels of generalization, namely,

1) systems of vector regression, or models where the primary form coincides with the reduced form;
2) the system of causal chains or recursive model further developed and applied by H. Wold--models where the primary form gives the reduced form by a chain of substitutions; and
3) interdependent systems initiated by Haavelmo (1943)--models where the passage to the reduced form involves not only substitution but also inversion of one or

more of the primary relations.

Generally more than one endogenous variable is present in each of the equations of the primary, "structural" form, and if the equation system is solved for the endogenous variables so that each equation contains only one endogenous variable, the system is said to be on the reduced form.

If the first equation of the system contains only one endogenous variable y_1, say, the second equation explains y_2 in terms of y_1 and the predetermined variables, the third one explains y_3 in terms of y_1, y_2 and the predetermined variables, and so on, then the system is called a recursive system or causal chain system. Formally it is described as a system whose matrix of the coefficients of the endogenous variables is subdiagonal. Such systems originated with Tinbergen (1939 and 1940) and further developed by Wold (1955, 1959, 1960). Wold shows that this type of system can be specified in such a way that the structural form as well as the reduced form are unbiased or _eo ipso_ predictors (Wold 1961, 1963), so that the k-th equation of the structural form gives the conditional expectation of y_k for given values of y_{k-1}, y_{k-2}, ..., y_1 and the predetermined values and the k-th equation of the reduced form gives the conditional expectation of y_k for given values of the predetermined variables.

If the system is not recursive so that the matrix of the coefficients is not subdiagonal, the system is generally specified so that the equations of the reduced form are *eo ipso* predictors. Such a system is called an interdependent system and is chiefly advocated by the Cowles Commission (Haavelmo 1943, and Koopmans 1950). If all of the equations of the system are "just identified" there are just enough relations between the coefficients of the reduced form and those of the structural form to get the coefficients of the structural form if those of the reduced form are known. In this particular case, the coefficients of the structural form are estimated with the aid of these relations, using least squares estimates of the coefficients of the reduced form. However, in most situations the systems are over-identified, so that we get too many equations for estimating the coefficients of the structural form. In this case, solution by the methods of ordinary least squares leads to a multiple solution for the structural parameters. As a consequence, specific estimation methods have been derived for the interdependent systems. The methods usually employed are 1) the method of maximum likelihood, 2) the limited information method and 3) the two-stage method of least squares. All three estimating methods give identical solutions when the system is just identifiable, but in the more frequent cases of overidentification these methods yield determinate estimates which will not, however, be identical.

We will have more to say about the problem of identification and the methods of estimation in Chapter II, after a fuller treatment of simultaneous equation models.

C. Objectives of This Study

The objective of this econometric study is an attempt at estimating the supply relations and, on the basis of these estimates, to explain the citrus cycle in the United States and two selected regions (within U.S.A.).

The "citrus cycle", as employed in this dissertation, includes three groups of cycles. These are: 1) the production or acreage cycle; 2) the price cycle; and 3) the demand cycle. Here we focus our attention on the first cycle only--the production cycle for citrus fruits and three component parts: oranges, grapefruits and lemons. The word "cycle" may or may not refer to fluctuations of approximately constant period and amplitude. "Cycle" is just a synonym for "fluctuations".

The objective outlined above is accomplished by constructing (that is, specifying and estimating the parameters of) econometric models of the citrus cycle and by testing hypotheses about their parameters. Several simultaneous equation models of the form defined in the next chapter are constructed for each area.[1] We then derive numerical

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[1]The term "area" refers to either the United States as a whole or to any one of the two selected regions.

estimates of the elements of the coefficient matrices $\underline{\Gamma}$ and $\underline{B}$ of the simultaneous equation model (see Chapter II) which are not specified to be zero on an a priori basis. Since cyclical fluctuations of the "explained" variables are of special interest in this study, much attention is given to an investigation of a possibly cyclical behavior of (i.e. nonlinearities in) the parameters. Linear estimation and ordinary hypothesis testing methods are applicable because these nonlinearities in the parameters are analyzed by means of dummy variables.

D. Significance of This Study

In this study, we specify econometric models which are a prerequisite for a future investigation of the possibilities of applying quantitative economic stabilization policy measures to the citrus-producing industry of the United States. On the basis of such models, one might investigate policy instruments which could be employed to stabilize the prices and/or the production (and, hence, the supply) of processed oranges or other variables related to the citrus-producing sector of the economy.

Since the ultimate purpose of our models is their use in their economic policy, it is necessary that they should predict well like any other type of model and, in addition, should have structural significance (Fox et al., 1966, p.

106). This means that policy models should predict the quantitative effects of policies which have not changed enough or independently enough to allow a forecast to be made from a regression on past experience (Koopmans, 1957, p. 202).

It is generally true that the economic reasoning that suggests the choice of variables and the form of the behavior relationships often also suggests which of the relationships are changed by given policies. It frequently suggests in which direction and sometimes also by how much these relationships are shifted or otherwise modified. But there is no way of tracing such knowledge through to its quantitative consequences for the economy as a whole or, as in this study, for a sector thereof except on the basis of estimated structural equations that represent the behavior of the relevant parties involved (Gruber, 1965, p. 24).

This econometric study is therefore deemed significant if it explains the fluctuations in the production of citrus fruits and if it also provides a means to do something about (e.g. stabilize the values of) some of the relevant variables whose fluctuations are undesirable in certain respects.

One reason for such an undesirability of fluctuations could be the impossibility of attaining satisfactory levels of allocative efficiency in the citrus-producing, citrus-trading and citrus-processing industries under fluctuating conditions.

E. Review of Literature

To the best of the author's knowledge, there is no previous work in the literature which has the same objectives as those of this study.

Most of the past studies on the citrus cycle in the U.S.A. have concerned themselves with prices and demand. Professors Hoos and Kuznets have made a number of studies of lemon prices and demand.[1] These studies generally indicate that some interrelation exists between the markets for fresh and processed lemons. Bressler's (1959) report to the Lemon Study Committee of Sunkist Growers showed, as did the Hoos and Kuznets studies, that the demand for fresh lemons is inelastic with respect to price. An interesting non-econometric study aimed at estimating citrus production by the use of frame count survey is undertaken by Stout (1962).

Probably only one econometric study may be considered relevant to the present study of the citrus cycle with emphasis on the citrus supply cycle. In their study of the lemon cycle, French and Bressler (1962) of Giannini Foundation, University of California, employ single equation multiple regression analysis to predict on-tree prices, given the predetermined supplies. Their econometric model consists of a supply

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[1]See Kuznets and Klein (1943), Hoos and Seltzer (1952), Hoos (1955) and Hoos and Kuznets (1962).

response equation and a set of demand equations. It is the supply equation that interests us. This supply equation involves two components: an equation that explains the acreage of trees planted each year, and hence additions to production some five years later,[1] and an equation that accounts for the acreage of trees removed from production each year. The change in bearing acreage is then given by the difference between the acreage coming into bearing and the acreage removed. Multiplying by average yields converts the acreage changes to a supply response equation.

Although the French-Bressler study was well constructed to meet its specific objective--predicting on-tree prices--some difficulty was encountered in adapting the results (specifically, of the supply response equation) to the present analysis; for example, the forms of the functions and the kinds of data used in the French-Bressler study created problems. All of their models are single equation models, which are estimated by ordinary least squares. They explain the acreage of new trees planted in any year, using as explanatory variables the expected long-run profitability of growing lemons (which is approximated by five-year averages of past

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[1]Lemon trees and citrus trees in general are normally considered bearing in the fifth year after planting; in some counties, however, the bearing age is six years. Trees actually may bear a little fruit in the third year after planting and a little more the fourth year.

net returns per acre), the age distribution of existing trees, and the expected profitability of alternative enterprises. For acreage of trees removed, the following explanatory variables are used: expected current (short-run) profitability, proportion of bearing trees over 25 years of age in time t, proportion of acres removed for urban expansion, and the intercept term accounts for average proportion of trees removed because of disease and similar factors. The total bearing acres in any year then equal bearing acres of the previous year plus the difference between acres coming into bearing and the amount of previous year's acreage removed prior to the current season. The supply response equation is obtained by multiplying the resulting acreage response by average yield.

With respect to data problems, we note that data on new citrus plantings and removals are not directly available for the years prior to World War II. Also in the prewar years (1921-1946) trees were younger and there was less pressure from urban expansion. Whereas annual net returns per acre (total returns less cost) can be obtained for some States, such as California, such data do not exist, or have only come to be published for the very recent years, for most citrus producing States. Again, data pertaining to trees that may have been removed at an early age (i.e., before reaching bearing age) to make way for urban expansion are not available. Moreover, it would be difficult, if not impossible, to separate trees removed for urban expansion from tree removals due to old age and disease.

As a result of these difficulties and the fact that our analysis has more than one endogenous variable in each of its equations, we have computed a completely new set of supply estimates that meet the needs of the present analysis more readily.

The general studies of agricultural supply response are very numerous indeed and no attempt is made to review them. An interested reader may consult the extensive bibliography of the works of Van de Wetering (1964). The following publications, however, are worthy of mention: Heady _et al_. (1961a), Dean and Heady (1958), Nerlove (1958b), and Nerlove and Backman (1960).

II. STATISTICAL METHODOLOGY

A. Econometric Method

Econometrics may be defined as a combination of economics, mathematics and statistics. It is an attempt at using the methods of mathematical economic theory and of mathematical statistics in order to accomplish two goals: to find numerical values for the postulated economic relationships and to verify economic laws and regularities (Tintner, 1954, p. 640). In other words, data, theory and inference methods are combined in order to test quantitative propositions about the real economic world (Christ, 1954, p. 521). The econometrician, therefore, is interested only in the quantitative propositions or theorems which are potentially testable against reality. They are derived from assumptions or postulates by the postulational method. (For detailed discussion of the last statement, see Kuenne, 1963, p. 26 ff.).

The models used in this study are interdependent systems. In the next section we develop a statistical model for the general case of a system of simultaneous linear economic relationships. In sections 3 and 4 we specify the statistical assumptions of, and give the estimation procedures for, interdependent systems.[1] The final section will discuss

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[1]For interdependent systems, see Goldberger (1964) and Johnston (1963).

tests of hypotheses.

B. Simultaneous Linear Equation Model

Following Goldberger (1964, p. 294 ff.), we consider an economic theory that specifies the existence of a system of simultaneous linear relationships, each of which expresses some aspect of the behavior of an individual, sector, or market. Generally, the variables of the system fall into two classes: 1) endogenous variables, the values of which the theory must account for, and 2) exogenous variables, the values of which are taken as data, so that the theory has no influence over them. For our purpose, the relevant distinction is between "jointly dependent variables" and "predetermined variables". The jointly dependent variables are the current endogenous variables; and the predetermined variables are the exogenous variables and the lagged endogenous variables. If no lagged endogenous variables appear, the endogenous/exogenous classification is equivalent to the jointly dependent/predetermined classification.

1. Structural form

We consider an economic model that has the following structural form:

$$
\begin{array}{l}
\gamma_{11}y_1(t) + \dots + \gamma_{M1}y_M(t) + \beta_{11}x_1(t) + \dots + \beta_{K1}x_K(t) + u_1(t) = 0 \\
\vdots \\
\gamma_{1M}y_1(t) + \dots + \gamma_{MM}y_M(t) + \beta_{1M}x_1(t) + \dots + \beta_{KM}x_K(t) + u_M(t) = 0
\end{array}
\tag{2.1}
$$

for

$t = 1, 2, \dots, T,$

where

$y_{m'}(t)$ is the t-th observation on the m'-th jointly dependent variable ($m' = 1, \dots, M$);

$x_k(t)$ is the t-th observation on the k-th predetermined variable ($k = 1, \dots, K$);

$\gamma_{m'm}$ is the coefficient, in the m-th structural equation, of the m'-th jointly dependent variable $y_{m'}(t)$, ($m, m' = 1, \dots, M$);

β_{km} is the coefficient, in the m-th structural equation, of the k-th predetermined variable $x_k(t)$, ($k = 1, \dots, K$; $m = 1, \dots, M$);

$u_m(t)$ is the unobserved disturbance at the t-th observation in the m-th structural equation, ($m = 1, \dots, M$).

A matrix formulation of the above model is as follows:

$$\underline{y}'(t)\underline{\Gamma} + \underline{x}'(t)\underline{B} + \underline{u}'(t) = \underline{0}' \quad (t = 1, \dots, T), \tag{2.2}$$

where

$$\underline{\Gamma} = \begin{bmatrix} \gamma_{11} & \cdots & \gamma_{1M} \\ \cdot & & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \gamma_{M1} & \cdots & \gamma_{MM} \end{bmatrix}$$

is the M x M matrix of the coefficients of the jointly dependent variables, each column of which refers to a single equation;

$$\underline{B} = \begin{bmatrix} \beta_{11} & \cdots & \beta_{1M} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \beta_{K1} & \cdots & \beta_{KM} \end{bmatrix}$$

is the K x M matrix of coefficients of the predetermined variables, each column of which refers to a single equation;

$$\underline{y}'(t) = [y_1(t), \ \ldots, \ y_M(t)]$$

is the 1 x M row vector of the t-th observations on the jointly dependent variables;

$$\underline{x}'(t) = [x_1(t), \ \ldots, \ x_K(t)]$$

is the 1 x K row vector of the t-th observations on the predetermined variables;

$$\underline{u}'(t) = [u_1(t), \ \ldots, \ u_M(t)]$$

is the 1 x M row vector of the t-th (unobserved) values of the disturbances; and

$\underline{0}'$ is a 1 x M row vector of zeros.

We note here that Equation 2.2 refers to only a single joint observation. To write the system in terms of all the observations, we define

$$\underline{Y} = \begin{bmatrix} \underline{y}'(1) \\ \cdot \\ \cdot \\ \cdot \\ \underline{y}'(T) \end{bmatrix} = \begin{bmatrix} y_1(1) & \ldots & y_M(1) \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ y_1(T) & \ldots & y_M(T) \end{bmatrix}$$

as the T x M matrix of observations on the jointly dependent variables;

$$\underline{X} = \begin{bmatrix} \underline{x}'(1) \\ \cdot \\ \cdot \\ \cdot \\ \underline{x}'(T) \end{bmatrix} = \begin{bmatrix} x_1(1) & \ldots & x_K(1) \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ x_1(T) & \ldots & x_K(T) \end{bmatrix}$$

as the T x K matrix of observations on the predetermined variables;

$$\underline{U} = \begin{bmatrix} \underline{u}'(1) \\ \cdot \\ \cdot \\ \cdot \\ \underline{u}'(T) \end{bmatrix} = \begin{bmatrix} u_1(1) & \ldots & u_M(1) \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ u_1(T) & \ldots & u_M(T) \end{bmatrix}$$

as the T x M matrix of the disturbances; and $\underline{0}$ as a T x M matrix with all zero entries. With these definitions the structural form may be written compactly as

$$\underline{Y\Gamma} + \underline{XB} + \underline{U} = \underline{0} \, , \tag{2.3}$$

the t-th row of which is indeed 2.2.

Note that $\underline{Y}$ and $\underline{X}$ each stand for a group of time series data discussed in Chapter 3. Since the structural form is a- representation of an economic theory, it must be soluble uniquely for $\underline{y}(t)$ in terms of $\underline{X}(t)$ and $\underline{U}(t)$, that is, we will assume that $\underline{\Gamma}^{-1}$ exists.

Each structural equation in 2.1--or its equivalents in 2.2 and 2.3--represents the behavior of endogenous variables related to the citrus-producing sector. In each structural equation several dependent variables may appear. Hence, the structural equations reflect the interdependencies among variables.

2. Reduced form

To bring out the explicit dependence of the dependent variables on the predetermined variables and the disturbances, we solve the structural form into the reduced form.

The reduced form is obtained by postmultiplying Equation 2.2 through by $\underline{\Gamma}^{-1}$ and rearranging:

$$\begin{aligned} \underline{y}(t) &= \underline{x}'(t)(-\underline{B\Gamma}^{-1}) + \underline{u}'(t)(-\underline{\Gamma}^{-1}) \qquad (2.4) \\ &= \underline{x}'(t)\underline{P} + v'(t) \qquad (t = 1, \ldots, T), \end{aligned}$$

where

$$\underline{P} = -\underline{B\Gamma}^{-1} = \begin{bmatrix} \pi_{11} & \cdots & \pi_{1M} \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \pi_{K1} & \cdots & \pi_{KM} \end{bmatrix}$$

is the K x M matrix of reduced-form coefficients, each column of which refers to a single equation; and

$$\underline{v}'(t) = -\underline{u}'(t)\underline{\Gamma}^{-1} = [v_1(t), \ldots, v_M(t)]$$

is the 1 x M row vector of the t-th values of the reduced-form disturbances.

The distinctive feature of the reduced form is that in each of its equations only one dependent variable appears. This contrast with the structural form is made explicit if we write out Equation 2.4 algebraically, analogously to Equation 2.1:

$$\begin{aligned} y_1(t) &= \pi_{11}x_1(t) + \ldots + \pi_{K1}x_K(t) + v_1(t) \\ &\ \ \vdots \\ y_M(t) &= \pi_{1M}x_1(t) + \ldots + \pi_{KM}x_K(t) + v_M(t) \end{aligned} \tag{2.5}$$

for t = 1, ..., T. Once again we take note of the fact that Equation 2.4 and 2.5 refer to a single joint observation. To write the system compactly in terms of all the observations, we define

$$\underline{V} = \begin{bmatrix} \underline{v}'(1) \\ \vdots \\ \underline{v}'(T) \end{bmatrix} = \begin{bmatrix} v_1(1) & \ldots & v_M(1) \\ \vdots & & \vdots \\ v_1(T) & \ldots & v_M(T) \end{bmatrix} = -\underline{U\Gamma}^{-1}$$

as the T x M matrix of values of the reduced-form disturbances. With this definition, the reduced form may be written compactly as

$$\underline{Y} = \underline{XP} + \underline{V} , \tag{2.6}$$

the t-th row of which is Equation 2.4.

Each reduced-form coefficient is in general a function of all the structural coefficients in $\underline{\Gamma}$ and in a row of $\underline{B}$.

This becomes clear if we write out $P = -\underline{B}\underline{\Gamma}^{-1}$:

$$\begin{bmatrix} \pi_{11} & \cdots & \pi_{1M} \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \pi_{K1} & \cdots & \pi_{KM} \end{bmatrix} = -\begin{bmatrix} \beta_{11} & \cdots & \beta_{1M} \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \beta_{K1} & \cdots & \beta_{KM} \end{bmatrix} \times \begin{bmatrix} \gamma^{11} & \cdots & \gamma^{1M} \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \gamma^{M1} & \cdots & \gamma^{MM} \end{bmatrix} \quad (2.7)$$

where $\gamma^{m'm}$ is the element in the m'-th row and m-th column of $\underline{\Gamma}^{-1}$. Thus we see that for a reduced-form coefficient

$$\pi_{km} = -\sum_{m'=1}^{M} \beta_{km'}\gamma^{m'm} \; . \qquad (2.8)$$

Each reduced-form disturbance is a linear function of all the contemporaneous structural disturbances, that is,

$$v_m(t) \;=\; -\sum_{m'=1}^{M} \gamma^{m'm} u_{m'}(t) \; . \qquad (2.9)$$

3. Stochastic specifications

The structural disturbances are generated by a stationary multivariate stochastic process with:

$$E\underline{u}(t) \;=\; \underline{0} \;(t = 1, \ldots, T) \quad \text{or} \quad E\underline{U} = \underline{0} \; , \qquad (2.10)$$

that is, each disturbance vector has a zero expectation, or $Eu_m(t) = 0$ for all m and t;

$$E\underline{u}(t)\underline{u}'(t) \;=\; \underline{S} \qquad (t = 1, \ldots, T) \; , \qquad (2.11)$$

where $\underline{S}$ is an M x M non-negative definite matrix. This means we assume that the contemporaneous covariance matrix of the disturbances in the different equations is the same for all t, or $Eu_m(t)u_{m'}(t) = s_{mm'}$ for all t; that is, we assume homoscedasticity. However, we do not assume that $\underline{S}$ is diagonal;

$$Eu(t)u'(t') = 0 \quad (t,t' = 1, \ldots, T;\ t \neq t') , \tag{2.12}$$

that is, the disturbance vector is temporally uncorrelated, all lagged covariances between disturbances in the same or different equations are zero, or $Eu_m(t)u_{m'}(t') = 0$ for all m, m', t, t' with $t \neq t'$.

These assumptions imply, under general conditions, that the sample variances and covariances of the structural disturbances have as their probability limits the corresponding population parameter, so that

$$\text{plim} \frac{\sum_{t=2}^{T} \underline{u}(t)\underline{u}'(t)}{T} = \underline{S} \quad \text{or plim } T^{-1}\underline{U}'\underline{U} = \underline{S} . \tag{2.13}$$

We also assume that the predetermined variables are generated by a stationary multivariate stochastic process with nonsingular contemporaneous covariance matrix $\underline{S}_{xx}$ and that any dependence in the process is sufficiently weak so that

$$\operatorname{plim} \frac{\sum_{t=1}^{T} \underline{x}(t)\underline{x}'(t)}{T} = \underline{S}_{xx} \quad \text{or } \operatorname{plim} T^{-1}\underline{X}'\underline{X} = \underline{S}_{xx} \ . \tag{2.14}$$

We further assume that the process generating the predetermined variables is contemporaneously uncorrelated with the process generating the disturbances, that is $E\underline{x}(t)\underline{u}'(t) = E\underline{x}(t)E\underline{u}'(t) = \underline{0}$; and that any dependence in each of the process is sufficiently weak that

$$\operatorname{plim} \frac{\sum_{t=1}^{T} \underline{x}(t)\underline{u}'(t)}{T} = \underline{0} \quad \text{or } \operatorname{plim} T^{-1}\underline{X}'\underline{U} = \underline{0} \ , \tag{2.15}$$

i.e.,

$$\operatorname{plim} \sum_{t=1}^{T} x_k(t)u_m(t)/T = 0$$

for all k and m. This assumption indicates that the predetermined variables are not determined by the system at time t and hence are not dependent on the disturbances at time t. When there are lagged endogenous variables among the predetermined variables, we may assume on the basis of specification 2.15 that the successive disturbances are not merely uncorrelated but are, in fact, mutually independent.

Modifications of some of these assumptions are possible, and may be found, for instance, in Goldberger (1964, p. 301) and Basmann (1960).

Since the reduced-form disturbances are linear combinations of the structural disturbances, their properties can be derived as follows:

$$E\underline{v}(t) = E[-\underline{\Gamma}'^{-1}\underline{u}(t)] = -\underline{\Gamma}'^{-1}E\underline{u}(t) = \underline{0} \quad (t = 1, \ldots, T)$$

$$\text{or } E\underline{V} = \underline{0} , \tag{2.16}$$

that is, each reduced-form disturbance vector has a zero expectation, or $Ev_m(t) = 0$ for all m and t;

$$\begin{aligned} E\underline{v}(t)\underline{v}'(t) &= E[(-\underline{\Gamma}'^{-1})\underline{u}(t).\underline{u}'(t)(-\underline{\Gamma}^{-1})] \\ &= \underline{\Gamma}'^{-1}.E\underline{u}(t)\underline{u}'(t).\underline{\Gamma}^{-1} \\ &= \underline{\Gamma}'^{-1}\underline{S\Gamma}^{-1} = \underline{W} \quad (t = 1, \ldots, T) , \end{aligned} \tag{2.17}$$

where $\underline{W}$ is an M x M nonnegative definite matrix. This specification means that the contemporaneous covariance matrix of the disturbances in the different equations is the same for all t, or

$$Ev_m(t)v_{m'}(t) = w_{mm'} \text{ for all t, where } w_{mm'} = \sum_{i=1}^{M} \sum_{i'=1}^{M} \gamma^{im} s_{ii'} \gamma^{i'm'} ;$$

$$\begin{aligned} E\underline{v}(t)\underline{v}'(t') &= E[(-\underline{\Gamma}'^{-1})\underline{u}(t)\underline{u}'(t')(-\underline{\Gamma}^{-1})] \\ &= \underline{\Gamma}'^{-1}E\underline{u}(t)\underline{u}'(t')\underline{\Gamma}^{-1} \\ &= 0 \qquad (t,t' = 1, \ldots, T; \ t \neq t') , \end{aligned} \tag{2.18}$$

that is the reduced-form disturbance vector is temporally uncorrelated; all lagged covariances between disturbances in the same or different reduced-form equations are zero, or $Ev_m(t)v_{m'}(t') = 0$ for all m, m', t, t', with $t \neq t'$. Under general conditions this implies that the sample variances and covariances of the reduced-form disturbances have as their probability limits the corresponding population parameters; from Equation 2.13

$$\begin{aligned}
\text{plim } T^{-1}\underline{V}'\underline{V} &= \text{plim } T^{-1}\underline{\Gamma}'^{-1}\underline{U}'\underline{U}\underline{\Gamma}^{-1} \\
&= \underline{\Gamma}'^{-1}\text{plim}(T^{-1}\underline{U}'\underline{U})\underline{\Gamma}^{-1} \\
&= \underline{\Gamma}'^{-1}\underline{S}\underline{\Gamma}^{-1} \\
&= \underline{W} \qquad (2.19)
\end{aligned}$$

or

$$\text{plim } \frac{\sum_{t=1}^{T} \underline{v}(t)\underline{v}'(t)}{T} = \underline{W} .$$

The predetermined variables will also be contemporaneously uncorrelated with the reduced-form disturbances; from Equation 2.15

$$\begin{aligned}
\text{plim } T^{-1}\underline{X}'\underline{V} &= -\text{plim } T^{-1}\underline{X}'\underline{U}\underline{\Gamma}^{-1} \\
&= -\text{plim } (T^{-1}\underline{X}'\underline{U})\underline{\Gamma}^{-1} = \underline{0} \qquad (2.20)
\end{aligned}$$

$$\text{or} \quad \operatorname{plim} \frac{\sum_{t=1}^{T} \underline{x}(t)\underline{v}'(t)}{T} = \underline{0} \ ,$$

i.e.,

$$\operatorname{plim} \sum_{t=1}^{T} x_k(t) v_m(t)/T = 0$$

for all k and m.

C. Specification of a Model

Houthakker (1953, p. 448) defines specification of a model as the process of stating explicitly the variables (including the error term (s)) and the number and mathematical form of the equations that constitute a model. It is a step which, by the process of induction, carries the econometrician from factual observations to the formulation of a theory or, equivalently, of a mathematical model (Kemeny and Snell, 1962, p. 3).

The general purpose of specification is to make possible the achievement of the objectives of an investigation under given conditions. The objective of this study is the explanation of the citrus cycle by means of structurally significant econometric models. Our aim, therefore, is to specify the models such that many economically meaningful hypotheses about the citrus-producing sector can be tested. This means that the models should be specified such that a large number of the consequences deduced from them can be verified or falsified (Kemeny and Snell, 1962, p. 3; Popper, 1962, p. 37). In the specification stage of econometric analysis we should also aim at choosing very carefully the variables which only affect (directly or indirectly) the particular relationships we are interested in. For example, if we want to analyze supply-, or production-, response of lemons, we do not have to introduce, say, general consumer price index as a variable in our supply relation. Any such choice of wrong variable(s) (also termed misspecification) immediately throws doubt on what relation we are truly dealing with. Is it the supply relation that we really set out to construct? Or, perhaps, can it be a relation possessing both supply and demand characteristics, i.e., a "mongrel" relation? This is the identification problem. We shall have more to say about the identification problem later on in this section.

1. Specification procedure

The specification procedure adopted in this study consists of: 1) the determination of the variables to be explained; 2) the determination of the explanatory[1] variables

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[1]The term "explanatory" deviates in this study from its commonly accepted meaning if there is more than one endogenous variable in an equation. In this case, explanatory variables consist of the predetermined variables and the right-hand side endogenous variables in an equation.

of each explained variable; 3) the determination of the endogeneity or exogeneity of the explanatory variables; 4) the test of identifiability of each equation of a model to be estimated; 5) the specification of the stochastic assumptions; and 6) the choice of the algebraic form of the equations. If several models are constructed, that is, if several maintained hypotheses are advanced, this procedure is applied to each one of them (Gruber, 1965, p. 37). We now discuss briefly the above six steps in the specification procedure.

For given objectives of a study, a decision has first to be made on the variables to be explained by the model. In economic terminology, this simply means the determination of the endogenous variables. In statistical language, it implies the determination of the jointly dependent variables. At this stage of econometric analysis, knowledge of the object under investigation and economic theory are the main aids of the econometrician.

We next determine the variables with which each one of the explained variables is functionally related. Houthakker (1953, p. 488) points out that for this second step of specification, economic theory provides only a very general superstructure, which is useful mainly in telling what variables not to include. There is, therefore, a large number of variables the inclusion of which would be economically meaningful.

This number is usually reduced by data limitations and/or statistical requirements.

Usually statistically meaningful estimates cannot be obtained if there is multicollinearity among the predetermined variables. Multicollinearity is the name given to the general problem which arises when some or all of the predetermined variables in a relation are so highly correlated one with another that it becomes very difficult, if not impossible, to disentangle their separate influences and obtain a reasonably precise estimate of their relative effects. If the explanatory variables were connected by an exact linear relation, the normal equations cannot be solved because the inverse of the moment matrix does not exist; that is, the moment matrix is singular, or $|\underline{X}'\underline{X}| = 0$. In practice, such an exact linear relation is not found among any two or more explanatory variables; and hence the inverse of the moment matrix usually does exist. However, the determinant of the moment matrix may be so small as to lead to relatively large elements of the inverse of the moment matrix. When this happens, the elements of the vector of regression coefficients and the elements of the covariance matrix are affected. Multicollinearity must therefore be kept low. Otherwise we may have to employ methods designed to improve the precision of the estimates of the separate effects of highly-correlated predetermined variables.[1] We shall not concern ourselves with these latter methods since there does not seem to be any high degree of multicollinearity among our predetermined variables and, more importantly, since some of these methods do not give the structural estimates desired in this study (e.g. the method of principal components--Kloek and Mennes, 1960).

The third step is necessary not only for the purpose of identification of the relation but also for determining which variables will be associated with matrix $\underline{\Gamma}$ and which with matrix $\underline{B}$. It is therefore simply a step of dividing each set of our explanatory variables (see footnote 1 on page 28) according to statistical properties into two subsets, namely, the jointly dependent variables and the predetermined variables. In the matrix notation of relation 2.2 these two subsets of variables are symbolized, respectively, as $\underline{y}(t)$ and $\underline{x}(t)$. If the explanatory variables of at least one structural equation contains one or more jointly dependent variables, then we have specified an interdependent system of equations. The first three steps together amount to a specification of the *a priori* restrictions on the matrices

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[1]For a discussion on multicollinearity and ways of avoiding it, see Goldberger (1964, pp. 192-194), Johnston (1963, pp. 201-207), Kloek and Mennes (1960), Frisch and Waugh (1933), and Wagner (1959).

$\underline{\Gamma}$ and $\underline{B}$.

We shall not engage in any detailed mathematical exposition of the identification problem since this is both lengthy and readily available from most modern econometrics textbooks.[1] Only a brief comment will be made.

Identification is defined as the problem of computing the parameters of the structural model, which is presumed to have generated the observations on the endogenous variables, from the parameters of the likelihood function. Suppose we ignore the problem of sampling variability and assume a knowledge of the population distribution of the observations, i.e., of the conditional distribution of the dependent variables for any and all values of the predetermined variables. We should be able to deduce from this knowledge alone the value of the parameter, if that parameter is identified (or identifiable). If the value of a parameter cannot be so deduced, then the parameter is not identified (or unidentifiable). Thus the problem of identification exists quite apart from the sampling problem of obtaining reasonably good estimates of the parameters of the likelihood function. Identification, therefore, is logically prior to the estimation problem and would still exist even if our samples were

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[1]On the problem of identification, see Koopmans (1953b), Goldberger (1964, pp. 306 ff.), Johnston (1963, pp. 240 ff) and Fisher (1959).

infinitely large (Johnston, 1963, p. 243; Goldberger, 1964, p. 307). It may be mentioned here that if all the parameters in a relationship are identified, the relationship is said to be identified; and if all the parameters in a system of relationships are identified, the system is said to be identified.

The identification of a particular relation in a system of relationships is a function of only one type of specification,[1] namely the valid exclusion from this relation of a sufficient number of predetermined variables occurring in the system. If this number, K^{**}, is as large as the number of endogenous variables included in the equation less one, $G^{*}-1$, then the equation is just identified; if K^{**} is less than $G^{*}-1$, the equation is underidentified (i.e., not identified); and if K^{**} is larger than $G^{*}-1$, the equation is overidentified. Thus a necessary and sufficient condition for the identifiability of a structural equation within a linear model, restricted only by the exclusion of certain variables from certain equations, is that the total number of variables excluded from the particular structural equation must be at

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[1]Koopmans (1953b, p. 38) lists two types of specifications-- a) the one stated above, which he calls homogenous linear restrictions on the coefficients of specified equations, and b) a rule of normalization (nonhomogenous restriction) on each equation, to preclude the trivial multiplication of all coefficients of an equation by a constant.

least equal to the total number of endogenous variables in the model less one. This condition, also known as the rank condition of identifiability, is satisfied in all the equations encountered in this study.

With respect to the fifth step of specifying the stochastic properties of the model, we find that the econometrician has to turn to statistics, for economic theory is of no great help here. The stochastic specifications underlying this study have been presented in the previous section, and hence will not be discussed here. However, it is noteworthy to state that while the stochastic specifications above did not consider the assumption of a normal distribution for the errors or disturbances in the equation as necessary for the derivation of consistent parameter estimates, such an assumption is indeed required if the tests of hypotheses are to be conducted via the method of Student's t-test (see section 4, below).

The final specification step is to specify the algebraic form of the equations. Economic theory may provide some guidelines here. All functions constructed in this study are linear in the variables. However, some of them are nonlinear in selected parameters. These latter functions do not pose extra problems since they all possess the statistical property of linear estimability; that is, the nonlinearities are of a type such that linear estimation methods can be applied in all cases.

The entire system of specified equations (with the underlying a priori and stochastic specifications) constitutes a "maintained" hypothesis. Generally, in econometric investigation, the probability of obtaining a satisfactory fit from the first specification is low. Therefore, several models of varying complexity (depending on the level of abstraction from reality encountered in the specification) are usually constructed, estimated, and statistically tested. If one specification gives unsatisfactory results, it is rejected and replaced by another maintained hypothesis. In studies involving (or requiring) experimentation, one of two kinds of results obtains. The experimentation may lead to the acceptance of a single maintained hypothesis. In other words, econometric analyses of different maintained hypotheses can contribute to an appraisal of numerical outcomes of each maintained hypothesis, and thus facilitate the selection of one preferred hypothesis. If it is impossible to decide between two or more maintained hypotheses, a class of acceptable hypotheses remains. For each parameter, several empirical estimates are obtained.

2. Consequences of misspecification

This subsection is based principally upon the works of Theil (1957 and 1958) and Theil and Kloek (1960).

There are various kinds of misspecifications which constantly beckon the unwary econometrician, the present author not excepted. Their major consequences include specification bias, unsatisfactory fit, and identification problems.

Theil (1958, p. 327) shows that incorrect specification can result in a specification bias in a single equation model, i.e., all the components of the partial regression coefficients may be different from their true values. Specification bias usually results whenever some or all correct explanatory variables in the incorrectly specified model are correlated with the one or more incorrectly-specified variable(s). If misspecification leads to multicollinearity, the standard errors of the coefficients are biased upward.

Misspecification also affects the "goodness of fit" of a model. Although it may leave parameter estimates still unbiased, misspecification usually gives relatively poor interval predictions because the standard errors will be relatively large.

Misspecification of an equation in a system of simultaneous equations may lead to underidentification of that equation. When this results, no estimates of the parameters of that equation can be obtained. Exact identification or overidentification determine to a large extent which statistical estimation method is most appropriate.

D. Estimation of Parameters

The maximum likelihood method is generally considered the ideal method for estimating parameters of interdependent systems. But in practice its use has been hampered by the very intricate equation systems which have to be solved. The difficulty of applying the maximum likelihood method to a whole interdependent system of equations has given rise to two methods which treat each equation separately. The older one is the limited information method (Anderson and Rubin, 1949), in which the maximum likelihood method is applied to one equation without taking into account the restrictions given by the other equations of the system. The second one is the two-stage least squares method (Theil, 1953 and 1958; Basmann, 1957), in which the explanatory endogenous variables are replaced by their least squares estimates according to the reduced form, and after that substitution the least squares method is applied again; this time to the structural equation itself.

Both methods give consistent estimates when applied to an identified structural equation with one or more right-hand-side dependent variables. In cases of exact identification both estimating methods give identical results, while in cases of overidentification the consistent estimates they yield are generally not identical. Again, in both methods normality assumption about the error terms in the equations is not required for consistent estimation. Also the asymptotic properties of the estimates are the same for the two estimation methods. However, the two-stage least squares method is simpler from the computational point of view than the limited information estimation. Goldberger (1964, p. 363) states that "although information presently available precludes the selection of one structural estimation method as the best, it does permit the following tentative conclusion. If computational costs restrict us to single-equation methods, then the two-stage least squares method seems to be the most preferable."[1] We shall therefore, employ the method of two-stage least squares in estimating the parameters of the functions in this study. The following is a presentation of the derivation of the two-stage least squares estimators of the parameters of a structural equation (see Goldberger, 1964, pp. 304, 329-331.)

The m-th structural equation to be estimated may be selected out of the system 2.3 and written as

$$\underline{Y}\underline{\gamma}_m + \underline{X}\underline{\beta}_m + \underline{u}_m = \underline{0} , \qquad (2.21)$$

where the M x 1 vector $\underline{\gamma}_m$ is the m-th column of $\underline{\Gamma}$, the K x 1

[1]For a comparison between structural estimation methods, see Goldberger (1964, pp. 357-364), Lyttkens (1963, pp. 329-334), and Koopmans and Hood (1965).

vector $\underline{\beta}_m$ is the m-th column of $\underline{B}$, and the T x 1 vector $\underline{u}_m$ is the m-th column of $\underline{U}$. Omitting the subscript m and deleting those columns of the matrices and elements of the vectors that correspond to variables excluded from the m-th equation and designating the reduced matrices and column vectors by the subscript or superscript *, we obtain

$$\underline{Y}_* \underline{\gamma}_* + \underline{X}_* \underline{\beta}_* + \underline{u} = \underline{0} . \qquad (2.22)$$

By the application of the normalization rule, the revision of the notation and finally taking the normalized variable (with coefficient of -1) over to the other side, we rewrite the m-th structural Equation 2.21--or its equivalent 2.22--as

$$\underline{y} = \underline{Y}_1 \underline{\gamma}_1 + \underline{X}_1 \underline{\beta}_1 + \underline{u} , \qquad (2.23)$$

where

$\underline{y}$ is the T x 1 vector of observations on the left-hand-side dependent variable--a column of Y_*;

$\underline{Y}_1$ is the T x (G*-1) matrix of observations on the right-hand-side included dependent variables--Y_* with one column deleted:

$\underline{\gamma}_1$ is the (G*-1) x 1 vector of coefficients of these right-hand-side dependent variables--$\underline{\gamma}_*$ with the -1 deleted;

$\underline{X}_1$ is the T x K* matrix of observations on the included predetermined variables--previously denoted as $\underline{X}_*$;

$\underline{\beta}_1$ is the K* x 1 vector of coefficients of these included predetermined variables--previously designated as $\underline{\beta}_*$; and

$\underline{u}$ is again the T x 1 vector of disturbances in this structural equation.

We partition the matrix of the reduced-form coefficients, $\underline{P}$ in Equation 2.4, into

$$\underline{P} = \begin{bmatrix} \underline{P}_{10} & \underline{P}_{11} & \underline{P}_{12} \\ \underline{P}_{20} & \underline{P}_{21} & \underline{P}_{22} \end{bmatrix} = \begin{bmatrix} \underline{P}_{x0} & \underline{P}_{x1} & \underline{P}_{x2} \end{bmatrix} . \qquad (2.24)$$

Let $\hat{\underline{P}}$ be the estimator of $\underline{P}$. Then we also partition $\hat{\underline{P}}$ just like $\underline{P}$, with $\underline{P}_{ij}$ replaced by $\hat{\underline{P}}_{ij}$. The first subscript refers to the predetermined variables: 1 to the included predetermined variables, 2 to the excluded predetermined variables; the second subscript refers to the dependent variables: 0 to the left-hand one, 1 to the included right-hand ones, and 2 to the excluded ones. We also partition matrix $\underline{X}$ into $(\underline{X}_1\underline{X}_2)$, where $\underline{X}_2$ is T x K^{**}.

By employing this matrix partitioning, the portion of the reduced form 2.6--i.e., $\underline{Y} = \underline{XP} + \underline{V}$--that refers to the right-hand dependent variables is

$$\underline{Y}_1 = \underline{X}_1\underline{P}_{11} + \underline{X}_2\underline{P}_{21} + \underline{V}_1 = \underline{XP}_{x1} + V_1 , \qquad (2.25)$$

where $\underline{V}_1$ is the appropriate $T \times (G^*-1)$ submatrix of $\underline{V}$. Inserting Equation 2.25 into 2.23 and rearranging, we obtain

$$\underline{y} = \underline{XP}_{x1}\gamma_1 + \underline{X}_1\beta_1 + (\underline{u} + \underline{V}_1\gamma_1) . \tag{2.26}$$

Since the predetermined variables are contemporaneously uncorrelated with all disturbances (structural and reduced form), we could obtain consistent estimates of γ_1 and β_1 by computing the least-squares regression of $\underline{y}$ on $\bar{\underline{Y}}_1 = \underline{XP}_{x1}$ and $\underline{X}_1$. This procedure is not available to us because we do not know $\underline{P}_{x1}$ and hence do not have observations on $\bar{\underline{Y}}_1$. We can, however, consistently estimate $\underline{P}_{x1}$ by $\hat{\underline{P}}_{x1}$ and hence $\bar{\underline{Y}}_1$ by $\underline{X\hat{P}}_{x1}$. We therefore, obtain the consistent estimates of γ_1 and β_1 by the following two-stage procedure.

Stage one: The classical least-squares estimator of $\underline{P}_{x1}$ are obtained by regressing each column of $\underline{Y}_1$ on $\underline{X}$; this yields the submatrix of $\hat{\underline{P}}$:

$$\hat{\underline{P}}_{x1} = (\underline{X}'\underline{X})^{-1}\underline{X}'\underline{Y}_1 . \tag{2.27}$$

We then calculate the predicted values of $\underline{Y}_1$ in these regressions:

$$\hat{\underline{Y}}_1 = \underline{X\hat{P}}_{x1} . \tag{2.28}$$

Stage two: The classical least-squares regression of $\underline{y}$ on $\hat{\underline{Y}}_1$ and $\underline{X}_1$ is now calculated. The resulting coefficients are the two-stage least-squares estimators of $\underline{\gamma}_1$ and $\underline{\beta}_1$.

Thus the two-stage least squares estimator of

$$\begin{bmatrix} \underline{\gamma}_1 \\ \underline{\beta}_1 \end{bmatrix} \text{ is the } \begin{bmatrix} \underline{c} \\ \underline{b} \end{bmatrix}$$

defined by the normal equations

$$\begin{bmatrix} \hat{\underline{Y}}_1'\hat{\underline{Y}}_1 & \hat{\underline{Y}}_1'\underline{X}_1 \\ \underline{X}_1'\hat{\underline{Y}}_1 & \underline{X}_1'\underline{X}_1 \end{bmatrix} \begin{bmatrix} \underline{c} \\ \underline{b} \end{bmatrix} = \begin{bmatrix} \hat{\underline{Y}}_1'\underline{y} \\ \underline{X}_1'\underline{y} \end{bmatrix} \tag{2.29}$$

a system of $G^*-1 + K^*$ equations in $G^*-1 + K^*$ unknowns which will, in general, have a unique solution.

E. Test of Hypotheses

The testing of hypotheses[1] is very closely related to the problem of estimation. In fact, the two together constitute the domain of statistical inference. To derive significance tests and confidence intervals for $\underline{c}$ and $\underline{b}$, we may proceed either by assuming the u_i (the elements of the matrix $\underline{u}$) to be normally distributed or by making no explicit assumption about the form of the distribution and appealing to the Central Limit Theorem to justify our

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[1]For a more detailed treatise on tests of hypotheses, see Mood and Graybill (1963, Chapter 12), Goldberger (1964, pp. 138-141), and Feller (1957, pp. 229, 238-241).

regarding the tests as approximately correct.

In this study we employ ordinary t-tests to test the statistical significance of individual explanatory variables. The null hypothesis generally advanced is that a variable has no effect upon the left-hand-side dependent variable; that is, the coefficient c_i or b_i associated with a specified right-hand variable is statistically not significant from zero, where c_i and b_i are the elements of $\underline{c}$ and $\underline{b}$ respectively. The levels of significance used in this study are:

$\alpha \leq 0.001$ means very significant

$0.001 < \alpha \leq 0.01$ means highly significant

$0.01 < \alpha \leq 0.05$ means significant

$0.05 < \alpha \leq 0.50$ means lowly significant.

We shall reject any variable which is not-significant at the $100\alpha\%$ level of significance, since such a value would contribute practically no valuable information to the reliability of predicting the value of $\underline{y}$ in the structural equation. If we possess any a priori knowledge that the effect of a left-hand variable on $\underline{y}$ is either positive or negative but not both, we make a one-sided test; otherwise a two-sided test is made.

The t-tests are exact if we make the normality assumption about the distribution of the error terms u_1; in the absence of such an assumption, t-tests are only approximate. The t-test serves our purpose so well that there is no point in searching around for more sophisticated tests which are considerably more expensive computationally.

III. FACTORS INFLUENCING CHANGES IN PRODUCTION

A. Trends in Citrus Production

Total United States production of citrus fruits for the 5 crops 1959-60 to 1963-64 averaged about four and a half times the 5 crops 1920-21 to 1924-25. The average seasonal value for the crops 1959-60 to 1963-64 was 520 million dollars which is 6 times the average value from 1920-21 to 1924-25.

Grapefruit was developed commercially later than oranges and lemons. During the crop years 1909-10 to 1913-14 grapefruit production was only about a tenth as much as oranges, but in recent years has been almost one-third as large as orange production. Processing of all kinds of citrus from the 5 crops 1959-60 to 1963-64 accounted for about half the total production. Prior to 1915 less than one percent of the crop was processed and 1926-27 was the first season with as much as 5 per cent of production so used.

United States orange production for the seasons 1909-10 to 1913-14 averaged about 19 million boxes annually. The output has since increased steadily and now averages over 100 million boxes per season. Florida and California grow about 95 per cent of the nation's orange crops. Until the 1930's, less than 5 percent of any orange crop was processed. In recent years processing has averaged about 60 per cent of production--outstripping grapefruit processing. Grapefruit was relatively unimportant during the seasons 1909-10 to 1913-14 and production averaged only about one and a half million boxes per season. The first 10 million-box crop was produced in 1928-29; in 1945-46 production reached an all-time record high of 63 million boxes, of which slightly more than half was processed. Thereafter, production declined until in the more recent years production has averaged 34 million boxes, of which about 46 per cent is processed. The bulk of grapefruit production is in Florida and Texas.

Lemons, the third major citrus crop,[1] are an important agricultural commodity in California. In recent years grower income from lemons has averaged about 40-50 million dollars annually. The production of lemon generally increased from the beginning of commercial lemon production in about 1875, until 1940. Production has tended to decrease since 1940, due in part to declining yield per bearing acre since 1940-41, and in part to the decreased bearing acreage since 1946-47. Until recently the nation's lemon crop was produced by California alone. In recent years (after 1958), California accounts for about 93 per cent of the lemon crop.

The three areas considered in this study are:

1) U.S.A., embracing all the citrus-growing states of

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[1]Citrus is a composite name given to a number of tropical fruits comprising oranges, grapefruits, lemons, limes, tangerines and tangeloes.

the United States. It includes a) the Southeastern States of Florida, Alabama, Mississippi and Louisiana; b) the South-central State of Texas; and c) the Western States of Arizona and California;

2) Southern States, comprising Florida, Texas and Louisiana; and

3) Western States, comprising Arizona and California.

We note that Alabama and Mississippi are not included in the first region, "Southern States". Data for quantities (in tonnage and/or boxes) and value of citrus production are not available for Alabama and Mississippi since after 1941-42 season. The severe freeze in the spring of 1940 in Alabama and Mississippi killed most of the citrus trees in these States and production has not been important enough since to be estimated. Consequently, we eliminate these two States from the regional analysis. We summarize the production conditions in the remaining five States briefly thus:

Florida: Florida citrus production has increased from an annual average of about 7,000,000 boxes during the seasons 1909-10 to 1913-14 to about 60,000,000 boxes average in the early 1940's and then to about 100,000,000 boxes annually during the last five years of this study, 1960-61 to 1964-65. Oranges have been of considerably greater importance than grapefruit ever since the citrus industry was established. Orange production, including tangerines, increased from about 5 million boxes in 1909-10 to slightly over 90 million boxes in 1963-64. Florida grapefruit production increased from an annual average of less than 2 million boxes during 1909-10 to 1913-14 to about 31 million boxes average for the seasons 1959-60 to 1963-64. A record crop of 42,000,000 boxes was harvested in 1953-54. Processing of Florida citrus was negligible prior to 1920 but has steadily increased until 1963-64 when processing took more than two-thirds of the orange crop and about a half of the grapefruit crop.

Texas: Texas citrus production was negligible prior to the 1920's and the combined orange and grapefruit crop did not amount to a million boxes until 1929-30. Production increased rapidly, reaching a peak in 1946-47 with 5 million boxes of oranges and about 24 million boxes of grapefruit. Since then Texas citrus production has had a marked downward trend, falling to a very low level in 1962-63 of 40,000 boxes of oranges and 70,000 boxes of grapefruits. Processing of Texas oranges did not rise to the 2 per cent level of production until 1946 and in recent years has been only about 20 per cent. Processing of grapefruit, on the other hand, took nearly half of the production in 1943-44, but has also suffered a setback, accounting for only about 20 to 25 per cent of production in recent years. Citrus crops other than oranges and grapefruits are not important in Texas.

Louisiana: Citrus production in Louisiana has never amounted to much. The combined orange and grapefruit crop was only about 50,000 boxes in 1920-21; it increased steadily to a total of about 560,000 boxes in 1946-47 and then took a tumble, until in 1963-64 a combined total crop of only 16,000 boxes was harvested. Processing of Louisiana citrus crop has never amounted to more than about 2 per cent of production. Citrus crops other than oranges and grapefruit are not important in Louisiana also.

Arizona: The Arizona orange crops were less than 100,000 boxes until 1929-30. They have since increased steadily; in 1943-44 they exceeded a million boxes and in 1963-64 amounted to nearly 2,500,000 boxes. Arizona grapefruit production exceeded 100,000 boxes for the first time in 1924-25. The 1963-64 crop was slightly more than 3 million boxes. A record crop of 4.1 million boxes was harvested in 1945-46. Arizona oranges processed are now about 20 per cent of the crop but processing of grapefruit takes about one-third to one-half the crop. Since the 1958-59 season lemon production has assumed some importance in Arizona, and in 1963-64 the Arizona crop made up about 5 per cent of the nation's lemon production.

California: Orange production from 1909-10 to 1913-14 averaged about 14 million boxes, about four-fifths of which were navels and miscellaneous and one-fifth Valencias. In the early 1940's California orange production averaged about 50 million boxes comprising about two-fifths navels and miscellaneous and three-fifths Valencias. This latter proportion has been maintained ever since, even with recent years' smaller crop of about 30 million boxes on the average. This means that navels and miscellaneous varieties increased from about 12,000,000 boxes per year in early 1910 to about 20,000,000 boxes in 1940's and then decreased to about 13,000,000 boxes in 1959-60 to 1963-64. During these same periods, Valencias increased from 3,000,000 to more than 30,000,000 boxes per year and then decreased to about 17,000,000 boxes annually. California Valencias are the only oranges available during the summer and early fall, which probably account for a large part of the greater increase in production of this variety. About 25 to 30 per cent of the California orange crop is processed, and in recent years about 70 per cent of these have been Valencias. California grapefruit production prior to 1913-14 was less than 100,000 boxes per year but since 1941-42 has been about 3,000,000 boxes per season. Processing of California grapefruit was negligible prior to 1933-34, and amounted to less than 400,000 boxes per year prior to 1941-42. A total of nearly 1.5 million boxes were processed in 1963-64, representing about one-third of grapefruit production.

California lemons averaged less than 2,000,000 boxes from 1909-10 to 1913-14 but increased steadily to 17,236,000 boxes in 1940-41. Thereafter production declined until it was resuscitated in the 1949-50 season; there has been a continued upward trend since then and production reached a record high of 17,300,000 boxes in 1963-64. Processing of lemons has been important since about the middle of the 1920's when an average of about a million boxes per year was so used for canned juice. The record quantity processed was from the 1963-64 crop--8,285,000 boxes used for juice. Until very recently (1958) virtually all of the lemons produced in the United States were grown in California. A small quantity (about 5 per cent) is now produced in Arizona and an insignificant quantity is grown in Florida.

The harvesting and marketing season for citrus crops extends over parts of two calendar years, with harvesting of fruit from the bloom in the spring, starting in the fall of the same year and extending into the following year. Harvest of early and midseason oranges starts in the early fall and is over by early spring. Valencia harvest does not start until about the first of February and, except for California, is completed by early summer. In California, harvest of Valencia oranges extends into December. Grapefruit harvest, except for California summer crop, begins in the fall in all States and ends in late spring or early summer. California summer grapefruit move to market from early summer through

September of the year after bloom. California lemons, which make up the major part of the nation's lemon production, are harvested in all months of the year. The crop year is generally considered to be from November 1 to October 31. In Arizona, lemon harvest begins in early September and continues through mid-February. Nearly all the nation's limes are grown in Florida and are picked mostly from April through December.

B. Determinants of Citrus Production Response

Because of the problem of identification--that is, the separation of the forces of supply and demand--it is very necessary to isolate for purposes of this study those variables which affect the supply (or more appropriately, the production) side of the citrus market. It is only a slight exaggeration to say that whatever has influenced or marked overall economic growth has had some bearing on growth in the supply of citrus fruits. Nevertheless the identification problem leads or guides us to reject some of these economic growth-inducing variables as unsuitable for our purpose. For example, economists have always looked upon national income, in one of its many measures, as representing economic growth of the United States in an aggregate physical sense. But in statistical price analysis, national income has been an almost universal "demand shifter" (Fox, 1953). Consequently, national income is eliminated from our analysis since its inclusion will very likely distort the supply picture.

In general, two phases can be distinguished in the supply of citrus products to the market. In the first phase, the quantity to be produced is determined by the various producers. In the second phase, total production becomes a datum, and new decisions are made as to the quantity to be be supplied (or harvested) out of the given output. The relations considered in this study encompass both phases. The citrus grower sells his output in a highly competitive market. He thus regards citrus prices as given to him. This is, in general, true also for the prices of other crops which may compete with citrus fruits for the resources at the farmers' disposal.

The theory of producers' behavior and the derivation of the individual and aggregate production response functions have been treated extensively in the economic literature and will not be repeated here.[1] The following discussion will, therefore, consist of a few general remarks concerning production response of citrus growers.

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[1]An extensive treatment of production theory can be found in Hicks (1939) and Carlson (1956). Applications to farmers' production response may be found in Heady (1952), Nerlove (1958), and Heady <u>et al</u>. (1961).

In order to gain a better perspective of the variables entering our crop supply-harvest supply relationships, we analyze the factors affecting crop supply and harvest supply spearately.

The crop supply schedule relates the total crop available for commercial harvest to lagged prices (citrus and competing crops) and lagged cost factors. Since the crop is perishable, decisions to plant and to remove trees must be made in the absence of knowledge about current prices. The acreage of new citrus trees planted in any year depends, inter alia, on the expected profitability of growing citrus fruits. Unfortunately expected profitability cannot be observed directly. Being well aware of the substantial year-to-year fluctuations in supplies and prices, citrus producers are likely to formulate their long-term expectations on the basis of average prices (per ton, or per box) during several recent years. An examination showed that new plantings seemed most closely related to five-year averages of past prices per ton of citrus crop. Trees are removed each year because of disease, old age, low production, and low profit or price expectations or to make way for urban expansion and related developments. Thus the crop supply schedule relates the current commercial crop to farm prices of the previous season, p_{t-1}, and the five-year averages of the (recent) past prices, p^*_{t-5}. In the short run the most important cost in the production of citrus is the lost opportunity to produce other things. The most important cost factors in the case of citrus are cotton lint, vegetables and grains--the most serious competitors for farm space.

The harvest supply schedule, on the other hand, relates quantity marketed to current farm price (for both citrus and competing crops), harvesting cost and the crop for harvest. The crop supply is merely the quantity of citrus available for harvest. But the quantity of citrus actually harvested and marketed constitutes the harvest supply. Unlike the decision to plant, which must be made in the absence of knowledge of current prices, the decision to harvest or leave the crop unharvested will depend on current price quotations as compared with the cost of harvesting.

Each relationship in the present study combines the characteristics of both the crop supply schedule and harvest supply schedule into a single supply relation. Thus our supply formulation relates citrus output to, among other variables, current prices, p_t, last season's price, p_{t-1}, five-year averages of past prices, p^*_{t-5}, prices of competing crops, prices of farm space-competing crops (like cotton) and new citrus tree plantings and removals. We thus see that individual production response function for citrus fruits may depend on past actual outputs.

The industry production response function is a simple summation of the individual functions, provided no net external economies or diseconomies of large-scale production exist. In the case of the citrus industry, net external economies of large-scale production are probably not important, although such may exist. External diseconomies may be important if expanded citrus output leads to higher prices of inputs. The actual situation with respect to this aspect is not clear, but it is believed that these diseconomies are relatively small. A simple summation of individual production response functions may therefore be a good approximation to the actual industry function. Consequently, the direction of change in the industry output or input is suggested directly by the corresponding microtheory.

Thus, given the market and production structure of the citrus industry in the United States as described above, economic theory suggests that an increase in citrus prices will generate a positive production response. An increase in prices of other crops, however, may bring about an increase, decrease, or no change in the production of citrus fruits, the actual response depending on the technical relation underlying the productive process.

C. General Remarks About Data

Production estimates and values as reported by the State and National (U.S.D.A.) Crop Reporting Boards are generally in relation to crop seasons, which extend over parts of two calendar years. To make the time series analysis a bit less cumbersome, I have translated these values into calendar years. This is done simply by considering the production data for any season as belonging to the end-year only. Thus, the data for the crop season 1929-30 are assigned to the calendar year 1930.

On this basis, annual time series for the period 1921 to 1965 are used for each of the three areas to be considered, namely, the United States, Southern States (or Region I) and Western States (or Region II). The choice of 1921 as the starting period is motivated by the fact that for seasons prior to 1919-20 production estimates related to California and Florida only; production in other States for those seasons was negligible and estimates are not available. But from 1920-21 production estimates are available for the various citrus crops for each State considered in this study. 1965 was taken as the last study period simply because presently there are no (complete) data available beyond this year.

The net content of box varies not only as between States but also as between different groups of the citrus family. Thus, whereas the net weight of a box of oranges is 90 pounds in Florida, in California a box of oranges weighs only 75 pounds (net). The net weight per box of grapefruit in Florida is currently 85 pounds, but it was 80 pounds prior to 1949. These differing box weights make it difficult to engage in a meaningful inter-States comparison of production estimates. Also earlier production figures may not be comparable with more recent ones, if the "box" is used as a production unit. Consequently, equivalent tons are derived and used as a unit of output throughout this study. Equivalent tons are calculated on the basis of the appropriate box weights--appropriateness with respect to the State and also to time. A "ton" always refers to a short ton of 2,000 pounds weight.

In our study of the citrus industry, we shall consider only the citrus products which are relevant to each "area" separately. For example, there is no point in making an analysis of lemon production for the Southern States, because these States produce only a negligible quantity of lemons.

Thus, for the United States as a whole, we have four separate analyses for the citrus cycle, the orange cycle, the grapefruit cycle, and the lemon cycle. For the Southern States, our analysis centers on the orange cycle and the grapefruit cycle. For the Western States, we shall concentrate on the orange cycle and the lime cycle. The selection was made on the basis of the importance of these citrus products in the respective "areas" (see Section 3.A above). We therefore have a total of eight separate analyses to consider in this study.

A single look at the production and price data (plotted as a function of time in Figure 2) will convince anyone that the fluctuations or "cycles" are quite different for the prewar and postwar years. The prewar fluctuations have greater amplitude and seem to suggest planning cycles. The postwar years are marked by short-amplitude fluctuations, similar to the hog cycle. Analyses will therefore be made for the two separate periods--the prewar period of 1921-39, and the postwar period of 1948-65--and for the entire period 1921-65, including the wartime years. The period as a whole from 1921 to 1965 embraces all the characteristics of the subperiods, and analysis for it chiefly reflects long-term relationships.

A list of the time series data for the included variables follow in the next subsection. Section D of this Chapter is devoted to a more detailed explanation of the included variables.

1. List of time series

a. Production, population and acreage variables

(In thousands of acres; population during calendar year t; and crop output in thousands of tons).

$y_{101}(t)$ Total production of all citrus fruits.

$y_{102}(t)$ *Per capita* production of all citrus fruits (in pounds).

$x_{11}(t)$ Total production of 16 noncitrus fruits (hereafter, referred to simply as noncitrus fruits).[1]

$x_{12}(t)$ One-year-lagged production of noncitrus fruits. It is $x_{11}(t-1)$.

$x_{13}(t)$ *Per capita* production of noncitrus fruits (in pounds weight).

$y_{201}(t)$ Total production of oranges (excluding tangerines).

$x_{21}(t)$ Total production of apples. From 1936, it includes apples from commercial areas only.

$x_{22}(t)$ One-year-lagged production of apples. It is $x_{21}(t-1)$.

$y_{301}(t)$ Total production of grapefruit.

$x_{31}(t)$ Production of oranges. It is the same as $y_{201}(t)$.

$x_{32}(t)$ One-year-lagged production of oranges. It is $x_{31}(t-1)$.

$y_{401}(t)$ Total production of lemons.

$x_{54}(t)$ Total population of the United States: U.S. Census Bureau estimates.

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[1]Apples (all apples prior to 1936; since then commercial crop only), appricots, avocados, cherries, cranberries, dates figs, grapes, nectarines, olives, pears, persimmons, plums, pomegranates, and prunes.

$x_{901}(t)$ Acreage of citrus fruits. It is slightly less than $(x_{902}(t) + x_{903}(t) + x_{904}(t))$.[1]

$x_{902}(t)$ Acreage of the orange crop.

$x_{903}(t)$ Acreage of grapefruits.

$x_{904}(t)$ Acreage of lemons.

$x_{445}(t)$ Yield per bearing acre of lemon.

b. Price variables (All crop prices are in dollars per ton of crop. Weighted average prices are derived by weighting State average prices by quantities sold. They refer to the calendar year).

$y_{103}(t)$ Weighted average price of all citrus fruits received by farmers.

$x_{104}(t)$ One-year-lagged price of citrus fruits.

$x_{105}(t)$ Five-year moving average of (recent) past prices of citrus fruits. $x_{105}(t)$ and its counterparts--$x_{205}(t)$, $x_{305}(t)$ and $x_{405}(t)$--are referred to in the text by the symbol p^*_{t-5} (see Section 3.B above).

$x_{15}(t)$ Weighted average price of noncitrus fruits received by farmers.

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[1]The difference consists of acreage devoted to the other (relatively unimportant) citrus fruits, viz., limes, tangerines and tangeloes.

$x_{18}(t)$ Index of average prices received by farmers for the following grains: corn, oats, barley and sorghum grain (1957-59 = 100).

$y_{106}(t)$ Ratio between the average price of a ton of citrus crop and the weighted average farm wage rate in dollars per day (without board) for hired day labor in South Atlantic States and Pacific States. The farm wage rate is derived from cash wage rates of hired farm workers and composite wage rate per month as summarized in Handbook of Labor Statistics, 1950, and in Agricultural Statistics, 1952, 1967.

$y_{107}(t)$ Ratio between the average price of citrus fruits and the average price of fertilizer used for commercial purposes. Both prices are in dollars per ton.

$y_{108}(t)$ Ratio between the average price of citrus fruits and the average price of cotton (lint)--both prices in dollars per ton. This variable is coded by a constant multiple of 100 to eliminate an all-fractional column.

$y_{109}(t)$ Ratio between the average price of citrus fruits and the average price of vegetables (or truck crops)--both prices in dollars per ton.

$y_{203}(t)$ Weighted average price of oranges (excluding tangerines) received by farmers.

$x_{204}(t)$ One-year-lagged price of oranges.

$x_{205}(t)$ Five-year moving averages of (recent) past prices of oranges.

$x_{25}(t)$ Weighted average price of apples received by farmers.

$y_{206}(t)$ Ratio between the average price of oranges and weighted average farm rates in the South Atlantic and Pacific States. Prices are in dollars per ton, and wages in dollars per day (without board).

$y_{207}(t)$ Ratio of price of oranges to the average price of commercial fertilizer.

$y_{211}(t)$ Ratio between the price of oranges and the price of grapefruits.

$y_{303}(t)$ Weighted average price of grapefruits received by farmers.

$x_{304}(t)$ One-year-lagged price of grapefruits.

$x_{305}(t)$ Five-year moving averages of (recent) past prices of grapefruits.

$x_{35}(t)$ Average prices of oranges received by farmers. It is the same as $y_{203}(t)$.

$y_{306}(t)$ Ratio between the average price of a ton of grapefruits and weighted average farm wage rates for hired day labor in the South Atlantic and Pacific

States.

$y_{307}(t)$ Ratio between the price of grapefruits and the price of commercial fertilizer.

$y_{309}(t)$ Ratio between the average price of grapefruits and the average price of truck crops (i.e., vegetables).

$y_{312}(t)$ Ratio between the price of grapefruits and the price of oranges. It is the reciprocal of $y_{211}(t)$.

$y_{403}(t)$ Weighted average price of lemons received by farmers.

$x_{404}(t)$ One-year-lagged price of lemons.

$x_{405}(t)$ Five-year moving averages of (recent) past prices of lemons.

$y_{406}(t)$ Ratio between the average price of lemons and weighted average farm wage rates in the South Atlantic and Pacific States.

$y_{407}(t)$ Ratio between the average price of lemons and the average price of commercial fertilizer.

$y_{413}(t)$ Ratio of the price of lemons to a weighted average price of a combined hay and cotton (lint) crop. Both prices are given in dollars per ton.

c. Miscellaneous variables

$x_0(t)$ Intercept.

$x_{96}(t)$ Time; (1921 = 1, ..., 1965 = 45).

$x_{97}(t)$ The square of time. It is $(x_{96}(t))^2$.

$x_{98}(t)$ Dummy variable representing the effect of World War II. Has value: 1, 1943-1946; 0 at all other time.

$x_{99}(t)$ Dummy variable representing cotton acreage allotment program. Has value: 0, 1921-1933; 1, 1934-1965.

The same definitions of variables are used for all areas. However, if a variable refers to a region, it will be designated by the superscript R.

D. Time Series on the Selected Variables

1. <u>All citrus fruits, $y_{101}(t)$</u>

The uppermost line of Figure 1 shows the total tonnage (in thousands of tons) of all classes of citrus fruits during any year t. Three different growth patterns can be discerned from this graph. For the prewar period 1921 to 1939, total citrus production shows marked cyclical fluctuations about a secular upward linear trend. For this period a linear regression of $y_{101}(t)$ on time results in the regression coefficient $c_{101} = 161.6105$. This indicates that the total production of citrus fruits increased by about 161,610 tons annually. During the war and the immediate prewar period 1940 to 1947 total citrus production showed

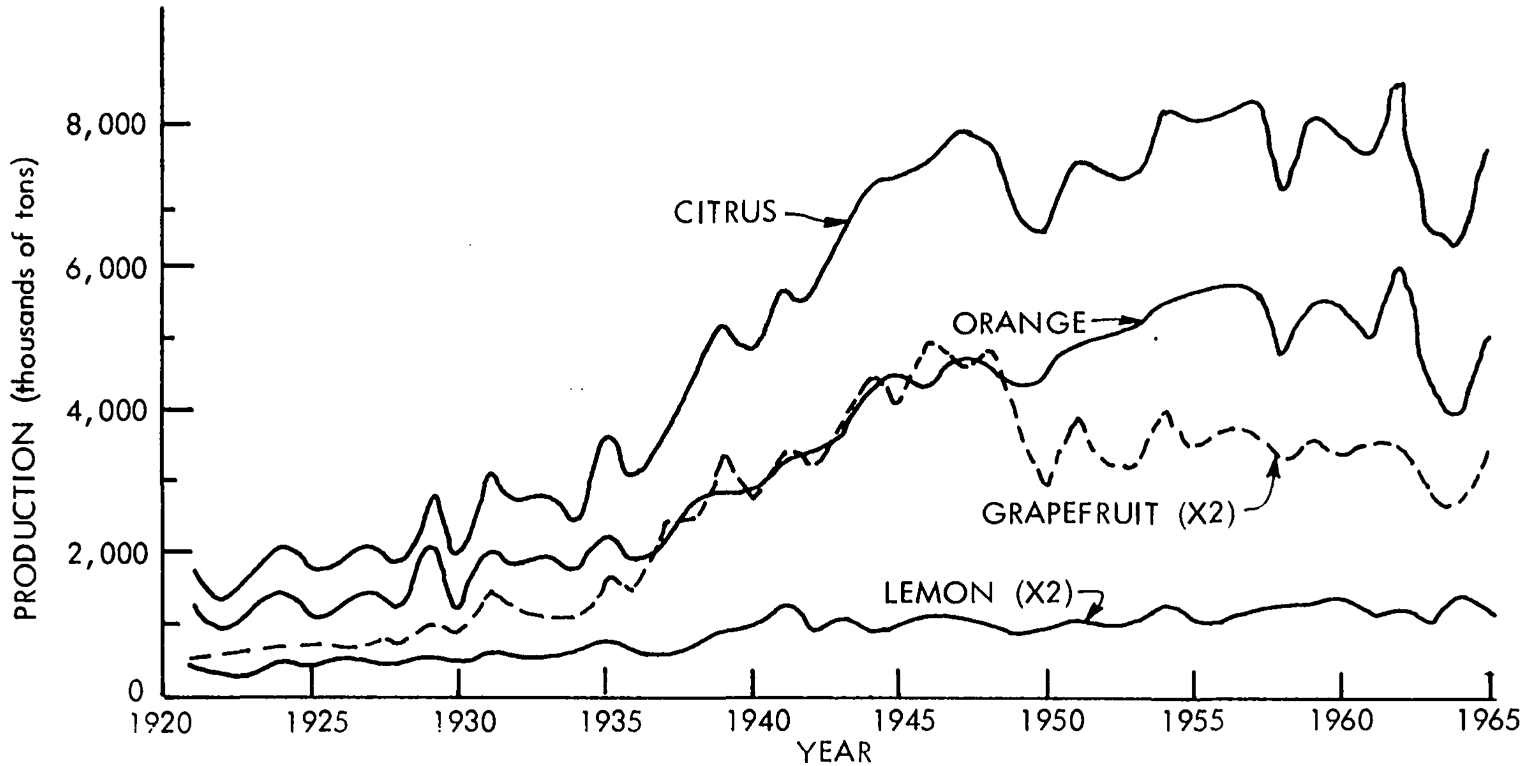

Figure 1. Supply of citrus fruit and its components: orange supply cycle, grapefruit supply cycle, and lemon supply cycle, U.S.A., 1921-1965

a very strong secular upward trend with only negligible cyclical fluctuations. The corresponding regression coefficient is $c_{101} = 433.8333$. In the postwar period 1948 to 1965 $y_{103}(t)$ once again exhibits considerable cyclical fluctuations but this time about a trend which is more of a quadratic than a linear form. There is an upward trend to 1956 followed by a downward trend through 1964. A reasonable value for c_{101} may be obtained by a linear regression of $y_{103}(t)$ on t and its square, t^2. The amplitude of the fluctuations in the postwar period is smaller than that in the prewar period.

If we consider the entire period, we observe that the citrus production curve is sigmoidal, i.e., it is S-shaped. Citrus production increases only slowly at first (1921-39), then rises very rapidly (1940-47), and finally shows a small increase (1948-65). The linear regression coefficient c_{101} = 172.6287, obtained by regressing $y_{103}(t)$ on time for the entire study period 1921 to 1965, may be used to obtain predicted values of $y_{101}(t)$. These predicted values represent the long run, secular, or trend values of $y_{101}(t)$. This method is only approximate, especially since the citrus production curve is sigmoidal rather than linear. Any analysis of the production changes during the entire study period should include time, t^2, and possibly t^3, among the independent variables.

In this study separate analyses are conducted for each of the following periods: a) the prewar period 1921-1939; b) the postwar period 1948-1965; and c) the entire study period 1921 to 1965.

The "cycles" or fluctuations are of different lengths as between the three subperiods. Also, even within any particular subperiod, the repetitions of the cycle are not of exactly equal length. Within one cycle, upswing and downswing phases are unequal in length.

2. Various classes of citrus fruits

The development of the various classes of citrus fruits can also be seen in Figure 1. The amplitude and regularity of the cyclical fluctuations are most pronounced for orange production. In fact, for the orange output curve, the fluctuations exactly match those of the total citrus production, except for the war period 1940-1947. There are more fluctuations in this subperiod in the case of orange production than for citrus production. The overall picture of the orange production is, therefore, sigmoidal.

The grapefruit production curve shows only a slight upward trend in the prewar period 1921-1939; the war years are marked by a sharp upward linear trend, which ends abruptly at about 1948. This is followed by a more or less horizontal trend curve (which starts from a lower production level) for

for the postwar period. Sizable fluctuations are encountered during the war and the postwar years. During the war years, the grapefruit production fluctuations are more marked, and the upward trend more steep, than for orange production. No one single curve can fit the overall production picture of grapefruit. A quadratic curve may be fitted for the prewar and war years 1921-1948; the remaining postwar year values are approximated by a horizontal linear trend.

The lemon production curve exhibits small cyclical fluctuations throughout the entire study period, but the amplitude of these fluctuations seem to be bigger for the postwar years than for the other years. Relatively high values for some (few) years are usually found during the upswing. The entire period can be fitted by a slightly upward linear trend.

3. Effect of price on supply

One of the most striking aspects of the citrus industry is the recurring pattern of high prices, followed by increasing supply, then by declining prices, and often later by decreasing production. This cycle is evident in Figure 2, when one compares total citrus production with the current price (p_t) received by farmers for all citrus fruits.
Over the entire study period, one can easily discern fourteen major price-rise "periods", beginning in 1921, 1924,

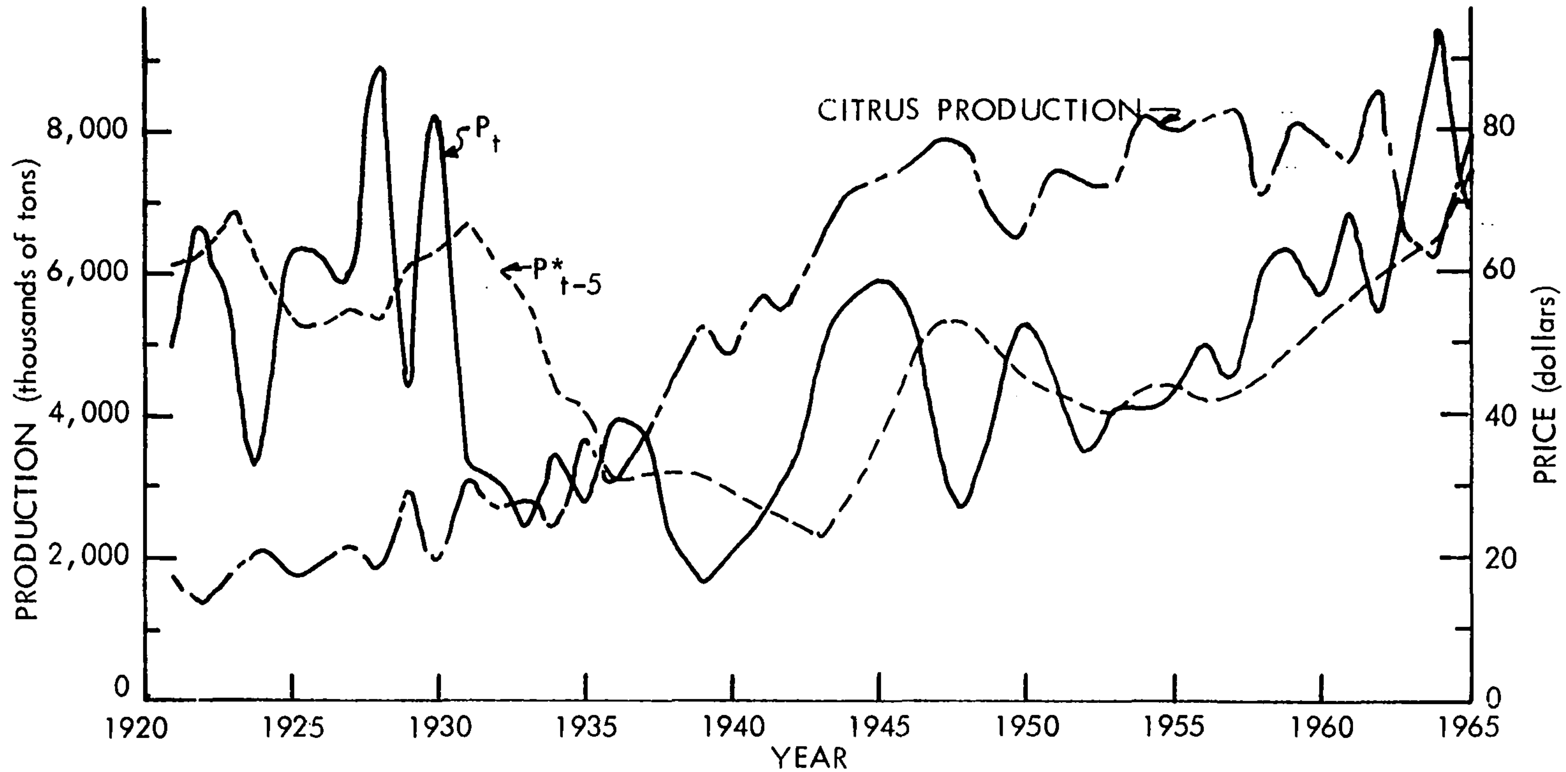

Figure 2. Citrus: price and supply cycle, 1921-1965

1927, 1929, 1931, 1933, 1935, 1939, 1948, 1952, 1954, 1957, 1960, 1962. Each of them was accompanied by increased citrus production a year or two (or sometimes, even six years) later. The variation in the lag between price rises and production is quite understandable. Increased prices can fairly quickly affect production of citrus fruit when the response to them is simply a rejuvenation of run-down plantations; but their effect is much slower when the increased prices stimulate planting activity.

Figure 2 reveals that the "war period", 1940-48, is a period of both increasing prices and increasing product output. The price rise which started in 1939 continued strongly upwards and was responsible for the sharp increase in citrus production--2.67 million boxes in 1934 as compared to 7.86 million boxes in 1947. This period stands apart from the unstable (or, more appropriately, the cobweb-type) nature of price-quantity relationship that characterizes the citrus economy in the prewar and postwar periods. The latter phenomenon more nearly describes the citrus economy.

The period of lag between price rises and production is also certainly affected by planters' judgments as to the business outlook, i.e. the planters' expectations regarding future yields and prices. Figure 2 also shows a curve for five-year moving averages of (recent) past prices of citrus fruits, p^*_{t-5}. It will be remembered that p^*_{t-5} is used as an approximation to the citrus farmers' expected price in the (foreseeable) future. Prior to 1925, citrus production was almost constant (i.e., could be fitted by a linear trend with zero slope). From 1925, however, there was a significant improvement in farmers' expectations, and this resulted in increased citrus production (rejuvenation of farms and new plantings) which continued into the late 1930's. Meanwhile, in mid-1930's, farmers' price expectations had changed; there was a general expectation of lower and lower prices for the second half of the "thirties" and, possibly, well into the "forties". True, prices fell in the late 1930's due to the great upsurge of production accompanying the 1925-1933 improvement in price expectation. Between 1928-29 and 1938-39 grapefruit production alone tripled, and the average price received by growers fell from $1.06 per box to $0.31. About 10 per cent of the 1938-39 crop was not harvested because returns would not cover marketing costs (Wilcox, 1947, p. 201). The "forecast" for the 1940's, however, did not come true as a result, mainly, of two very unpredictable forces. The phenomenal price rise during 1939-1945 can be explained by a tremendous increase in demand arising from a) processing activity, and b) wartime demand.

Although processing of citrus products started around early 1930's, it was not until about 1936 that the consumption of processed citrus products reached 0.1 pound per person.

Insignificant though this may be, it was a gate-opener for a new product; the massive advertising campaign of late 1930's and early 1940's helped greatly to popularize the product.

The 1939-40 citrus crop was somewhat smaller and prices were substantially higher than a year earlier. The 1940-41 orange and grapefruit crops reached new record levels, but defense mobilization had increased demand to such an extent that orange growers obtained an average of $1.20 per box in contrast to $0.77 two years earlier. Grapefruit prices in 1941 rose to 43 cents--40 percent above the all-time record low of 31 cents a box in 1938-39. Average yields were slightly lower the next year, but prices continued to rise and incomes to growers were 30 per cent higher. Increases in production, prices, and total value of the citrus crop during the war years are as shown in Table 1.

Costs of maintaining orchards and harvesting fruit increased around 50 per cent during the war period, especially wages paid to hired day labor. U.S.D.A. reports that for the first time Negro citrus pickers were paid more than $1.00 an hour in Florida in 1945 (U.S.D.A., 1945b). Note that hired day labor comprises about 35 per cent of factor cost. The rapid rise in gross income, however, permitted an even more rapid rise in the net incomes of citrus grove owners. Net returns per acre increased from almost nothing or losses in 1938 and 1939 to more than $500 in 1944 (see Figure 3).

Table 1. Citrus production statistics in the war years, 1935-39 = 100

Crop year	Production	Prices	Value of sales	Average yield per acre
1939-40	113	81	97	109
1940-41	134	87	129	130
1941-42	131	117	169	134
1942-43	149	168	285	123
1943-44	168	191	365	130
1944-45	171	194	390	150
1945-46	176	177	383	119

Oranges, grapefruit and lemons normally come into bearing around five years after planting. The yield of an orange or grapefruit grove continues to increase until it is around forty-five years of age in most citrus-producing areas. Wilcox estimates that about 12 per cent of the citrus trees were not yet of bearing age at the outbreak of war. The increase in citrus fruit production during the war years, therefore, he argues, largely resulted from normal yield increases on young plantings made several years earlier. Without the wartime demand, these large crops might have sold for extremely low prices. High prices, however, stimulated better irrigation, heavier use of fertilizer and better care of

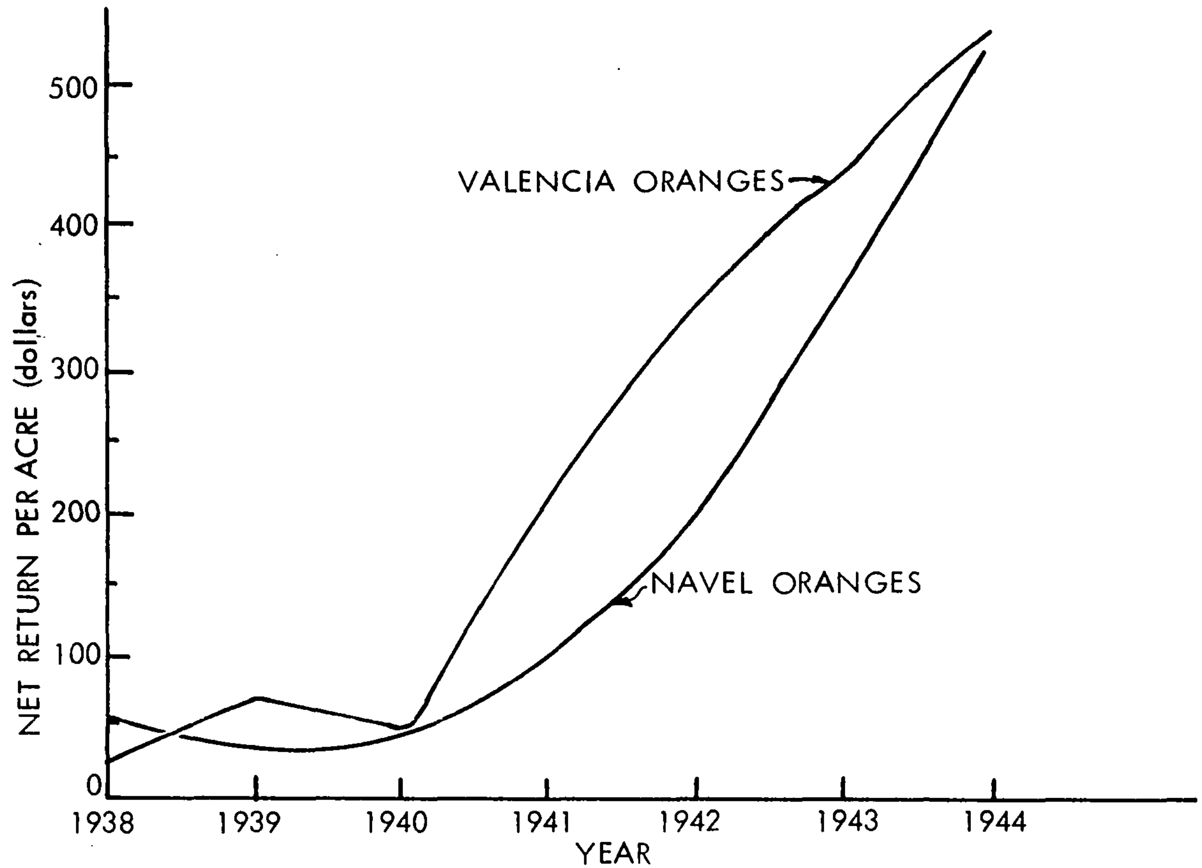

Figure 3. Net return per acre for orange growers after deducting all costs except interest and a charge for management, 1938-44

established groves. As a result, yields were somewhat above levels which would have been obtained at prewar prices (Table 1).

The increased yield per acre reinforced the declining factor-product price ratios (especially fertilizer-citrus price ratio--see Figure 4) not only to contribute their quota to the production increase in 1939-48 but also, and more importantly, to counteract the negative effects of declining p_t and p^*_{t-5} on citrus production during 1936-39.

4. Competing products

We take account of competing products in our analyses of supply of citrus fruits because we expect to find significant effects of the supply and price of rival products on the supply and price of these citrus fruits. There are two categories of competing products: a) those which compete with citrus fruits for the consumers' income; and b) those which compete with citrus fruits for farm space and other resources.

In the first category are such noncitrus fruits as apples, grapes and cranberry. This group pertains to a demand analysis, but it plays an important role in establishing the supply of citrus products in the future. Price differentials engender substitution in consumption since the products of this group generally serve the same use as citrus

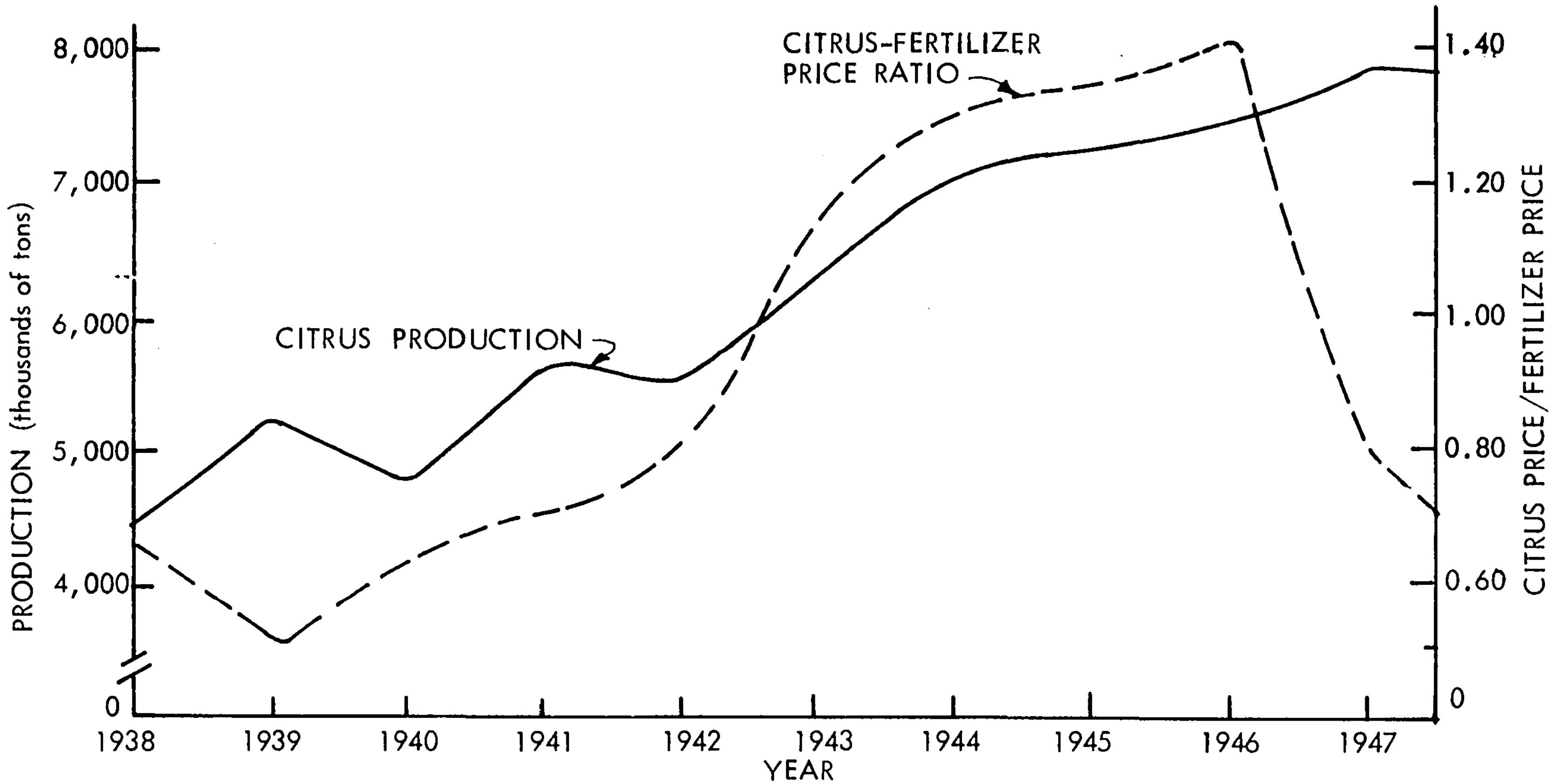

Figure 4. Comparison of the citrus supply curve and the citrus-fertilizer price ratio curve, 1938-1948

fruits.

Cotton lint, vegetables, grains and hay are the principal products in the second group. In the Western States, hay, cotton lint and vegetables compete very strongly for agricultural land and resources with citrus orcharding. In Texas grains and cotton lint production are the most important competitors; and in the other Southern States vegetables are the main competitors for the farmer's resources. Resource allocation among competing products (in the sense of category (b)) is based on changes in relative prices of the products rather than on their absolute prices. Consequently, the variables used for the second-group competing products are the product price ratios, with the price of citrus fruit (or its component) as the numerator.

5. Other variables

It is stated elsewhere in this chapter that in the short run the most important cost factor involved in the production of citrus fruits is cotton. This cost factor was included in our analysis as a second-group competing product, where it enters as the ratio of the price per ton of citrus fruits to the average cotton price per ton received by farmers the previous year. However, the price of cotton will not always affect citrus production in the same way. In particular the program of cotton acreage allotments put into effect in 1934 and thereafter presumably had some effect on the supply of citrus fruits. This cotton acreage allotment program is represented in this study by a dummy variable that has the values 0 for the years before 1934 and 1 for 1934 and thereafter.

The supply of citrus fruits seems to have been influenced by the World War II. The choice was either to omit the war years from the process of fitting our supply models, or to include some recognition of the effect of the wartime program. Both alternatives were adopted, though only one was used in fitting a particular model. For the models employing the first alternative, the war years (and immediate postwar years, up to 1948) were eliminated from the analyses and separate regressions were applied to the prewar data (1921-1939) and the postwar data (1948 to 1965). For the models employing the second alternative, a second dummy variable, W, was employed to represent the presence of the war. This variable is entered with a one-year lag and has the value 1 during the years 1943 through 1946 and 0 at all other times. In these latter models an attempt is made to test the importance of the war variable in explaining the supply variation in the war years.

We therefore have supply equations fitted to data for the entire period (1921 through 1965), and other supply equations fitted to data either for the prewar period alone or for the postwar period alone.

IV. EMPIRICAL RESULTS FOR THE UNITED STATES

A. Introduction

We present the empirical results of the analyses for the United States as a whole in this chapter. The empirical results for the two regions--Southern States and Western States--are presented in Chapter V. The following general remarks will hold true for this as well as the next chapters.

An explanatory variable is included in an equation if its coefficient is significant or highly significant. Occasionally we include a variable with a lowly significant coefficient if its sign is correct (i.e., agrees with economic theory) and if the variable is needed to help test the importance of the effect of another explanatory variable on the explained variable. The number of explanatory variables is usually kept low enough so that significant coefficients are obtained for nearly all variables.

With respect to the levels of significance, the following terminology is employed throughout this study. A coefficient is said to be very significant if its probability of type I error, α, is equal to or smaller than .001, highly significant if α is larger than .001 but not greater than .01, significant is α lies between .01 and .05, and lowly significant if α is greater than .05 but not larger than .50.

An estimated equation is presented in the tables below if it possesses a satisfactory R^2-value and if its coefficients satisfy the above-mentioned conditions. We may also include an equation with a relatively low R^2-value and/or relatively low significance levels if it contains a set of explanatory variables which allows us to compare the explanatory value of two or more variables.

The following conventions and arrangements will also be observed throughout the study. The estimated unit effects are arranged in tables. The standard errors are put in parentheses below the corresponding coefficients. Because of the (sometimes) wide differences among the coefficients for the same explanatory variable in different estimated equations, it was considered inappropriate to obtain a single average value (be it a simple average, geometric average or any other form of average) to represent many of the explanatory variables. Consequently, for many such variables, only a range of values will be given, and the exact single value will depend upon what equation number one chooses to work with. For the other explanatory variables, the average is very informative.

All elasticities encountered in this thesis are mean elasticities--calculated from the mean values of the variables. Again, we shall deal with individual mean elasticities rather than a single average mean elasticity for any explanatory variable. The elasticity coefficients (not presented in the tables) indicate the estimated mean elasticities of the explained or dependent variable with respect to the appropriate explanatory variables.

From each table, we observe that the magnitudes of individual unit effects indicate the estimated unit effect of the explanatory variables in the columns upon the dependent or explained variable on the left-hand side of the equation. The unit effects are given in the same units of measurement as the explained variables to which they refer.

1. Variables explained

In this chapter we concentrate on the dependent variables dealing with the United States as an entity. We seek to explain the following variables:

- $y_{101}(t)$ the total production of all citrus fruits (Tables 2, 3 and 4);
- $y_{201}(t)$ the total production of oranges (Tables 5, 6 and 7);
- $y_{301}(t)$ the total production of grapefruits (Tables 8, 9 and 10);
- $y_{401}(t)$ the total production of lemons (Tables 11, 12 and 13).

The numbers of the tables in which the estimated coefficients are presented are added in parentheses. Each "explained" variable is given in three tables. The first table number in the parentheses refers to the coefficients relating to the entire study period, 1921 to 1965. The next two table numbers refer to the coefficients relating to the prewar period (1921 to 1939) and postwar period (1948 to 1965), respectively. The entire 45-years study period analysis is always discussed first; then the prewar and the postwar analyses are next discussed, bringing out comparisons between them and the full period.

B. Analysis of Citrus Fruits Production

1. Variables in selected equations explaining $y_{101}(t)$--(1921-1965)--the total production of all citrus fruits for the entire study period

a. Current citrus price, $y_{103}(t)$ The coefficient of the endogenous variable $y_{103}(t)$, the current citrus price received by farmers, is in an one-sided test significant in three of the four equations in which it appears in Table 2. It is lowly significant in Equation 4.6, with α of slightly less than .30. All the coefficients are greater than zero.

An average value was attempted for this variable since all the signs were in one direction and there seems to be no "big" differences among the individual coefficients. This estimated average coefficient was obtained as a simple average of only the significant coefficients. The average

Table 2. U.S.A. (1921-1965), $y_{101}(t)$: Estimated unit effects and elasticities of variables in selected equations explaining $y_{101}(t)$, the total production of all citrus fruits

Equation number	$y_{103}(t)$ Current citrus price	$x_{11}(t)$ Supply of noncitrus fruits	$x_{12}(t)$ Lagged supply of noncitrus fruits	$x_{54}(t)$ Population of U.S.A.	$x_{15}(t)$ Current price of noncitrus fruits	$x_{104}(t)$ Lagged citrus price
4.1	81.8896	-0.0812				-1.0321
	(42.4723)	(0.1447)				(9.3151)
4.2	139.5120	-0.0287				-1.9458
	(47.7082)	(0.1388)				(8.8193)
4.3			-6.3752	6,830.2503		-117.3680
			(3.1232)	(3,238.2112)		(63.3426)
4.4			0.3496	-680.8225		28.7851
			(0.5915)	(560.5245)		(12.9121)
4.5	205.1415			24.3677	9.2006	-2.1311
	(157.8508)			(206.2272)	(22.8466)	(14.9895)
4.6	55.5098			-215.7495	-25.2701	9.1870
	(96.3691)			(175.7789)	(23.4349)	(10.2553)
4.7					-27.6797	3.2110
					(9.4241)	(8.3246)
4.8					-26.2750	3.7730
					(8.2670)	(7.2914)
Average[a]	120.5132	-0.0549			-26.4083	
Elasticities:						
e_M	1.09				-0.28	

[a]Average coefficient is based on the at least significant coefficients.

Table 2 (Continued)

Equation number	$x_{105}(t)$ Five-year moving average of citrus prices	$x_{18}(t)$ Index of price of grains	$y_{106}(t)$ Ratio of citrus price to wages	$y_{107}(t)$ Citrus-fertilizer price ratio	$y_{108}(t)$ Citrus-cotton lint price ratio	$y_{109}(t)$ Citrus-vegetable price ratio
4.1	11.1629 (17.0706)	5.3251 (4.8809)	-113.8223 (64.1770)	-2,947.2172 (2,020.0870)		1,429.5546 (1,787.4904)
4.2	28.3722 (17.8815)	0.4789 (5.0986)	-49.8686 (67.0834)	-4,255.2922 (1,997.8804)		-353.1566 (1,868.7131)
4.3	-29.5911 (21.4222)		-1,928.1280 (868.5454)	29,975.0010 (14,500.8666)	-18.0900 (47.9216)	-45,633.6342 (22,075.4005)
4.4	0.1805 (18.4240)		87.2784 (148.1077)	-3,066.0589 (3,801.2199)	-67.1443 (46.0025)	4,802.9503 (5,536.8703)
4.5	21.8632 (25.8520)		-20.3319 (59.6326)	-6,834.1539 (4,936.4931)	-39.6840 (44.6103)	
4.6			21.0967 (57.1644)	-2,219.5396 (3,041.9727)	13.2788 (54.7201)	
4.7	3.3956 (13.5733)	2.5760 (4.8674)	-67.3449 (58.6915)	-755.8541 (1,158.7508)		771.6839 (1,757.2532)
4.8		4.5648 (4.5512)				
Average[a]						
e_M						

Table 2 (Continued)

Equation number	$x_{901}(t)$ Citrus acreage	$x_{96}(t)$ Time	$x_{97}(t)$ Square of time	$x_{98}(t)$ Dummy variable for war effect	$x_{99}(t)$ Dummy variable for cotton program	x_0 Intercept	R^2
4.1	1.0322	-50.3411				-887.8652	0.950
	(3.5000)	(55.7622)				(2,446.7073)	
4.2	6.5169	187.3771	-4.6328			-1,763.0625	0.956
	(3.7210)	(118.5639)	(2.0695)			(2,346.7976)	
4.3		-7,739.1412	-150.5694	9,329.0138	14,134.4257	-582,606.5000	0.964
		(3,807.9002)	(69.7278)	(3,968.6300)	(7,187.5213)	(279,091.4890)	
4.4		1,087.2432	11.1465		-2,430.2664	65,000.5742	0.958
		(675.7137)	(12.1213)		(1,509.5512)	(47,607.4289)	
4.5	12.9580	132.4879	-5.2990		-1,769.1129	-6,703.0000	0.962
	(9.5912)	(305.2493)	(6.2163)		(878.7055)	(24,863.4962)	
4.6	5.3000	410.8052	1.7012	-1,144.5488	-1,285.0072	20,533.2656	0.963
	(6.5208)	(252.6002)	(4.5607)	(885.1221)	(917.9155)	(19,071.7403)	
4.7	2.3398	161.2097	-2.1358			609.3540	0.955
	(3.2813)	(116.0673)	(1.7584)			(1,941.3465)	
4.8		320.2284	-4.2046			-1,225.0095	0.941
		(41.5238)	(0.8645)			(578.8449)	
Average[a]	4.7189	242.4216	-4.0680				

coefficient $c_{103} = 142.1810$ indicates that an increase (or reduction) in the current citrus price of one dollar per ton of all citrus fruits (fresh equivalent) will ceteris paribus lead to or be associated with an increase (or reduction) in the next year's citrus supply of about 142.1810 thousands of tons. The average price elasticity of supply computed at the mean values of $y_{101}(t)$ and $y_{103}(t)$ is given by $\epsilon_M = 1.097$.

The sign of the c_{103}-coefficients conforms to the theory of production. Other things remaining equal, a citrus producer will react to an increase (reduction) in the current citrus price by producing and marketing more (fewer) citrus fruits. Whereas this statement is true in the short run, it is not likely that citrus farmers generally base their long run expectations about future profitability conditions of the citrus industry upon such temporary price changes. Expectations about future profitability are more likely to be changed "if last year's citrus price shows a change and if the current developments of the citrus price do not give rise to contrary expectations". It is stated elsewhere that the five-year moving averages of (recent) past prices serve as a reasonable approximation to expected future prices. We shall have more to say about this in subsection B.1.g on page 93.

_b_. _Supply of noncitrus fruits, $x_{11}(t)$_ The coefficient b_{11} of the predetermined variable $x_{11}(t)$ is negative and very small in the two selected equations in which the variable appears. The coefficients are also lowly significant in both supply relations. The average coefficient $b_{11} = -0.0549$ indicates that if the supply of noncitrus fruits increases (decreases) by one unit--one thousand tons--the total harvesting and marketing of citrus fruits will, _ceteris paribus_, decrease (increase) by nearly 55 tons (i.e., 0.055 x 1,000 tons). The sign of this change is in agreement with economic theory since citrus fruits and noncitrus fruits are substitutes of category (a)--i.e., both products compete for the consumers "fixed" income.

_c_. _Lagged supply of noncitrus fruits, $x_{12}(t)$_ The coefficient of the predetermined variable $x_{12}(t)$ is negative and highly significant in three relations (only one of which was selected for inclusion in Table 2) whereas in a fourth relation it was positive but lowly significant, with α of nearly .30. The mean of the negative values of b_{12} was $b_{12} = -2.7812$; it indicates that if the lagged supply of noncitrus fruits increases (decreases) by 1,000 tons, _ceteris paribus_, citrus supply will decrease (increase) by about 2,781 tons. The sign of the coefficient is consistent with short-run economic theory.

The coefficients for the predetermined variable $x_{11}(t)$ and its lagged values $x_{12}(t)$ have the same negative signs, but their respective effects on $y_{101}(t)$ are different. Not only are the absolute values of b_{12} substantially larger than the b_{11}-values, but also that with a probability of type I error, α, of less than or equal to .05, almost all the b_{12}-values are highly significant or significant whereas the values of b_{11} are non-significant. The latter statement implies that the variable $x_{12}(t)$, lagged supply of noncitrus fruits, is important in predicting the values of $y_{101}(t)$ in the regression equations and that $x_{11}(t)$, current supply of noncitrus fruits adds very little (if any) valuable information to the reliability of the estimate of total citrus production, $y_{101}(t)$.

d. Population of the United States, $x_{54}(t)$ In two out of four relations involving $x_{54}(t)$, the total population of the United States, the coefficients were positive with one being highly significant and the other relation 4.5--lowly significant, with α of nearly .50. In the other two relations--relations 4.4 and 4.6--the b_{54} values are negative and lowly significant at α of smaller than .10. The magnitude of the positive value of the highly significant b_{54} in relation 4.3 overshadows all the negative b_{54}-values in the other relations, so that no meaningful explanation can be accorded to an average value of b_{54}.

General theory suggests that the coefficient b_{54} should be positive, that is, an increase (decrease) in population should result in an increase (decrease) in total citrus fruits produced and marketed. A simple average of the individual values would give a b_{54}-value in agreement with the theory, but we should also note that, in general, the coefficients of relation 4.3 are unrealistically high. An equation intended for use as a check on the direction of change of b_{54} failed to yield significant coefficients in almost all variables and was therefore not considered. There is only one conclusion then to be made about the predetermined variable $x_{54}(t)$; that is, the results of the study for the entire 45-years period proved inconclusive with respect to the effect of the population variable $x_{54}(t)$ on total citrus production in U.S.A., $y_{101}(t)$.

This inconclusive result could be due to the fact that the population variable $x_{54}(t)$ has a very high correlation with the variables time, $x_{96}(t)$, and square of time, $x_{97}(t)$, especially during the postwar period. In the postwar period $R_{54.96} = 0.9995$ and $R_{54.97} = 0.9989$. Moreover, from Table 2 we see that smaller values for the coefficients of $x_{96}(t)$ and $x_{97}(t)$ are always associated with smaller values for b_{54} in the same relation, and larger values of b_{96} and b_{97} give rise to larger b_{54}-values. These two observations may suggest to us that the population variable $x_{54}(t)$ probably does not have an independent existence as a variable in the citrus supply relation; that is, the effect of $x_{54}(t)$ on $y_{101}(t)$ may already have been taken into account in the prediction of $y_{101}(t)$ values by prior inclusion of $x_{96}(t)$ and/or $x_{97}(t)$, so that $x_{54}(t)$ does not play any significant role in the regression analysis. In fact, it is more a demand function variable and will henceforth be omitted from discussion.

e. Current price of noncitrus fruits, $x_{15}(t)$ The coefficient b_{15} of the predetermined variable $x_{15}(t)$ is negative in three of the selected equations and highly significant or significant for these positive values. In a fourth relation b_{15} is positive and only lowly significant. The average of the at-least significant values is $b_{15} = -26.4083$ and indicates that an increase (decrease) of current price of noncitrus fruits by one dollar per ton of noncitrus fruits will lead to, other things remaining equal, a decrease (increase) in citrus fruit marketing by nearly 26,408 tons. The sign of the change is as expected since citrus fruits and noncitrus fruits are competitive products. The cross elasticity of citrus supply with respect to the price of noncitrus fruits is about -0.28.

f. <u>Lagged citrus price, $x_{104}(t)$</u> This variable appeared in all the eight relations selected, but were evenly divided among positive values and negative values for b_{104}. In each group of four, two of the coefficients were significant and the other two lowly significant. With the exception of relation 4.3, the absolute values of all positive coefficients are greater than those of the negative values.

A positive coefficient b_{104} indicates that an increase in lagged citrus price will delay plant cuttings and hence increase the production of citrus. This is especially true if future prospects are considered bright for the industry, that is, if the citrus industry finds itself on the upward rising portion of the P^*_{t-5} curve in Figure 2. On the other hand, a negative b_{104} would imply that an increase in lagged price would lead farmers to expect that citrus prices cannot rise any further and that very soon citrus prices will begin to fall. In such a case, where farmers hold some idea of a "normal" range of prices, an increase in lagged citrus price will result in cutting of citrus trees and hence in smaller or reduced citrus production. What the actual psychological nature of farmers is, however, was not revealed by the analysis. But a comparison of the c_{103} and b_{104} values in relations 4.1, 4.2 and 4.5 reveals that whenever current citrus price, $y_{103}(t)$, and lagged citrus price, $x_{104}(t)$, are represented in the same supply relation, the coefficients bear opposite signs, with b_{104} being negative always. However, whenever $x_{104}(t)$ appears with $x_{105}(t)$--but not $y_{103}(t)$--the sign of the coefficient b_{104} is always positive, except for relation 4.3.

g. Five-year moving average of past citrus price, $x_{105}(t)$ The predetermined variable $x_{105}(t)$, the five-year moving average of (recent) past citrus prices, has positive coefficients in all the selected relations (except 4.3) and is significant or lowly significant in all of them. The positive coefficient b_{105} (no single average value was calculated) indicates that if the five-year moving average of citrus price increased by one dollar per ton, *ceteris paribus*, the citrus fruit production would go up.

The contrast between the effects of $y_{103}(t)$ on $y_{101}(t)$ and the effects of $x_{105}(t)$ on the same dependent or "explained" variable may be explained as follows: citrus producer takes the current citrus price, reflected in the coefficient c_{103}, as an indicator of short run developments, and the five-year moving average of citrus prices (with coefficient b_{105}) as an indicator of longer run developments. The variable $x_{105}(t)$, therefore, may form the basis for expectations about future profitability conditions.[1] Hence

[1]This is the reason why right from the beginning of this analysis we have always associated the variable $x_{105}(t)$ with expectations of future prices.

in the short run or in the long run, farmers will tend to increase (decrease) the tonnage of citrus fruits harvested and marketed as a result of a rise (fall) in citrus prices.

The last statement, however, need not hold true if we take account of a possible negative values for the coefficients of variable $x_{104}(t)$. Where the idea of a normal price is prevalent among farmers, $b_{104}(t)$ may as well be negative. The duration of the effectiveness of changed prices must necessarily be somewhere between the short run and the long run, say, "medium range". Generally, an individual farmer may not know whether to interpret a changed citrus price, whose length of effectiveness is usually not known with certainty, as a short run, a "medium range" or a long run profitability indicator. Citrus farmers as an aggregate may not show a response to citrus price changes of such a duration because some farmers may react as short run, others as "medium range", and yet some others as longer run profit maximizers. The effects of these behavior groups may conceivably cancel out.

h. Index of price of grains, $x_{18}(t)$ This is an index of average prices received by farmers for corn, oats, barley and sorghum (1957-59) = 100). The coefficients b_{18} are all positive but small and all are only lowly significant. The positive coefficients imply that a one-percentage point increase in the grains price index will be associated with some increase in citrus production.

The sign of the coefficient b_{18}, therefore, will conform to theory only if citrus fruits and grains are competitive in the sense that they compete for the consumers' "fixed" dollar income. But the competition between these two products is in the sense of category (b)--i.e., that they compete for land space and other farm resources. For category (b) type competitive products, economic theory suggests negative b_{18}-values. Thus we can conclude either that the economic theory of production is wrong or that grains do not constitute much competition for citrus fruits in the use of farm resources. The latter alternative conclusion seems more plausible since the most important farm resources (hired day labor and fertilizer) used in citrus production do not feature highly in the production of grains. In fact, with the exception of a few counties in Texas and California, there is very little substitution of grains for citrus fruits in the farm product mix as prices move in favor of grains.

<u>i. Ratio of citrus price to wages, $y_{106}(t)$</u> Wages paid to hired day workers constitute the most important part (about 30 per cent) of the direct cost of citrus orcharding. In general, a decrease in the cost of citrus production--and, hence, an increase in the ratio $y_{106}(t)$--will tend to

induce farmers to increase their citrus production. The value of c_{106} will therefore be expected to be positive. In this study, however, the positive coefficients c_{106} are all lowly significant, with α of slightly less than .40, and the negative c_{106}-values are similarly nonsignificant, with $\alpha \leq .30$. Thus the ratio $y_{106}(t)$ does not play any significant role in explaining the variance in citrus fruits production, $y_{101}(t)$.

j. Citrus/fertilizer price ratio, $y_{107}(t)$ The second most important direct cost item in citrus orcharding is fertilizer cost. Like c_{106}, the coefficient c_{107} is expected to be positive. The c_{107}-values are negative for almost all the selected relations and are also nonsignificant in each one. The negative c_{107}-coefficient of the citrus/fertilizer price ratio is therefore also not important in explaining the variation in citrus fruits production.

k. Variables $y_{108}(t)$ and $x_{99}(t)$ Cotton lint[1] and vegetables are the principal competitors of citrus fruits for farm space, farm labor and other resources in most of the citrus-producing States of the United States.

The negative values of coefficient c_{108} indicate that

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[1]We would not expect too much relationship between cotton lint and lemons through price, since they are not grown in the same locations in California and thus badly compete for the same land and other farm resources.

a decrease in citrus production is associated with an increase in citrus-cotton lint price ratio. There seems to be an apparent contradiction here between our results and the teachings of economic theory, which suggest positive c_{108}-values. Theory has it that if citrus orcharding and cotton farming are competitors for farm resources, then changes in relative prices in favor of citrus orcharding (i.e., increase in citrus-cotton price ratio) must lead to an increase in citrus production. As noted above, only apparent contradiction exists, for implied in the theory of production is the assumption that the products are mutual substitutes; that is, not only do we have cotton substituted for citrus fruits in the production decision-making process when the price of cotton goes up relative to the price of citrus fruits, but also citrus fruits orcharding is increased at the expense of cotton production when citrus price rises relative to the price of cotton. This assumption is generally not true for citrus farmers. Some acreage is usually diverted to cotton production when cotton prices are very favorable, but it must be emphasized that this is strictly for purposes of maintaining farm income. For general substitution of cotton for citrus fruits as a farm practice, not only must the price of cotton increase but there must also be a decline (actual or potential) in the price of citrus fruits. A glance at $\hat{Y}$ values of current citrus prices (used in constructing variables

$y_{108}(t)$ and $y_{109}(t)$ shows that a trend line of close-to-zero slope can be fitted to these $\hat{y}$ values. This observation together with the one-way substitution relationship between citrus orcharding and cotton production (cotton is substituted for citrus but not the reverse to any significant acreage because of the time element and heavy initial cost involved in citrus orcharding) would therefore indicate that the theory is not necessarily faulty but that it does not apply in this case. The increased cotton prices are likely to have been caused by the government cotton acreage control programs which have been in effect for the last thirty two out of the 45 years currently under study. If farmers are aware of this unnatural cotton situation (which the results seem to confirm) then it is not surprising that the higher the cotton price soars upward the more determined citrus farmers are to "stick" to citrus--an act of hedging against the day that cotton acreage control programs will be relaxed or eliminated in the main cotton-producing States, the cotton market "busted" widely open and prices will start falling. Under conditions of such expectations the coefficient c_{108} is negative.

The coefficient b_{99} of the dummy variable $x_{99}(t)$ representing the influence of the cotton acreage allotment programs, indicates a tendency toward lower citrus production; but this is not significant. The acreage control program imposed upon the cotton-producing States probably had a tendency to raise cotton prices and encourage diversion of resources from citrus orcharding to cotton production (i.e., intensification of cotton production on the limited acreage), especially in Texas and California. The actual cutback in citrus production, however, was negligible at a reasonable significance level.

1. Citrus-vegetable price ratio, $y_{109}(t)$ Barring relation 4.3 (because of its overall high coefficients), the only other negative value of c_{109} among the selected relations is not significant, as its sampling error shows. Of the positive c_{109}-values, two are significant and one lowly significant. Because of the great disparity in the individual values, no attempt was made to average them.

The sign of the coefficient c_{109} of the endogenous (but predetermined) variable $y_{109}(t)$, the citrus-vegetable price ratio, is in agreement with the theory of production discussed in the preceding subsection. An increase in vegetable price (relative to citrus price) will result in substitution of vegetables for citrus orcharding, *ceteris paribus*. These changes in farm production pattern are visible in the States of California and Florida. The sign of c_{109} is correct if price changes are interpreted in the short run framework.

m. Citrus acreage, $x_{901}(t)$ The coefficient b_{901} of the predetermined variable $x_{901}(t)$ is positive in all selected equations and highly significant, significant, or lowly significant depending on the particular equation considered. The average coefficient $b_{901} = 5.0364$ indicates that if citrus acreage increases (decreases) by one thousand acres, citrus production will *ceteris paribus* increase (decrease) by about 5,036 tons. The sign of this change is in conformity with theory because increased acreage must always result in increased total supply of citrus fruits (not considering the irrational negative returns portion of the production function).

n. Time, $x_{96}(t)$, and square of time, $x_{97}(t)$ The coefficient of time, $x_{96}(t)$, is highly significant or significant in all but one of the eight selected relations. In all the selected relations the term "time" represents the effects of changing technology of citrus production--new high-yielding technologies, lower costs, etc. Short run theory of production therefore would suggest that the b_{96}-coefficients be positive, since the continuously improving farm technology[1]

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[1]The variable "time" is also related to income and/or population factors. But these factors affect demand far more than they affect (if at all) supply, and hence are not considered in the specification of our supply functions. It is only when we interpret "time" in the sense of a demand shifter that it becomes obvious why the direction of change of variable $x_{54}(t)$, the population of the United States, is inconclusive and also why the b_{54}-values are almost all nonsignificant (see subsection B.1.d above).

has the effect of increasing citrus supply. The b_{96}-values are in fact positive, except, once again, for relation 4.3.

The coefficient of the square of time, $x_{97}(t)$, is generally negative and highly significant. An examination of Figure 1 shows that the signs of b_{96} and b_{97} are in conformity with the sigmoidal nature of the citrus supply curve.

Because of the sigmoidal nature of the total citrus production curve (with time as the abscissa) the third and fourth powers of time, t^3 and t^4, were originally included in the regression analyses. Most of the coefficients associated with t^3 and t^4 turned out to be very lowly significant, with α of .40 or greater. Consequently, they were eliminated from subsequent analyses. It is not clear to the author why t^3 and t^4 (especially t^3) gave nonsignificant coefficients at α of less than .40. No regression analysis was made with the fifth or higher powers of time as variables.

o. War effect, $x_{98}(t)$ The comparison of Equations 4.3 and 4.4 will reveal the tremendous impact of wartime policy on citrus production. The inclusion of dummy variable $x_{98}(t)$ in relation 4.3 gave estimates of coefficients which, though very high for our purpose, were in general highly significant or significant, with a highly significant b_{98}-value. This is in contrast to relation 4.4 in which we have the same predetermined variables, except for $x_{98}(t)$. The coefficients of this second relation were almost all nonsignificant (except for 3 out of 12) at α of less than .05. Other relations (not selected) gave positive and significant coefficients for $x_{98}(t)$. One relation (4.6) out of five gave a negative, lowly significant value of b_{98}.

The wartime policy can therefore be said to have increased the supply of citrus fruits significantly, but more work is needed to ascertain the size of the parameter.

p. Intercept, x_0 The intercept coefficient b_0 is not significantly different from zero in most of the relations. It also seems that the intercept coefficient b_0 is about the same in magnitude for upswings and downswings in citrus production. No test was made in this thesis for such a hypothesis. A significant difference in the intercept coefficient for upswings and downswings may be interpreted as a change of the mood of the majority of citrus growers "from optimism about the expected profitability of the citrus enterprise during an upswing to pessimism during a downswing".

2. $\underline{y_{101}(t)}$ <u>during the prewar and postwar years only--a comparison</u>

The statistical results for the prewar years (1921-39) and for the postwar years (1948-65) are presented in Tables 3 and 4 respectively.

The important differences between the coefficients of the prewar and the postwar years can be summarized as follows. The current citrus price coefficients c_{103} are both negative and significant, with the postwar values being generally higher than the prewar values, in absolute terms. This contrasts with the positive c_{103}-values obtained for the entire study period; the latter value also lies between (in absolute terms) the prewar and the postwar values.

A probable explanation of the negative c_{103}-coefficients is that a high proportion of the costs in agriculture are fixed, once the investment is made. When prices decline suddenly, the producer cannot reduce his costs much by cutting production. In fact, faced with falling prices, he may attempt to meet his fixed costs by producing more, not less. The situation is further complicated by the additional fact that he has even less control over price than over his cost of production, as he does not know how his competitors will

Table 3. U.S.A. (1921-1939), $y_{101}(t)$: Estimated unit effects and elasticities of variables in selected equations explaining $y_{101}(t)$, the total production of all citrus fruits

Equation number	$y_{103}(t)$ Current citrus price	$x_{11}(t)$ Supply of noncitrus fruits	$x_{12}(t)$ Lagged supply of noncitrus fruits	$x_{54}(t)$ Population of U.S.A.	$x_{15}(t)$ Current price of noncitrus fruits	$x_{104}(t)$ Lagged citrus price
4.9	1.9630 (53.3158)	0.1153 (0.1090)				-1.4087 (7.7069)
4.10	-90.8706 (77.1989)	-0.0164 (0.0131)				12.3053 (11.3958)
4.11			-0.0339 (0.1216)	-591.7605 (2,658.7898)		-0.5928 (17.9511)
4.12	-146.1978 (119.2246)				-14.2768 (25.1303)	14.8745 (72.0578)
4.13	-49.5748 (79.7588)			921.2386 (939.0777)	-7.3408 (29.7911)	15.3284 (13.9017)
4.14					-12.3384 (24.8173)	3.4601 (6.5163)
4.15					-2.0374 (16.8889)	13.7623 (6.1922)
Average[a]	-93.5133				-11.2987	
Elasticities:						
e_M					-0.14	

[a]Average coefficient is based on the at least significant coefficients.

Table 3 (Continued)

Equation number	$x_{105}(t)$ Five-year moving average of citrus prices	$x_{18}(t)$ Index of price of grains	$y_{106}(t)$ Ratio of citrus price to wages	$y_{107}(t)$ Citrus-fertilizer price ratio	$y_{108}(t)$ Citrus-cotton lint price ratio	$y_{109}(t)$ Citrus-vegetable price ratio
4.9	-25.5790 (42.4144)	-5.0278 (6.6085)	-33.4809 (77.9261)	-2,089.2840 (1,303.8446)		1,277.1544 (2,660.9612)
4.10	-22.0564 (39.1335)	-0.8778 (6.6441)	-64.9659 (74.5671)	-486.8847 (1,580.9589)		3,804.7880 (2,939.0111)
4.11	10.7533 (25.8673)		-172.4707 (387.0411)	-3,056.5251 (7,797.5916)	-20.8651 (94.2473)	5,348.3691 (14,368.8491)
4.12	-62.5893 (51.9651)		65.6472 (144.1493)	2,159.8782 (1,367.3313)	50.3446 (147.8699)	
4.13			11.3628 (54.1406)	1,129.0623 (2,339.2702)		
4.14	-6.0370 (39.4224)	-1.5098 (6.6619)	-61.5167 (64.1110)	-1,309.3612 (1,510.8200)		1,519.8872 (1,973.1648)
4.15		-3.9372 (5.9324)				
Average[a]						
e_M						

Table 3 (Continued)

Equation number	$x_{901}(t)$ Citrus acreage	$x_{96}(t)$ Time	$x_{97}(t)$ Square of time	$x_{99}(t)$ Dummy variable for cotton program	x_0 Intercept	R^2
4.9	-16.8703 (22.2759)	476.3978 (459.6930)			9,442.5195 (9,324.1451)	0.951
4.10	-18.7104 (20.5525)	203.7135 (455.9767)	15.8979 (10.2005)		10,286.1133 (8,605.5915)	0.963
4.11		1,235.9436 (5,533.8794)	-16.3023 (110.5732)	-902.0171 (2,715.3584)	65,991.0625 (285,598.2350)	0.956
4.12	-59.7638 (47.8003)					0.965
4.13	4.0607 (17.2207)	-2,071.0781 (2,338.4040)	50.6979 (42.8548)		-97,821.9375 (105,836.8890)	0.955
4.14	-9.4676 (18.8980)	208.5398 (435.4183)	6.8292 (6.3499)		6,663.5195 (9,034.7798)	0.956
4.15		-54.0783 (76.0990)	12.0750 (3.5815)		1,153.6172 (769.1235)	0.906
Average[a]						
e_M						

Table 4. U.S.A. (1948-1965), $y_{101}(t)$: Estimated unit effects and elasticities of variables in selected equations explaining $y_{101}(t)$, the total production of all citrus fruits

Equation number	$y_{103}(t)$ Current citrus price	$x_{11}(t)$ Supply of noncitrus fruits	$x_{12}(t)$ Lagged supply of noncitrus fruits	$x_{54}(t)$ Population of U.S.A.	$x_{15}(t)$ Current price of noncitrus fruits	$x_{104}(t)$ Lagged citrus price
4.16	-2,936.2690 (2,095.8611)	10.5592 (10.9192)				54.0010 (29.1128)
4.17			0.0994 (0.9685)	-326.1542 (534.8915)		41.8148 (29.2794)
4.18	-493.4736 (1,596.9419)				-11.5518 (48.2491)	44.0419 (33.6420)
4.19	-91.5634 (86.0559)			95.7776 (463.8750)	-15.3627 (48.8764)	38.3850 (25.1685)
4.20					-27.2976 (44.0392)	58.8335 (28.7582)
4.21					20.6453 (24.5148)	51.9746 (17.4582)
Average[a]		10.5592	0.0994		-17.4647	
Elasticities:						
e_M					-0.18	

[a]Average coefficient is based on the at least significant coefficients.

Table 4 (Continued)

Equation number	$x_{105}(t)$ Five-year moving average of citrus prices	$x_{18}(t)$ Index of price of grains	$y_{106}(t)$ Ratio of citrus price to wages	$y_{107}(t)$ Citrus-fertilizer price ratio	$y_{108}(t)$ Citrus-cotton lint price ratio
4.16	142.7216 (106.5443)	-103.1810 (92.3158)	11,106.9422 (7,016.4154)	29,051.0684 (30,615.8102)	
4.17	181.3563 (137.7632)		-3,517.5712 (4,099.5000)	21,983.5704 (29,486.8901)	2,189.9904 (2,283.2821)
4.18	178.4172 (151.3361)		-703.0020 (6,924.6789)	19,690.7528 (31,626.3550)	1,402.8411 (2,208.0500)
4.19			1,235.4230 (5,726.4177)	-10,240.0828 (17,721.6956)	
4.20	136.7258 (102.2287)	-115.4350 (95.1703)	-725.2290 (2,500.5562)	30,652.8197 (30,223.6143)	
4.21		-26.7417 (11.0349)			
Average[a]	159.8052				
e_M					

Table 4 (Continued)

Equation	$y_{109}(t)$ Citrus-vegetable price ratio	$x_{901}(t)$ Citrus acreage	$x_{96}(t)$ Time	$x_{97}(t)$ Square of time	x_0 Intercept	R^2
4.16	-51,223.4729 (60,95[illegible]53)	-117.1087 (107.4900)	4,370.4545 (3,163.5670)		-87,613.6875 (66,724.5659)	0.775
4.17	-10,865.2988 (16,423.9228)		12,165.8278 (9,390.6372)		155,563.2500 (147,969.3670)	0.770
4.18		-2.9348 (23.5114)	8,762.7762 (8,284.4078)	-114.7937 (127.8340)	-109,590.8120 (122,634.0480)	0.767
4.19				18.7502 (95.5449)	12,403.9766 (90,648.7221)	0.674
4.20	-34,894.0758 (31,458.5754)	-11.4189 (16.1722)	10,198.7507 (6,951.4291)	-150.7110 (106.5336)	-141,158.0000 (103,293.2570)	0.779
4.21			1,205.5269 (411.4175)	-19.4667 (5.8118)	-11,250.1484 (7,658.9346)	0.612
Average[a]						
e_M						

react to the price change. His individual action has no bolstering effect on the prices of his products. He does not dare to cut production; so nobody cuts production.

Conversely, when prices rise, production cannot expand very much. During World War II, the expansion in citrus production was about 50 per cent, but to a large extent this expansion was the result of favorable weather conditions.

The postwar coefficients for lagged citrus price $x_{104}(t)$ are also consistently higher than for either the prewar period or the entire study period. Moreover, both prewar and postwar values of b_{104} are positive, as opposed to negative for the entire study period. The b_{105}-values, however, bear the same signs. Our subperiod analyses therefore seem to give results that do not conform to theory. It is not plausible for the price elasticity of supply to be negative (e_M = -0.67 for prewar years and e_M = -0.89 for the postwar years). Judging from the signs of the coefficients, we seem to have obtained some demand equations or some hybrid supply-demand equations in our subperiod analyses. Moreover, the price elasticities obtained for all three periods considered seem quite high. The high elasticities in the interdependent systems confirm Wold's hypothesis of a built-in bias due to the fact that the models of this type "are constructed as a hybrid between static and dynamic approaches".

The cross elasticities of citrus supply with respect to the price of noncitrus fruits are about the same in magnitude for the two subperiods, except that they have opposite signs. The cross $e_M = -0.28$ for the entire period is substantially higher than for the individual subperiods.

Another interesting feature of the subperiod analyses is that in the prewar years the citrus-vegetable price ratio $x_{109}(t)$ influenced citrus supply positively, but in the postwar years the effect of $x_{109}(t)$ on $y_{101}(t)$ seems to have changed, as shown by the negative b_{109}-values for the latter subperiod.

The square of time $x_{97}(t)$ does not seem to play any important role in the prewar period. This is not surprising considering the approximately linear trend of $y_{101}(t)$ during these years (see Figure 1).

3. Summary

The objectives of this section were the estimation of equations or relations explaining the total supply of all citrus fruits and the test of the "significance" of the various predetermined variables. The proportion of the explained variance in $y_{101}(t)$ as expressed in the R^2-values is quite high for all the selected relations. In most equations presented in Tables 2, 3 and 4, all coefficients are statistically significant or highly significant. The signs of most of the coefficients are in agreement with the theory of production. In some of the variables the coefficients have the same sign in all selected relations, but in some other variables the coefficients may have different signs. In the latter case, almost invariably the coefficients with the wrong signs (i.e., contrary to theory) are non-significant.

Tests of hypotheses about the price coefficients c_{103}, b_{104} and b_{105} (e.g., $H_0:b_{104} = 0$; $H_A:b_{104} > 0$--one-tailed Student's t-test is significant, therefore accept H_A) leads one to infer that citrus farmers do respond to the current and lagged citrus prices. Gruber (1965) argues that prices are generally taken as substitutes for profit variables, which are not available, so that our statistical results may be taken as support for the hypothesis that the actual and expected profits in the citrus industry are major factors in the development over time of citrus marketing. Price manipulation therefore provides a sound policy instrument for influencing the course of the citrus cycle.

The same conclusion can be made for all other variables in the selected relations, including the level of technology of citrus production for which the variable time stands as a proxy.

C. Analysis of Orange Production

1. Current orange price, $y_{203}(t)$

The coefficients of the current orange price, $y_{203}(t)$, are almost all negative for the entire study period and also for the postwar period. However, their sampling errors show that none of them is significant. On the contrary, the c_{203}-values for the prewar period (1921-39) are all positive and at least significant at α of less than .10. Hence, there appears to be a change in the importance of current orange price over the years; and the downgrading of the influence of $y_{203}(t)$ on $y_{201}(t)$ during the postwar period seems to have overcome the prewar positive influence, with the result that the overall (total) period analysis fails to pick up any influence of current orange price on orange supply.

The statistical results, therefore, imply that in the prewar period (see Table 6) a fall in current price of oranges by one dollar per ton resulted *ceteris paribus* in the decrease of oranges supplied to the market by about 25,264 tons. Almost all the decrease in supply came from the farmers' refusal to harvest part of their orange crop. This is understandable since only fresh-fruit market was the only possible outlet. However, since after late 1930's, orange processing has assumed a tremendous importance in the orange market. About 66 per cent of Florida oranges are processed now and

Table 5. U.S.A. (1921-1965), $y_{201}(t)$: Estimated unit effects and elasticities of variables in selected equations explaining $y_{201}(t)$, the total production of oranges

Equation number	$y_{203}(t)$ Current orange price	$x_{21}(t)$ Supply of apples	$x_{22}(t)$ Lagged supply of apples	$x_{25}(t)$ Current price of apples	$x_{204}(t)$ Lagged orange price
4.22	-274.6163	1.4630			96.2913
	(515.2938)	(1.5418)			(101.5548)
4.23					-84.3993
					(32.6162)
4.24	-19.5127			14.6704	3.0402
	(97.8644)			(7.8984)	(6.1871)
4.25					5.5354
					(8.1378)
4.26			-0.2387		
			(0.1905)		
4.27	-5.0398			16.4694	2.3585
	(27.6886)			(5.5929)	(4.4308)
Average[a]		1.4630	-0.2387	15.5654	
Elasticities:					
e_M				0.27	

[a]Average coefficient is based on the at least significant coefficients.

Table 5 (Continued)

Equation number	$x_{205}(t)$ Five-year moving average of orange prices	$y_{206}(t)$ Ratio of orange price to wages	$y_{207}(t)$ Orange-fertilizer price ratio	$y_{211}(t)$ Orange-grapefruit price ratio	$x_{902}(t)$ Orange acreage
4.22	-28.7313 (64.7082)	-246.0184 (162.4301)	11,685.3562 (20,474.5549)	8,560.3208 (7,798.6490)	-63.9794 (80.0582)
4.23	-33.1577 (19.5218)		8,392.3375 (14,618.0223)	-12,096.2223 (8,602.1379)	134.9907 (176.6386)
4.24	-3.1430 (17.7134)	-42.5419 (36.2028)	826.7729 (3,703.5536)		8.2246 (2.6841)
4.25	-1.7471 (7.8528)	-111.0582 (33.8931)	935.4926 (376.8005)	494.0445 (766.9872)	9.9828 (7.2235)
4.26		-148.1944 (48.9764)	1,079.3107 (416.5998)		12.6338 (4.8499)
4.27		-38.6487 (36.8365)			
Average[a]					10.2804
e_M					

Table 5 (Continued)

Equation number	$x_{96}(t)$ Time	$x_{97}(t)$ Square of time	$x_{98}(t)$ Dummy variable for war effect	x_0 Intercept	R^2
4.22	1,458.8281 (1,609.4891)	5.4598 (21.3348)		65,610.3750 (106,756.6630)	0.959
4.23	1,752.1024 (1,962.2047)	29.3802 (100.3101)	-7,588.3932 (21,549.0254)		0.960
4.24		1.0812 (6.1532)			0.953
4.25	-38.0864 (134.1973)	0.4005 (1.9191)		-1,198.7444 (1,500.6845)	0.945
4.26	-185.7959 (115.1335)			-8,523.2266 (7,142.0491)	0.947
4.27	148.2651 (33.1323)	-1.5342 (0.8348)		951.8901 (786.4297)	0.945
Average[a]					
e_M					

in California the proportion of oranges so used is about 30 per cent. It is not surprising then that the farmers' willingness to let fruits go unharvested has given way to a now-almost-ritual full harvest, since the orange processing industries compete with the fresh fruit market so that the market price does not fall too low. So long as the orange intake by the processing industries continues to have a steady growth, current citrus price $y_{203}(t)$ will always yield nonsignificant coefficients c_{203}. A saturation of the orange market (both the fresh fruit market and processed orange market) will undoubtedly lead to the situation existing in the prewar years, with farmers deliberately embarking upon a policy of "only partial harvest". The price elasticity of orange supply for the prewar period is 0.73, and is rather high.

2. Apple supply, $x_{21}(t)$, and lagged supply of apples, $x_{22}(t)$

The coefficient b_{21} of the supply of apples is positive in all relations for all the three periods considered. Only one relation containing $x_{21}(t)$ passed the "selection test" for each period. Generally the prewar period's b_{21}-values are larger than those for the 1921-65 and 1948-65 periods. The latter b_{21}-values are not much different. All the b_{21}-values are positive and significant at the probability of type I error of less than .25.

The coefficients of lagged supply of apples $x_{22}(t)$, are all negative and just barely significant at α of .50. For all practical purposes one may take the variable $x_{22}(t)$ as nonsignificant.

A conclusion to be drawn from this difference in $x_{21}(t)$ and $x_{22}(t)$ is that the current supply of apples (a substitute product for oranges) has a positive influence on orange harvesting and marketing but that one-year lagged supply of apples has no effect on $y_{201}(t)$ or, if it does at all, the influence is negative. Both signs are as expected in the short run because, for instance, if last year's apple supply was very large demand for oranges (the alternative crop) would be low and the discouraged farmers would either cut down their annual orange grove maintenance or even remove some orange trees.

3. Current prices of apples, $x_{25}(t)$

The average coefficient b_{25} = 15.5654 (Table 5) indicates that if the current prices of apples increase (decrease) by one dollar per ton of apples then *ceteris paribus* the supply of oranges will increase (decrease) by about 15,565 tons.

The coefficients of $x_{25}(t)$ for the postwar period (Table 7) are in close agreement with those for the entire study period (Table 5). They are both positive and significant

Table 6. U.S.A. (1921-1939), $y_{201}(t)$: Estimated unit effects and elasticities of variables in selected equations explaining $y_{201}(t)$, the total production of oranges

Equation number	$y_{203}(t)$ Current orange price	$x_{21}(t)$ Supply of apples	$x_{22}(t)$ Lagged supply of apples	$x_{25}(t)$ Current price of apples	$x_{204}(t)$ Lagged orange price
4.28		24.9773 (28.6943)			-553.9437 (547.1528)
4.29			-0.3750 (0.2498)		61.2362 (46.3134)
4.30	17.2440 (45.9597)			-9.9371 (14.2898)	0.9319 (4.9654)
4.31					
4.32			-0.0505 (0.0928)		3.4377 (3.5411)
4.33	33.2849 (38.0545)			-4.7189 (9.3969)	1.1460 (4.8637)
Average[a]	25.2644	24.9773	-0.3750	-7.3280	
Elasticities:					
e_M	0.73			-0.17	

[a]Average coefficient is based on the at least significant coefficients.

Table 6 (Continued)

Equation number	$x_{205}(t)$ Five-year moving average of orange prices	$y_{206}(t)$ Ratio of orange price to wages	$y_{207}(t)$ Orange-fertilizer price ratio	$y_{211}(t)$ Orange-grapefruit price ratio	$x_{902}(t)$ Orange acreage
4.28	-372.0834 (443.4577)	1,470.9450 (2,700.7877)	-3,844.4127 (1,746.8461)	-8,510.7930 (5,015.2072)	-5,865.2345 (6,783.3446)
4.29	-56.1375 (42.9015)	-685.5303 (483.7708)	12,673.2346 (9,370.0460)	-6,636.8898 (4,747.2444)	-58.4862 (45.3101)
4.30	-7.7106 (23.5823)	-24.0358 (28.0346)	-910.2819 (1,463.2226)		-15.6305 (27.2468)
4.31	6.2179 (12.6812)	-58.8004 (45.0585)	724.5523 (1,035.2118)	-461.4617 (621.9733)	-2.4624 (15.5411)
4.32		-10.9197 (28.5053)	-358.0546 (464.0711)		
4.33		-36.8909 (20.6386)	-1,116.7059 (1,371.3292)		
Average[a]		-39.9090			
e_M					

Table 6 (Continued)

Equation number	$x_{96}(t)$ Time	$x_{97}(t)$ Square of time	x_0 Intercept	R^2
4.28	145,046.2900 (158,024.2290)	-1,711.7048 (1,847.8695)		0.948
4.29	7,323.8187 (5,794.9860)	-82.0196 (70.4638)	411,758.4370 (324,632.1030)	0.939
4.30		3.1585 (7.2324)	-9,853.9766 (9,311.3683)	0.924
4.31	21.8262 (26.5792)	6.6019 (6.4568)	2,554.2524 (3,941.2817)	0.922
4.32	-672.1414 (1,013.0959)	14.5938 (15.0649)	-37,332.2695 (48,342.6978)	0.924
4.33	142.3756 (120.2283)	-3.3332 (6.9197)	1,807.8435 (787.4772)	0.914
Average[a]				
e_M				

Table 7. U.S.A. (1948-1965), $y_{201}(t)$: Estimated unit effects and elasticities of variables in selected equations explaining $y_{201}(t)$, the total production of oranges

Equation number	$y_{203}(t)$ Current orange price	$x_{21}(t)$ Supply of apples	$x_{22}(t)$ Lagged supply of apples	$x_{25}(t)$ Current price of apples	$x_{204}(t)$ Lagged orange price
4.34			-4.6751 (5.0440)		528.1638 (549.5666)
4.35	-892.4521 (495.7931)			14.0491 (30.2394)	-35.9740 (28.1325)
4.36					29.6468 (49.5285)
4.37			-1.1798 (0.6587)		16.1135 (23.6525)
4.38	-33.4011 (170.2250)			18.6361 (11.7503)	5.3767 (15.6196)
4.39		1.1647 (2.8911)			74.3402 (177.8048)
Average		1.1647	-2.4774	16.3381	
Elasticities:					
e_M				0.25	

Table 7 (Continued)

Equation number	$x_{205}(t)$ Five-year moving average of orange prices	$y_{206}(t)$ Ratio of orange price to wages	$y_{207}(t)$ Orange-fertilizer price ratio	$y_{211}(t)$ Orange-grapefruit price ratio	$x_{902}(t)$ Orange acreage
4.34	-1,398.4183 (1,599.6595)	-406.7883 (631.1061)	19,531.9870 (22,410.5971)	17,336.2196 (18,332.8005	-122.2689 (134.3750)
4.35	-92.9316 (133.9986)	2,767.3027 (1,928.5041)	17,095.7357 (21,997.6806)		9.7761 (20.2554)
4.36	-24.2048 (190.2908)	-64.7393 (481.1602)		728.7715 (1,271.3580)	1.8936 (18.2706)
4.37		-313.2823 (498.5027)	2,281.1400 (5,773.8418)		9.9375 (5.9530)
4.38			1,703.4523 (3,868.3563)		
4.39	-220.7185 (395.2860)	-604.8039 (4,173.5927)	12,440.4000 (29,235.9673)	3,230.0326 (6,271.0367)	
Average					
e_M					

Table 7 (Continued)

Equation number	$x_{96}(t)$ Time	$x_{97}(t)$ Square of time	x_0 Intercept	R^2
4.34	-18,655.3919 (24,632.6117)	275.0882 (334.8731)	492,770.6250 (536,069.1670)	0.860
4.35		38.5856 (27.9382)	34,940.8164 (44,183.0280)	0.840
4.36	733.8276 (1,375.3996)			0.814
4.37	1,346.1564 (1,563.1121)	21.8640 (19.5735)	-28,844.3594 (22,784.1537)	0.794
4.38	184.6338 (931.6162)	12.7028 (16.5297)		0.806
4.39	178.7958 (364.5329)	18.9447 (28.5702)	69,980.5625 (103,048.5670)	0.849
Average				
e_M				

and have cross price elasticities with $y_{201}(t)$ of $e_M = 0.25$ and $e_M = -.27$ for the respective periods. The prewar period, on the other hand, has a negative cross-elasticity of orange supply with respect to apple price, $e_M = -0.11$ (Table 6).

4. Lagged orange price, $x_{204}(t)$, and moving average orange price, $x_{205}(t)$

Lagged orange price, $x_{204}(t)$, has a significant positive effect on orange supply in all the three periods. The magnitude of the b_{204}-values is much larger for the postwar period than for the other two periods, implying that the influence of $x_{204}(t)$ on $y_{201}(t)$ has increased over time. The elasticity of orange supply with respect to lagged orange price has also increased over the past four and a half decades.

The coefficients of the five-year moving average of orange prices $x_{205}(t)$ have been consistently negative and only lowly significant for all the periods.

Thus a comparison of the coefficients of $y_{203}(t)$, $x_{204}(t)$ and $x_{205}(t)$ would indicate that only lagged orange price exercises some influence on orange supply, and that current orange price and moving-average orange prices have only a minimal effect on $y_{201}(t)$. This is in contrast to the total citrus supply situation (already discussed) in which all three price variables have some effect on supply.

This statistical analysis therefore points the way to an effective policy instrument for influencing the orange cycle by infering that orange growers in determining the size of their crop harvest do respond principally to lagged orange prices.

5. Other variables

The price ratios $y_{206}(t)$, $y_{207}(t)$, orange acreage $x_{902}(t)$, time variables and the dummy variable for war effect $x_{98}(t)$--all have the same signs as their counterparts in the citrus analysis; their influence on $y_{201}(t)$, i.e. the significance of their coefficients, too is not much different from that of their counterparts on $y_{101}(t)$.

The orange-grapefruit price ratio, $y_{211}(t)$, has positive c_{211}-values all of which are significant for the entire study period (Table 5) as well as for the postwar period (Table 7). The sign is correct if interpreted in the short run framework, since oranges and grapefruits serve as substitute products. However, for the prewar period the coefficient c_{211} has only negative values, all of which are significant at α of less than .05. We may infer from this that probably there has been a change in the decision-making process. That is, in the prewar years changes in $x_{211}(t)$ were taken into account only in the formulation of long-term plans but in the postwar years such changes also enter into short-term plans.

6. Summary

The statistical analysis of the orange cycle point to two interesting results. One is that orange growers do respond in aggregate to lagged orange prices but do not respond very much (if at all) to current prices and a five-year moving average of orange prices. Also, prices of rival products (apples and grapes) have greater influence on orange supply now than before. These together imply not only that the cross elasticity of orange supply with respect to a rival product has increased, but also that now more than ever before the changes in the prices of rival products (for farm space, e.g. grapes) are becoming more important in the determination of the size of the orange crop, i.e. are featuring greatly in short run decision making.

D. Analysis of Grapefruit Production

1. Current grapefruit price, $y_{303}(t)$

The endogenous variable $y_{303}(t)$, the current grapefruit price received by farmers, has positive coefficients in all the selected relations for the entire study period (Table 8) and is significant or lowly significant in all of the relations. The average coefficient c_{303} - 55.6183 indicates that an increase (reduction) in the current grapefruit price of

Table 8. U.S.A. (1921-1965), $y_{301}(t)$: Estimated unit effects and elasticities of variables in selected equations explaining $y_{301}(t)$, the total production of grapefruits

Equation number	$y_{303}(t)$ Current grapefruit price	$x_{31}(t)$ Supply of oranges	$x_{32}(t)$ Lagged supply of oranges	$x_{35}(t)$ Current price of oranges	$x_{304}(t)$ Lagged grapefruit price	$x_{305}(t)$ Five-year moving average of grapefruit prices
4.40	79.6611 (171.2035)	0.5862 (0.2687)			10.7465 (6.8477)	6.0777 (18.0127)
4.41	53.2571 (141.4464)				-3.0151 (8.7469)	17.1872 (21.8022)
4.42				-13.9450 (16.7423)	-2.6436 (4.2734)	23.6927 (7.6373)
4.43			0.1678 (0.5549)		10.3628 (6.4854)	20.1500 (35.7418)
4.44	6.4537 (28.7499)			-21.2506 (11.1047)	4.9043 (5.0506)	
4.45	33.9369 (63.9607)				3.2631 (6.6470)	
Average[a]	55.6183	0.5862	0.1678	-17.5978	7.3191	16.7865
Elasticities:						
e_M	1.21			-0.7143		

[a]Average coefficient is based on the at least significant coefficients.

Table 8 (Continued)

Equation number	$Y_{306}(t)$ Ratio of grapefruit price to wages	$Y_{307}(t)$ Grapefruit-fertilizer price ratio	$Y_{312}(t)$ Grapefruit-orange price ratio	$Y_{309}(t)$ Grapefruit-vegetable price ratio	$x_{903}(t)$ Grapefruit acreage
4.40	557.2541 (447.0944)	-4,832.9070 (8,259.4792)		-4,067.0498 (3,411.7598)	
4.41	-372.6298 (145.4700)		-5,256.9496 (2,201.4175)		8.6214 (7.1180)
4.42	-348.5098 (84.3612)	-1,827.9630 (1,068.5028)		4,689.0580 (2,846.5287)	8.8461 (1.1289)
4.43	-651.2996 (275.9674)			6,899.4545 (6,063.1920)	17.4541 (13.3490)
4.44	-172.0139 (68.0856)				
4.45	-236.9006 (244.2794)	5,084.7069 (2,016.9049)	-7,318.3603 (2,882.9298)	-4,512.6390 (4,809.7482)	4.0081 (4.4451)
Average[a]	-356.2707	-2,834.9351	-6,237.6555	5,789.2563[b] -4,289.8522[c]	9.7324
e_M					

[b]Computed from positive values only.

[c]Computed from negative values only.

Table 8 (Continued)

Equation number	$x_{96}(t)$ Time	$x_{97}(t)$ Square of time	$x_{98}(t)$ Dummy variable for war effect	x_0 Intercept	R^2
4.40	200.5128 (101.1713)			8,126.9727 (16,879.6704)	0.957
4.41		-2.7865 (6.7115)			0.955
4.42		-0.7524 (0.3853)	778.9209 (457.4966)	683.6560 (430.3950)	0.954
4.43	-218.7640 (405.7891)	-2.1050 (3.1146)	665.9903 (1,745.0832)	-9,871.3203 (18,893.6792)	0.955
4.44	100.3635 (21.5357)	-2.6884 (0.4032)		1,205.1943 (558.4879)	0.908
4.45		-1.5950 (1.5075)	620.2255 (510.7189)	6,666.4218 (1,501.3042)	0.952
Average[a]	150.4335	-1.9854	688.3789		
e_M					

Table 9. U.S.A. (1921-1939), $y_{301}(t)$: Estimated unit effects and elasticities of variables in selected equations explaining $y_{301}(t)$, the total production of grapefruits

Equation number	$y_{303}(t)$ Current grapefruit price	$x_{31}(t)$ Supply of oranges	$x_{35}(t)$ Current price of oranges	$x_{304}(t)$ Lagged grapefruit price	$x_{305}(t)$ Five-year moving average of grapefruit prices
4.46	312.6342 (310.9006)	9.6923 (9.6487)		47.2147 (46.8850)	425.6187 (423.6959)
4.47			-2.5047 (16.5109)	5.0513 (8.4402)	3.0359 (3.1732)
4.48	6.5731 (18.0719)		-26.0115 (15.1701)	1.3159 (3.4233)	7.0278 (1.9622)
4.49	9.0963 (9.3677)			4.0679 (3.3770)	
Average[a]	7.3842	9.6923	-26.0115	3.1448	5.0318
Elasticities:					
e_M	0.32		-1.15		

[a]Average coefficient is based on the at least significant coefficients.

Table 9 (Continued)

Equation number	$y_{306}(t)$ Ratio of grapefruit price to wages	$y_{307}(t)$ Grapefruit-fertilizer price ratio	$y_{312}(t)$ Grapefruit-orange price ratio	$y_{309}(t)$ Grapefruit-vegetable price ratio	$x_{903}(t)$ Grapefruit acreage
4.46	-2,104.1703 (2,274.2889)	13,023.5047 (13,619.1294)			725.0408 (737.5309)
4.47	122.7243 (288.8172)	1,535.4540 (3,371.8630)		-3,364.3097 (6,687.1214)	-21.2104 (28.5172)
4.48	-46.7196 (14.9723)	1,475.2764 (1,238.1401)			
4.49	-108.1616 (203.8348)	1,480.2706 (1,543.7013)	-162.6954 (516.3877)	-3,240.3061 (7,170.5222)	-19.0628 (10.2219)
Average[a]	-77.4406	1,497.0003	-162.6954	-3,252.3083	-20.1316
e_M					

Table 9 (Continued)

Equation number	$x_{96}(t)$ Time	$x_{97}(t)$ Square of time	x_0 Intercept	R^2
4.46	-34,972.5281 (34,582.0080)	509.7973 (492.5984)		0.967
4.47		13.4703 (13.6565)	960.7185 (965.4084)	0.962
4.48	26.7754 (18.1624)	0.7188 (3.4889)	948.6169 (335.5111)	0.949
4.49		12.8289 (6.0918)	878.8916 (1,268.3123)	0.963
Average[a]	26.7754	12.6546	929.4090	
e_M				

Table 10. U.S.A. (1948–1965), $y_{301}(t)$: Estimated unit effects and elasticities of variables in selected equations explaining $y_{301}(t)$, the total production of grapefruits

Equation number	$y_{303}(t)$ Current grapefruit price	$x_{31}(t)$ Supply of oranges	$x_{32}(t)$ Lagged supply of oranges	$x_{35}(t)$ Current price of oranges	$x_{304}(t)$ Lagged grapefruit price	$x_{305}(t)$ Five-year moving average of grapefruit prices
4.50	4,260.7144 (3,410.9968)	5.3853 (4.0546)			-186.6796 (147.4580)	-212.5049 (230.0592)
4.51				-22.5331 (17.2442)	12.3306 (5.2959)	-50.5200 (39.6242)
4.52			-0.6266 (1.1324)		20.2658 (52.7104)	-48.2350 (49.2013)
4.53	245.9757 (125.0760)			-16.3831 (5.8322)	11.8558 (4.1147)	
4.54	283.5694 (219.0686)				13.0251 (5.9401)	
Average[a]	264.7676	5.3853	-0.6266	-19.4581	14.3693	-49.3775
Elasticities:						
e_M	4.69			-0.65		

[a]Average coefficient is based on the at least significant coefficients.

Table 10 (Continued)

Equation number	$y_{306}(t)$ Ratio of grapefruit price to wages	$y_{307}(t)$ Grapefruit-fertilizer price ratio	$y_{312}(t)$ Grapefruit-orange price ratio	$y_{309}(t)$ Grapefruit-vegetable price ratio	$x_{903}(t)$ Grapefruit acreage
4.50	-20,071.3432 (15,451.1674)	-7,671.7327 (13,107.9164)		-21,588.8599 (22,294.8661)	257.1646 (199.1102)
4.51	96.1526 (287.6322)	99.2732 (154.6081)		-4,173.0228 (5,176.2603)	11.7677 (4.8240)
4.52		6,486.8021 (11,107.3721)	-2,151.7677 (2,077.2632)	4,990.4546 (2,720.7822)	21.6823 (33.3975)
4.53	627.8676 (259.2530)	5,226.6806 (4,729.7071)			
4.54	944.3295 (803.8228)	13,110.3174 (10,826.3815)	-4,368.7532 (3,284.1112)	-7,234.5046 (9,240.8219)	4.7805 (13.2076)
Average[a]	556.1165	5,856.7413	-3,260.2605	-5,703.7637	12.7435
e_M					

Table 10 (Continued)

Equation number	$x_{96}(t)$ Time	$x_{97}(t)$ Square of time	x_0 Intercept	R^2
4.50	13,014.5941	-224.4282		0.860
	(10,365.5041)	(182.3080)		
4.51		-0.1039	1,480.5957	0.820
		(0.3167)	(700.5795)	
4.52	1,565.0679	-17.9808		0.826
	(4,145.6268)	(63.6819)		
4.53		1.7442		0.819
		(4.1260)		
4.54	1,259.2917	-16.0971	-21,477.6992	0.832
	(1,703.1344)	(24.1241)	(30,242.6969)	
Average[a]	1,412.1798	-17.0389		
e_M				

one dollar per ton ceteris paribus will result in an increase (decrease) in the next year's grapefruit supply of about 55.6183 thousands of tons. The mean price elasticity of grapefruit supply is given by $e_M = 1.212$.

In general, the statistical results of $y_{303}(t)$ for the prewar and postwar periods (Tables 9 and 10) agree with that for the entire period--all coefficients are positive and are significant or lowly significant in the selected relations. However, we note that the c_{303}-values are much larger for the postwar period than for the prewar period, with the values for the entire study period lying in between those of the two subperiods. Traditionally, current grapefruit price is considered not of great importance in decisions concerning production because of the perishable nature of the fruit. Since World War II, however, the greatly increased processing activity of grapefruits (and citrus fruits, in general) seems to have changed the relative importance of some of the variables affecting grapefruit production. The greater values of c_{303} and mean price elasticity of supply for the postwar period with respect to the prewar period may reflect such a change in the production-determining variable $y_{303}(t)$. This study was not designed to test this hypothesis, and so we can only surmise that such a change is suggested by our analysis.

The evaluation of c_{303}-coefficient in terms of microeconomic theory shows that the sign is correct in all relations. In the short run, other things remaining equal, a grapefruit producer will increase (decrease) production if the current grapefruit price increases (decreases).

2. <u>Supply, $x_{31}(t)$, and lagged supply, $x_{32}(t)$, of oranges</u>

The coefficient of the supply of oranges $x_{31}(t)$ is positive in all relations for all the three periods considered. All the b_{31}-coefficients are significant or lowly significant. The prewar values are larger than those for the other periods, whereas the values for the 1921-65 period are all smaller than unity (Table 8)--only one relation containing $x_{31}(t)$ was selected for inclusion in each period.

Lagged supply of oranges, $x_{32}(t)$, has coefficients which are positive for 1921-39 and 1921-65 but negative for the postwar period. All the coefficients are nonsignificant and close to zero in absolute terms. Thus, while the current supply of oranges (a substitute product for grapefruit) has a slightly positive effect on production of grapefruit, the one-year lagged supply of oranges has practically no influence at all on $y_{301}(t)$.

3. <u>Current price of oranges, $x_{35}(t)$</u>

The coefficient b_{35} of the predetermined variable $x_{35}(t)$ is negative and significant in the selected relations (Table 8). The average value $b_{35} = -17.5978$ indicates that an increase (decrease) of current price of oranges by one dollar per ton will, other things remaining equal, lead to or be associated with a decrease (increase) in grapefruit marketing by almost 17,598 tons. The sign of the change conforms to theory because an increase in the price of a competitive product like orange will adversely affect the supply of grapefruit and thus cause, in the short run at least, a decrease in supply of grapefruit. The cross elasticity of grapefruit supply with respect to orange price is about -0.72.

The analyses for the prewar and postwar periods are not much different from that for the entire period sketched above. The b_{35}-values are negative and significant and the average values for the three periods are reasonably close to each other, with the value for 1921-1965 lying between the other two values but closer to that for 1948-65. The same relationship is encountered when the values for the cross elasticity are compared; the $e_M = -1.15$ seems to be slightly too high.

4. Lagged grapefruit price, $x_{304}(t)$

The coefficient of lagged grapefruit price, $x_{304}(t)$, is positive and significant or lowly significant in four of the six relations selected for the entire study period. In the other relations the b_{304}-values were lowly significant and negative. The mean of the positive values is $b_{304} = 7.3191$;

it indicates that if lagged grapefruit price increases (decreases) by one dollar per ton, <u>ceteris paribus</u>, grapefruit supply will increase (decrease) by about 17,319 tons. The sign of the coefficient b_{304} is consistent with short-run economic theory.

With the exception of one relation (4.50 in Table 10), all the b_{304}-values for the prewar and postwar periods are also positive and significant or lowly significant. The average values are 3.1448 and 14.3693 for the prewar and postwar periods, respectively.

A comparison between the endogenous variable $y_{303}(t)$ and its lagged values $x_{304}(t)$ shows that both variables are of almost equal importance in influencing grapefruit production. The number of relations which yield significant c_{303}-values and b_{304}-values is about the same. However, the values of c_{303} are consistently higher than the b_{304}-values for all the three periods under study.

5. Five-year moving average of grapefruit prices, $x_{305}(t)$

For the total study period, the coefficient b_{305} of the predetermined variable $x_{305}(t)$ is positive and significant or lowly significant in the relations selected for Table 8. The average coefficient $b_{305} = 16.7865$ indicates that if the five-year moving average of grapefruit prices increased (decreased) by one dollar per ton, other things remaining equal, grapefruit production would go up (down) by about 16,786 tons.

We note here that all the three grapefruit price variables--$y_{303}(t)$, $x_{304}(t)$ and $x_{305}(t)$--have positive coefficients, though the magnitude of these (average) values differ. It seems reasonable, therefore, to conclude that in the short run as well as in the long run farmers usually tend to increase (decrease) the quantity of grapefruits harvested and marketed as a result of a rise (fall) in grapefruit prices.

The b_{305}-values for the prewar period are positive and generally lowly significant, whereas for the postwar period the coefficients are negative and significant or lowly significant. At the probability of type I level, α, of .10, all the positive b_{305} values for the prewar period are nonsignificant while the negative values for the postwar period are significant. This implies that the variable $x_{305}(t)$ has become more important in influencing decisions on grapefruit production over the years. A plausible explanation of the negative value of b_{305} may be the following: farmers generally hold some notion of a "normal" price range so that the higher (lower) the price is at any given time, the greater is the chance that it will fall (rise). Clearly, where such expectations are commonplace, an increase (decrease) in the five-year moving average of grapefruit prices will lead to or be associated with a reduction (increase) in grapefruit production.

6. Ratio of grapefruit prices to wages, $y_{306}(t)$

The coefficient c_{306} of the ratio $y_{306}(t)$ is negative in all the relations (except 4.40) for the total study period. In relation 4.40, this coefficient is positive. The average value $c_{306} = -356.2707$ indicates that an increase in the ratio $y_{306}(t)$--and hence a decrease in the cost of grapefruit production--will reduce grapefruit production. This is in contradiction to the teachings of short-run microeconomic theory which asserts that the decrease in the cost of production must induce farmers to increase their production of grapefruits. However, in most relations presented in Table 8, the c_{306}-values are not significantly different from zero; so that they do not help us much (if any) in explaining the variation in $y_{301}(t)$, the total production of grapefruits.

Under certain circumstances negative c_{306}-coefficients may be justifiable. Negative c_{306}-coefficient may, for instance, be interpreted within the framework of the longer run. As explained elsewhere, in the longer run, an increase in the ratio $y_{306}(t)$ will, other things remaining equal, improve the profitability expectations of grapefruit growers and induce them to make new plantings and renovate the orchard. This general renovation may result in an immediate but temporary cutback in grapefruit production.

The negative values of c_{306} for the prewar period are also nonsignificant, and hence contribute practically nothing to our knowledge of the variation in $y_{301}(t)$. However, for the postwar period, the c_{306}-values are positive (except for that in relation 4.50) but also barely significant at $\alpha = 0.05$, except for relation 4.53 which yields significant c_{306}-value. This suggests that the variable $y_{306}(t)$ is now beginning to influence grapefruit production. Like some other variables considered, this variable $y_{306}(t)$ now enters into short-run decisions concerning the production of grapefruits, whereas before World War II the influence of $y_{306}(t)$ on grapefruit production, $y_{301}(t)$, was very negligible.

7. Grapefruit-fertilizer price ratio, $y_{307}(t)$

The negative average value of $c_{307} = -2,834.9351$ for the entire study period is rather large. The c_{307}-values are also nonsignificant at $\alpha \leq .05$; they are therefore statistically not much different from zero.

The subperiod analysis reveals that, except for relation 4.50, all the relations for the prewar and the postwar periods yield positive c_{307}-coefficients which are only lowly significant. This implies that for these two subperiods the grapefruit-fertilizer price ratio--another cost item in the production of grapefruits--slightly affects grapefruit production by the way of short-run decision plans.

8. Grapefruit-orange price ratio, $y_{312}(t)$

The coefficient c_{312} of the variable $y_{312}(t)$ has positive values in all relations and for all the three periods considered. The c_{313}-values are significant or lowly significant. Actually this variable has been encountered previously--in the guise of current price of oranges, $x_{35}(t)$. A decrease in the grapefruit-orange price ratio simply implies that the (current) price of oranges is increasing relative to the price of grapefruits; this mya be interpreted as a rise in current orange price, *ceteris paribus*. Thus, under the *ceteris paribus* condition the conclusions of the analysis of $x_{35}(t)$ also hold true for $y_{312}(t)$, and hence need not be repeated. Note that b_{35} and c_{312} have opposite signs, as required by the *ceteris paribus* analysis.

9. Grapefruit-vegetable price ratio, $y_{309}(t)$

The c_{309}-values for the entire study period are evenly divided between positive and negative values--two on each side. The absolute values are about the same for all of them, but the positive values are significant at α of less than .05 while the negative values are significant only at significance level α of less than .10. The positive values have an average of c_{309} = 5,789.2563 and the negative values have an average of c_{309} = -4,289.8522.

Short run theory of production suggests that c_{309}-values be positive; i.e. an increase in vegetable price (relative to grapefruit price) will result in substitution of vegetables for grapefruit farming, other things remaining equal. This may well be the situation facing grapefruit growers in the United States. But one cannot fail to realize that the negative average value of c_{309} may equally well be the relevant value. This is seen by considering the subperiod analyses. Except for relation 4.52, the c_{309}-values for the prewar and postwar periods are all negative. The level of α at which these negative c_{309}-values become significant is also close to .10. Whereas the average values of c_{309} are negative for the prewar and postwar periods, there is no reason to believe this is so for the entire study period. A definitive statement as to the sign of c_{309} for the study period will require additional information which is not presently at hand. For an explanation of the negative values of the c_{309}-coefficients, read subsection B.1.k above.

10. Grapefruit acreage, $x_{903}(t)$

The predetermined variable $x_{903}(t)$ has coefficients which are positive and highly significant, significant or lowly significant for the postwar period as well as for the entire study period. The average coefficient $b_{903} = 9.7324$ for the study period indicates that an increase (decrease) in grapefruit acreage by one thousand acres will, _ceteris paribus_, lead to an increase (decrease) in grapefruit production by 9,732 tons. For these two periods, the positive sign of change is in agreement with economic theory.

For the prewar period, only one out of six b_{903}-values turned out positive and it was lowly significant (relation 4.46 in Table 9). The remaining b_{903}-values (only two of which were selected for inclusion in Table 9) were negative and significant or lowly significant. The negative average value of b_{903} for the prewar period suggests that production might have been carried into the negative returns portion of the production function, given the technological knowhow and the culturally fixed factors of that period. Under the assumption of producer profit maximization, such a production practice is obviously irrational. It is contended here that as a result of education or learning by experience as well as increases in the level of fixed factors and technical progress in agriculture since the war, farmers have come to realize the irrationality[1] of the prewar production pattern and are

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[1]Heady (1952, p. 92) states that irrational production (as it relates to profit maximization) exists if resources can be rearranged in any manner whatsoever to either a) give a greater product from the same collection of resources or b) give the same product with a smaller aggregate outlay of fixed and variable resources.

now employing production plans which fall in an economic area of production (Heady, 1952, Chapter 4), and hence the positive b_{903}-values of the postwar period.

11. Time, $x_{96}(t)$

The coefficient b_{96} of time, $x_{96}(t)$, is positive in all relations and for all the three periods under study, except in relations 4.43 and 4.46. All the positive values of b_{96} are highly significant or significant; the negative values are just significant at α of close to .10. The positive sign of the average b_{96}-values is in agreement with economic theory, since the level of farm technology (for which the variable $x_{96}(t)$ stands as a proxy) affect grapefruit production positively.

12. Square of time, $x_{97}(t)$

The coefficient b_{97} has negative values for the entire study period as well as for the postwar period. On the other hand, the b_{97}-values for the prewar period are positive. These signs are as expected when one considers the shape of the grapefruit supply curve over the years, as depicted in Figure 1. The curve is quadratic upward (or concave from below) for the prewar period, thus implying that both the first and the second partial derivatives of $y_{301}(t)$ with respect to $x_{97}(t)$ are positive (Allen, 1938, p. 185). Similar reasoning can be used to explain the signs for the post-war period and the total study period.

13. War effect, $x_{98}(t)$

The World War II did have a great impact on grapefruit production. The b_{98}-coefficients are all significant at $\alpha = 0.05$ and are also all positive. The average value $b_{98} = 688.3789$ indicates that the wartime conditions or expectation of inflated land and capital values as well as the favorable prices of the wartime period was responsible for a large part of the tremendous increase in grapefruit production that occurred in the years 1940-1946.

14. Intercept, x_0

For most of the relations included in Tables 8, 9 and 10, the intercept coefficient, b_0 is not statistically significant from zero, with a probability of type I error of .05. Only very few of these relations (such as 4.45) are highly significant or significant in one-sided tests. The present analysis does not reveal the direction of change for this variable x_0. Because of the nature of the different factors making up the term "intercept", it is not easy to see a clear-cut unidirectional cause-effect relationship between x_0 and $y_{301}(t)$. The evaluation of x_0 in terms of microeconomic theory is therefore difficult.

15. Summary

The highest significance levels are observed for $y_{303}(t)$, the current grapefruit price, $x_{304}(t)$, the lagged grapefruit price, $y_{306}(t)$, the ratio of grapefruit prices to wages, $x_{35}(t)$, the supply of oranges, $x_{96}(t)$, time, and $x_{98}(t)$, the wartime effect. The coefficients of the last three variables indicate the degree of dependency of the grapefruit-producing sector upon the competing sectors within agriculture, and upon the general conditions (wartime or peacetime) and the level of technical know-how (note that "time" stands for supply-increasing technology) in the economy as a whole. The coefficients of the other (first three) variables show the importance of revenue and cost factors in grapefruit-orcharding decision plans. This is just another way of asserting that grapefruit farmers are really responsive to price changes both of inputs and of outputs.

E. Analysis of Lemon Production

1. Current lemon price, $y_{403}(t)$

The coefficient of the endogenous variable $y_{403}(t)$, the current lemon price received by farmers, is in a one-sided test nonsignificant at a significance level of $\alpha = 0.05$, for the entire study period analysis. The c_{403}-values are all smaller than zero but from the point of view of statistical tests of hypotheses, none of these values is significantly different from zero. In other words, the current lemon price, $y_{403}(t)$, does not have any statistically meaningful influence on lemon production, $y_{401}(t)$, when the total study period is considered.

The same conclusion is reached for the postwar period analysis, even though the negative c_{403}-values of this period are considerably larger in absolute terms. That is, for the postwar period (like the total study period), manipulation of current lemon price will not result in an increase or curtailment of planting and harvesting of lemons to any significant degree.

For the prewar period, however, this conclusion does not hold true. The c_{403}-values for the prewar period are not only positive but also highly significant in all the relations. This implies that in the prewar period, current lemon price featured prominently in the lemon-grower's decision to produce, but that this variable has over time lost such influence. The average coefficient $c_{403} = 1.6690$ indicates that in the prewar period an increase (decrease) in current lemon price of one dollar per ton was accompanied <u>ceteris paribus</u> by an increase (decrease) in lemon production by about 1,669 tons. The sign of the coefficient c_{403} is in agreement with short-run production theory. The price elasticity of lemon supply is $e_M = 0.396$.

2. Lagged lemon price, $x_{404}(t)$

The coefficient b_{404} of lagged lemon price is negative and highly significant or significant for the entire study period and the prewar period. The direction of change portrayed by out analysis seems to be in conflict with short-run theory of production. In the short run, farmers will delay plant cuttings and renovation activities of the orchard if lagged lemon price showed an increase. This has the effect of increasing lemon production. Hence, b_{404} has the "wrong" sign according to this explanation.

However, as pointed out in subsection D.5, if farmers generally hold some idea of a "normal" price range, then the higher the price is at any given moment, the greater is the chance that it will fall. Thus where such a notion is widespread among farmers an increase (decrease) in the lagged lemon price will very likely be associated with a fall (rise) in lemon production, *ceteris paribus*. This is an acceptable explanation of the negative b_{404}-values. The average value $b_{404} = -1.3718$ indicates that an increase (decrease) in the lagged lemon price of one dollar per ton will *ceteris paribus* lead to a decrease (increase) in the lemon production by nearly 1,372 tons.

For the postwar period, the b_{404}-values are also highly significant or significant, but the direction of change is different from that of the two periods discussed above.

The positive values of b_{404} indicate that in the postwar period an increase in lagged lemon price will lead to a change in the same direction (i.e., an increase) in lemon production. The sign, therefore, is in agreement with the short-run production theory.

The preceding discourse indicates that in the postwar period lagged lemon price has come to influence short-run production decisions and hence now more actively helps to determine the annual tree cutting and harvesting, as opposed to the more passive but nonetheless significant longer-run influence it exerted on lemon production decisions of the prewar and war times.

3. Five-year moving average of lemon prices, $x_{405}(t)$

The predetermined variable $x_{405}(t)$, the five-year average of lemon prices received by farmers, has negative coefficients in all of the selected equations, for all the three periods under consideration. The negative b_{405}-values are significant or lowly significant. The average coefficient $b_{405} = -0.4561$ (in Table 11) indicates that if the price trend continued to move upward by an addition of one dollar per ton of lemons to the variable $x_{405}(t)$, the lemon production would decline by about 456 tons, holding all other variables constant. Clearly, such a production behavior can only be explained in terms of the longer run and the "normal"

Table 11. U.S.A. (1921-1965), $y_{401}(t)$: Estimated unit effects and elasticities of variables in selected equations explaining $y_{401}(t)$, the total production of lemons

Equation number	$y_{403}(t)$ Current lemon price	$x_{404}(t)$ Lagged lemon price	$x_{405}(t)$ Five-year moving average of lemon prices	$y_{406}(t)$ Ratio of lemon price to wages	$y_{407}(t)$ Lemon-fertilizer price ratio	$y_{413}(t)$ Lemon-cotton/hay price ratio
4.55		-1.3362 (0.3789)	-0.4561 (0.5407)	-15.4742 (3.2898)	-365.0940 (31.4383)	354.1483 (55.8968)
4.56	-3.8229 (4.0619)	-1.4075 (0.6322)		-21.0614 (4.4308)	-91.6377 (345.7203)	293.2971 (195.5426)
4.57	-0.3454 (2.0682)			-2.5043 (4.2394)	-268.2298 (145.7188)	135.1591 (46.0909)
4.58	-3.0085 (0.4663)					43.6182 (13.6416)
4.59		-0.3626 (0.2883)		-1.7691 (1.0257)	-178.8041 (17.3948)	
Average	-3.4157	-1.3718	-0.4561		-225.9414	260.8681
Elasticities:						
e_M	-0.53					

Table 11 (Continued)

Equation number	$x_{904}(t)$ Lemon acreage	$x_{96}(t)$ Time	$x_{98}(t)$ Dummy variable for war effect	$x_{99}(t)$ Dummy variable for cotton program	x_0 Intercept	R^2
4.55	1.3787 (1.8493)	5.2019 (1.0611)		63.6894 (31.8358)	420.9565 (125.9712)	0.984
4.56	5.1006 (8.7955)	4.6917 (1.8980)	12.1094 (58.1138)	183.7584 (104.5025)	747.1360 (485.7454)	0.985
4.57	4.3946 (3.7820)	15.5630 (4.0424)		65.1567 (83.6003)	586.0036 (228.9790)	0.980
4.58		8.9486 (0.9917)		35.4911 (19.1783)	508.4302 (35.0926)	0.959
4.59	3.7601 (1.2360)	6.8286 (0.6967)			305.7549 (81.8826)	0.962
Average	3.6585	8.2467	12.1094	54.7790	565.6315	
e_M						

Table 12. U.S.A. (1921-1939), $y_{401}(t)$: Estimated unit effects and elasticities of variables in selected equations explaining $y_{401}(t)$, the total production of lemons

Equation number	$y_{403}(t)$ Current lemon price	$x_{404}(t)$ Lagged lemon price	$x_{405}(t)$ Five-year moving average of lemon prices	$y_{406}(t)$ Ratio of lemon price to wages	$y_{407}(t)$ Lemon-fertilizer price ratio
4.60		-0.8010	-1.1972	-5.2989	-71.4358
		(0.1490)	(0.3618)	(1.0316)	(8.2466)
4.61	1.4648	-0.3738		-1.9547	-128.0186
	(0.4370)	(0.2211)		(1.6746)	(22.9490)
4.62	1.6311			-1.9781	-164.0463
	(0.3629)			(0.8920)	(12.3536)
4.63	1.9113				
	(0.4475)				
4.64		-0.3007		-1.8494	-75.0029
		(0.1463)		(0.5178)	(7.3672)
Average	1.6690	-0.4918	-1.1972	-1.9274	-109.6259
Elasticities:					
e_M	0.40				

Table 12 (Continued)

Equation number	$y_{413}(t)$ Lemon-cotton/hay price ratio	$x_{904}(t)$ Lemon acreage	$x_{96}(t)$ Time	$x_{99}(t)$ Dummy variable for cotton program	x_0 Intercept	R^2
4.60	27.9278 (5.4693)	-15.3235 (2.1937)	14.9051 (0.5654)	42.4647 (16.7432)	1,128.1001 (98.4834)	0.997
4.61	1.0351 (9.9302)	-9.4282 (3.1906)	17.0769 (0.7414)	-16.8358 (29.6378)	748.1555 (154.3846)	0.997
4.62	11.9433 (3.7725)			-49.7139 (14.0043)	754.7202 (729.3477)	0.997
4.63	8.9915 (9.9632)		9.3684 (2.2783)		326.2839 (27.7011)	0.913
4.64		-7.5482 (1.4161)	14.3878 (0.9971)		676.6589 (67.1265)	0.985
Average	16.2875	-10.7666	13.9345	-33.2748	626.4546	
e_M						

Table 13. U.S.A. (1948–1965), $y_{401}(t)$: Estimated unit effects and elasticities of variables in selected equations explaining $y_{401}(t)$, the total production of lemons

Equation number	$y_{403}(t)$ Current lemon price	$x_{404}(t)$ Lagged lemon price	$x_{405}(t)$ Five-year moving average of lemon prices	$y_{406}(t)$ Ratio of lemon price to wages	$y_{407}(t)$ Lemon-fertilizer price ratio
4.65	−2.6244 (2.3945)				
4.66		1.6160 (0.4146)		−34.0306 (14.6620)	80.6330 (116.8365)
4.67	−53.0540 (89.0650)	1.8846 (0.7004)		−105.0648 (131.9956)	215.9338 (352.8503)
4.68		5.0038 (9.2808)	−16.9516 (45.8297)	−241.5577 (577.6595)	363.0559 (834.7396)
4.69	−106.8404 (108.5088)	1.3811 (1.3346)	−38.4352 (23.1455)	−472.3269 (328.2477)	328.4926 (359.6045)
Average	−54.1730	1.6273	−27.6934	−272.9831	302.4941
Elasticities:					
e_M	−7.24				

Table 13 (Continued)

Equation number	$y_{413}(t)$ Lemon-cotton/hay price ratio	$x_{904}(t)$ Lemon acreage	$x_{96}(t)$ Time	x_0 Intercept	R^2
4.65	-60.5361 (102.0400)		7.1183 (2.4232)	608.3735 (103.3704)	0.837
4.66		0.7944 (1.9292)	-6.9913 (5.7567)	1,079.3821 (312.2512)	0.934
4.67	820.0806 (1,426.1646)	25.0516 (40.4450)	-31.9864 (48.6186)	3,805.2895 (4,753.6544)	0.937
4.68	1,230.0301 (3,400.6922)	8.5975 (20.6735)	-118.0552 (308.5185)	6,748.5312 (15,581.0926)	0.935
4.69	646.8646 (1,497.3352)			1,789.1558 (1,225.6509)	0.950
Average	733.4726	16.8245	-15.3653		
e_M					

price notion discussed in the preceding subsection.

The contrast between the effects of $y_{403}(t)$, the current lemon price, $x_{404}(t)$, the lagged lemon price, and $x_{405}(t)$, the five-year average of lemon prices on the dependent variable $y_{401}(t)$ is best explained by considering each period separately. In the prewar period, the lemon producer considered the current lemon price (with coefficient c_{403}) as an indicator of short run changes in the lemon market, and the past price variables $x_{404}(t)$ and $x_{405}(t)$--with emphasis on the one-year lagged price, $x_{404}(t)$--as indicators of longer run developments. Thus the lemon grower tended to increase (decrease) lemon supply whenever the current price increased (decreased) in the short run, while as a longer run policy he decreased (increased) lemon supply as the past prices reached and passed (in the upward direction) a certain level.

In the postwar period, the current price ceased to influence decisions or plans concerning lemon supply, and at the same time the one-year lagged price became a dominant variable affecting short run lemon supply plans. Thus in the period 1948-65, short run developments in the lemon-producing sector have been signalled, according to farmer behavior protrayed in this analysis, by changes in the lagged lemon price, $x_{404}(t)$, while the five-year average of lemon prices, $x_{405}(t)$ has continued to serve as an indicator of longer run developments.

4. Ratio of lemon prices to wages, $y_{406}(t)$

The endogenous variable $y_{406}(t)$, the ratio of lemon prices to wages received by hired day labor, has coefficients which are highly significant, significant or lowly significant for each of the three periods considered. For all three periods too the coefficient c_{406} is negative. This indicates that a reduction (increase) in the cost of lemon production--i.e., an increase (decrease) in the ratio $y_{406}(t)$--will reduce (increase) lemon production. As pointed out in subsection B.1.i, the negative value of c_{406} can be explained in the longer run context.

5. Lemon-fertilizer price ratio, $y_{407}(t)$

Fertilizer is another important cost item in lemon production. For the entire study period, the coefficient c_{407} is highly significant, significant or lowly significant and, like c_{406}, is negative. The same argument used to explain the negative c_{406}-values, therefore, can be employed to explain the negative c_{407}-values.

The negative values of c_{407} for the prewar period are all highly significant. The average coefficient c_{407} = -109.6259 can similarly be explained in the framework of the longer run. For the postwar analysis, however, we find that the coefficient c_{407} is positive and only lowly significant (at α of slightly less than .30) in all the relations. This implies that the influence of the cost variable $x_{407}(t)$ on lemon production is probably slipping; its sign indicates that the variable $x_{407}(t)$ is influencing short run production plans in the postwar period.

6. Lemon/hay-cotton price ratio, $y_{413}(t)$

The coefficient of the ratio of lemon price to a weighted average price of a combined hay and cotton lint crop, $y_{413}(t)$, is highly significant, significant or lowly significant (at $\alpha < 0.30$) in all relations for all the three periods. The c_{413}-values are all positive (except for relation 4.65).

The sign of the coefficient c_{413} of the endogenous variable $y_{413}(t)$ is as expected. An increase in the average price of combined hay-cotton crop (relative to lemon price) will result in lemons being substituted for by hay and/or cotton. This explanation is consistent with the short run theory of production.

7. Lemon acreage, $x_{904}(t)$

For the entire study period (Table 11), the predetermined variable $x_{904}(t)$ has positive coefficients which are highly significant, significant or lowly significant depending on the relation considered. The average coefficient

$b_{904} = 3.6585$ indicates that if lemon acreage increases (decreases) by one thousand acres, other things remaining equal, lemon production will increase (decrease) by about 3,658 tons. The sign of b_{904} is correct since in the short run framework increased acreage is associated with greater supply of lemons. This is also true of the postwar period.

The above explanation is unsatisfactory when applied to the subperiod analyses. For both the prewar and postwar periods the c_{904}-values are negative. The negative coefficients are highly significant for all relations in the prewar period but lowly significant (with $\alpha < 0.35$) in the relations of the postwar period. A probable explanation of the negative c_{904}-values may be that production is probably carried to the limit so that the marginal cost of production increases rapidly with changes in acreage.

8. Time, $x_{96}(t)$

From Figure 1 it is obvious that the lemon supply curve can be fitted by a slightly upward sloping linear trend. Consequently, there is no need for a quadratic term and the variable $x_{97}(t)$, the square of time, was eliminated from the analysis. It is worth repeating here that the variable $x_{96}(t)$, time, is only a proxy for technological factors which result in higher yielding varieties and also in lowering the cost of production.

For the entire study period as well as for the prewar period the coefficient b_{96} is positive and highly significant in all relations. This indicates that as the economy grows with time through changes in production technology, the supply of lemons can be expected to increase. This is as expected, since lemon is not an inferior good.

The b_{96}-values for the postwar period are negative, except for relation 4.65 whose b_{96} coefficient is positive and highly significant. The negative coefficients are not significant and hence are of very little explanatory value.

9. War effect, $x_{98}(t)$

The coefficient b_{98} was lowly significant in all relations considered, and the b_{98}-values were positive. Thus, unlike the other citrus fruits, lemon production was not affected to any appreciable degree. The direction of change is as expected.

10. Cotton acreage allotment program, $x_{99}(t)$

The coefficient of the dummy variable $x_{99}(t)$, representing the influence of the cotton allotment programs, is nonsignificant for all time periods. The coefficient b_{99}, however, is positive for the entire study period and the postwar period but negative for the prewar period.

In the prewar period, the negative b_{99}-values indicate that cotton acreage control program might have brought about higher cotton prices. This would reduce the ratio $y_{413}(t)$ and hence, via the positive c_{413}-coefficient, result in lower supply of lemon.

For the other periods, the positive b_{99}-values are as one would expect. An increase in lemon acreage on part or all of the land released from cotton production would increase lemon supply (Table 11).

11. Intercept, x_0

The intercept coefficient b_0 is positive and highly significant or significant. This suggests that factors which are not accounted for in the conventional statistical data used in this analysis play an important role in the development of the lemon cycle.

12. Summary

The empirical results presented in Tables 11, 12 and 13 show, among other things, that lagged lemon price, cost factors represented by lemon-fertilizer price ratio, and the general level of farmer technology (as represented by "time") are the major determining factors in the development of lemon supply. Equivalently, actual and expected profits seem to be very important factors in determining the production of lemon.

The statistical results also show that a relatively small number of variables explains about 95 per cent of the variance of $y_{401}(t)$, the total production of lemons. The inclusion in the equations of more variables leads to small increases in the values of R^2 at the cost of a reduction in the significance levels of the included variables.

The Durbin-Watson d statistic[1] for the relations in the national analyses falls in the insignificant test region, so that we fail to reject the hypothesis of random disturbances (or error terms) in the statistical models. The smallest d-value obtained from the relations is 1.699 and the highest d-value is 3.073.

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[1]Durbin and Watson (1951). For what to do when the null hypothesis of serial independence in the disturbances is rejected, see Theil and Nagar (1961) and Johnston (1963).

VI. EMPIRICAL RESULTS FOR TWO SELECTED REGIONS--COMPARISONS

A. Introduction

Citrus fruits are grown in a number of States--from the South Atlantic States through the South Central States into the Far West or the Pacific States. On commercial basis, however, there is a large concentration of citrus-growing activity in Florida and California. These two States normally produce over 90 per cent of the total U.S. citrus fruits, which comprise oranges, grapefruits, lemons, tangerines, tangeloes, and limes (see section III.B).

The two regions of the United States selected for study in this thesis naturally therefore revolves around Florida and California as the focal States. The regions or "areas" are:

Region I, Southern States. This region includes Florida, Louisiana and Texas. These comprise two South Atlantic States and one South Central State. Cotton and vegetables are the principal competitors for the farm space and labor used in citrus production. Substitution in consumption of citrus fruits (especially between oranges and grapefruits) engendered by price differences is higher for this region than for the country as a whole; noncitrus fruits, e.g. apples, "were noticeably less popular" (Powell and Godwin, 1955, pp. 23ff.).

Region II, Western States. It includes California and Arizona, the only two important (commercially) citrus-producing States in the Far West. The serious competitors for farm resources in this region are grapes, cotton (lint), and hay. While oranges substitute for grapefruits as a result of price ratio changes, the reverse is generally not true. In this region, high orange prices engender substitution by apples.

The regional analysis is expected to reveal the "effects of variables whose inclusion seems not advisable" in the analysis at the national level. It is also expected to give a "better understanding of the regional implications of changes in variables at the national level".

1. Variables explained

The explained variables and the respective tables are:

$y^R_{201}(t)$ the regional total production of oranges during year t. For Region I, this variable is designated as $y_{501}(t)$ and the estimated unit effects are given in Tables 14 through 16. For Region II, the variable is designated as $y_{701}(t)$ and the estimated unit effects are presented in Tables 17 through 19.

$y^R_{301}(t)$ the regional total production of grapefruits during year t. Florida and other Southern States produce close to 90 per cent of all grapefruits in the United States. Hence, this regional analysis was restricted to Region I. The variable was designated as $y_{601}(t)$ and the estimated unit effects are given in Tables 20 through 22.

$y^R_{401}(t)$ the regional total production of lemons during year t. California and Arizona produce nearly 100 per cent of the United States lemon output. This regional analysis is, therefore, obviously for the Western States alone. The variable is designated as $y_{801}(t)$ and is associated with Tables 23 through 25.

The redesignation of the explained variable is necessitated by the fact that the regional analyses do contain some new variables and also that the variables representing some particular economic relationship may not be the same as for the analysis at the national level. For example, as pointed out earlier, at the national level and also for Region II, apples substitute in consumption for oranges; but in Region I, it is grapefruit which substitutes in consumption for oranges.

2. List of explanatory[1] variables

For the most part, the regional variables used are defined in the same way as the national time series listed in section III.C, once a proper redesignation is made. For example, $y_{501}(t)$ and $y_{701}(t)$ are new designations for $y^R_{201}(t)$ and all three are defined in the same way as the national variable $y_{201}(t)$. Similarly, by removing the first figure "5" (also "7") and replacing it by the appropriate designation--"2", in this case--we transform all regional variables like x_{504} and x_{704} into x^R_{204}, the lagged orange price at the regional level. To avoid any confusion, however, the reader is advised to constantly refer to the tables, where all the included variables are always defined. For variables of the above nature, no separate list of regional variables will be presented.

A second group of regional variables is appearing for the first time in this study. These variables are listed and defined as follows:

$y^R_{608}(t)$ the ratio between grapefruit price and the price of cotton lint. Both prices are given in dollars per ton.

$y^R_{508}(t)$ the ratio between the price of a ton of oranges and the price of a ton of cotton lint.

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[1]See footnote on page 28.

$y_{509}^{R}(t)$ the orange-vegetable price ratio. Both prices are in dollars per ton.

$x_{92}^{R}(t)$ the regional supply of fertilizer.

$y_{714}^{R}(t)$ the ratio of orange price to the price of grapes. Both prices are in dollars per ton.

$y_{808}^{R}(t)$ the lemon-cotton lint price ratio. Both prices are in dollars per ton.

$y_{815}^{R}(t)$ the ratio of the price of a ton of lemons to the price of a ton of hay in Region II.

3. Procedure and conventions

The estimation procedure and the manner of presentation of tables of estimates are essentailly the same as for the national analysis. All the relations (and hence the model) satisfy the identifiability conditions--i.e., $K^{**} \geq G^{*} - 1$--and the two-stage least squares was therefore considered the appropriate estimation method. The estimated unit effects of variables, their standard errors, and the average coefficients are presented in a separate table for each region, for each explained variable, and for each time period. In contrast to the treatment of Chapter IV, the estimates of the coefficients will not be interpreted in detail. Instead, we make regional analyses or comparisons of the signs of the coefficients, of their significance levels, and, where applicable, of the elasticity estimates derived from the average coefficients. Each regional analysis is concluded by a brief summary. A complete summary and conclusion of the results of both the national level analyses and the regional analyses will be given in Chapter VII.

B. Comparison of Estimated Unit Effects of Variables in Selected Equations Explaining $y^R_{201}(t)$, the Regional Total Production of Oranges

1. Current orange price, $y^R_{203}(t)$

The estimated unit effect of the current regional orange price upon the regional total production of oranges is positive for the entire study period and also for the prewar period, but negative for the postwar period. For Region I, the positive c_{203}-coefficients are significant, while for Region II they are only lowly significant in all selected relations. For the postwar period, the negative estimated coefficients are lowly significant for both regions. The results indicate that current orange price has always been an important variable in the orange-producing sector of Region I, but that in recent years (due to processing and improved storage facilities) this variable is gradually becoming unimportant. For Region II, this variable seems never to have played an important role in orange

Table 14. Region I, Southern States (1921-1965), $y_{201}^{R}(t)$: Estimated unit effects of variables in selected equations explaining $y_{201}^{R}(t)$, the regional total production of oranges

Equation number	$y_{203}^{R}(t)$ Current orange price	$x_{204}^{R}(t)$ Lagged orange price	$x_{205}^{R}(t)$ Five-year moving average of orange prices	$x_{51}^{R}(t)$ Supply of grapefruit	$x_{52}^{R}(t)$ Lagged supply of grapefruit
5.1		-9.7868 (8.0226)		0.0636 (0.3598)	
5.2		-1.1794 (5.6654)			
5.3		-1.8053 (5.0563)	16.6465 (8.3026)		0.1256 (0.2311)
5.4	44.2107 (18.5134)	-3.5897 (6.1030)			
5.5		-1.6823 (5.3235)	2.1972 (13.5038)		
Average[a]	44.2107	-2.0641	16.6465	0.0636	0.1256

[a]Average coefficient is based on the at least significant coefficients.

Table 14 (Continued)

Equation number	$x_{55}^{R}(t)$ Current grapefruit price	$x_{92}^{R}(t)$ Supply of fertilizer	$Y_{206}^{R}(t)$ Ratio of orange price to wages	$Y_{508}^{R}(t)$ Orange-cotton lint price ratio	$Y_{509}^{R}(t)$ Orange-vegetable price ratio	$x_{902}^{R}(t)$ Orange acreage
5.1		0.7933 (0.5998)	-112.1346 (103.1504)	86.2941 (123.9185)		18.2462 (5.1991)
5.2				90.0205 (32.0219)	27.8729 (86.6311)	
5.3		0.3718 (0.4271)	-34.3423 (15.6193)			11.1866 (3.2199)
5.4	-32.8631 (17.5385)	0.5333 (0.6911)	-93.4606 (25.2719)			
5.5		0.4754 (0.6220)	-65.5248 (46.5837)	74.7618 (136.2361)		15.3618 (3.6538)
Average[a]	-32.8631	0.5434	-76.3655	83.6921	27.8729	14.9315

Table 14 (Continued)

Equation number	$x_{96}^{R}(t)$ Time	$x_{97}^{R}(t)$ Square of time	$x_{98}^{R}(t)$ Dummy variable for war effect	$x_{99}^{R}(t)$ Dummy variable for cotton program	x_0 Intercept	R^2
5.1	-232.9197 (147.5909)	2.2983 (1.1730)	184.4419 (310.8415)	-19.1944 (86.0003)	1,000.2402 (1,374.9552)	0.958
5.2	128.2190 (41.9650)		246.6455 (283.7980)	-1,056.0817 (358.1201)	761.4719 (596.6135)	0.928
5.3						0.940
5.4	60.8668 (30.0911)	0.1827 (1.0923)			1,749.2722 (667.0017)	0.928
5.5	-159.3299 (56.9200)	1.8472 (1.2866)			417.7443 (1,466.9172)	0.950
Average[a]	94.5429[b] -196.1248[c]	2.0727	215.5437		982.1821	

[b]Computed from positive values only.

[c]Computed from negative values only.

Table 15. Region I, Southern States (1921–1939), $y_{201}^{R}(t)$: Estimated unit effects of variables in selected equations explaining $y_{201}^{R}(t)$, the regional total production of oranges

Equation number	$y_{203}^{R}(t)$ Current orange price	$x_{204}^{R}(t)$ Lagged orange price	$x_{205}^{R}(t)$ Five-year moving average of orange prices	$x_{51}^{R}(t)$ Supply of grapefruit	$x_{52}^{R}(t)$ Lagged supply of grapefruit
5.6		−0.3308 (2.3278)			
5.7		−0.8985 (2.6204)	1.1106 (4.7761)		0.2765 (0.2164)
5.8	26.5778 (9.0871)	1.5712 (1.8804)			
5.9		−0.8867 (2.3525)			
5.10		−1.4546 (1.6691)		0.5911 (0.2440)	
Average	26.5778	−1.0799	1.1106	0.5911	0.2765

Table 15 (Continued)

Equation number	$x_{55}^{R}(t)$ Current grapefruit price	$x_{92}^{R}(t)$ Supply of fertilizer	$y_{206}^{R}(t)$ Ratio of orange price to wages	$y_{508}^{R}(t)$ Orange-cotton lint price ratio	$y_{509}^{R}(t)$ Orange-vegetable price ratio	$x_{902}^{R}(t)$ Orange acreage
5.6				7.4938 (11.2918)	56.9946 (33.1306)	
5.7		0.3802 (0.2513)	-14.1238 (4.5898)			4.9672 (2.3074)
5.8	-8.2817 (3.3592)	0.4898 (0.3356)	-42.8612 (12.9627)			
5.9		0.2477 (0.2506)	-24.5518 (11.4067)		42.5776 (39.0087)	
5.10		0.1202 (0.2221)	-7.2021 (6.1825)	6.0246 (7.1880)		2.6529 (4.8177)
Average	-8.2817	0.3095	-22.1857	6.7592	49.7861	3.8100

Table 15 (Continued)

Equation number	$x_{96}^R(t)$ Time	$x_{97}^R(t)$ Square of time	$x_{99}^R(t)$ Dummy variable for cotton program	x_0 Intercept	R^2
5.6	-39.2660 (21.6066)	4.1199 (1.2146)	-120.6674 (149.2278)	808.2974 (223.8668)	0.913
5.7				2,128.5090 (2,045.5495)	0.904
5.8	24.5878 (23.2964)	2.2011 (0.7419)		696.5766 (158.9149)	0.960
5.9	-26.6601 (41.3675)	2.7752 (1.1433)		644.8140 (601.9292)	0.931
5.10	-27.0004 (56.4546)	1.0598 (1.4385)	-138.3453 (119.7086)	298.3003 (345.5538)	0.970
Average	-30.9755	2.5390	-129.5063	611.9970	

Table 16. Region I, Southern States (1948–1965), $y^R_{201}(t)$: Estimated unit effects of variables in selected equations explaining $y^R_{201}(t)$, the regional total production of oranges

Equation number	$y^R_{203}(t)$ Current orange price	$x^R_{204}(t)$ Lagged orange price	$x^R_{205}(t)$ Five-year moving average of orange prices	$x^R_{51}(t)$ Supply of grapefruit	$x^R_{52}(t)$ Lagged supply of grapefruit
5.11		5.9318 (12.0474)		0.6210 (0.6761)	
5.12		7.4922 (7.2777)			
5.13		5.8521 (10.1450)	21.3091 (20.9242)		0.0126 (0.0519)
5.14	−58.1649 (52.8490)	17.7784 (8.3730)			
5.15		5.0592 (8.0005)	99.5790 (51.8630)		
Average[a]	−58.1649	6.0838	60.4440	0.6210	0.0126

[a]Average coefficient is based on the at least significant coefficients.

Table 16 (Continued)

Equation number	$x_{55}^{R}(t)$ Current grapefruit price	$x_{92}^{R}(t)$ Supply of fertilizer	$y_{206}^{R}(t)$ Ratio of orange price to wages	$y_{508}^{R}(t)$ Orange-cotton lint price ratio	$y_{509}^{R}(t)$ Orange-vegetable price ratio	$x_{902}^{R}(t)$ Orange acreage
5.11		1.0359 (1.1838)	96.8996 (163.1859)	-289.1144 (190.2049)		11.1247 (6.4432)
5.12				-69.0956 (80.1462)	-140.6694 (97.8460)	
5.13		0.4595 (0.9179)	160.8872 (47.0022)			7.1705 (4.5137)
5.14	-54.2646 (28.9563)	0.2547 (0.9241)	392.9333 (373.0798)			
5.15			11.3491 (199.2139)		-196.6952 (261.7732)	4.4271 (4.2801)
Average[a]	-54.2646	0.5833	216.9067	-179.1050	-168.6823	7.5741

Table 16 (Continued)

Equation number	$x_{96}^{R}(t)$ Time	$x_{97}^{R}(t)$ Square of time	x_0 Intercept	R^2
5.11	218.1881 (601.6767)	-1.7986 (8.6451)	-7,582.3750 (8,842.7704)	0.901
5.12	1,121.8232 (298.2697)	-13.9315 (4.4785)	-17,248.1875 (5,174.6878)	0.831
5.13			-4,431.7734 (2,526.6039)	0.851
5.14	842.6130 (289.4652)	-9.8888 (4.4516)	-14,090.3437 (4,575.6561)	0.890
5.15	2,765.9090 (1,177.3512)	-39.3044 (17.4127)	-49,088.0625 (21,266.5196)	0.914
Average[a]	982.2181	-16.2308	-10,838.1693	

Table 17. Region II, Western States (1921-1965), $y^R_{201}(t)$: Estimated unit effects of variables in selected equations explaining $y^R_{201}(t)$, the regional total production of oranges

Equation number	$y^R_{203}(t)$ Current orange price	$x^R_{204}(t)$ Lagged orange price	$x^R_{205}(t)$ Five-year moving average of orange prices	$x^R_{21}(t)$ Supply of apples	$x^R_{22}(t)$ Lagged supply of apples	$x^R_{25}(t)$ Current price of apples
5.16	17.1239 (38.0651)	-8.3581 (23.5618)	-2.8628 (23.5128)			9.6555 (41.8420)
5.17		4.1400 (2.6403)		0.3128 (0.9920)		
5.18		4.8520 ((1.7498)				
5.19		5.4299 (1.9551)	-7.3231 (2.9999)		-0.2707 (0.8974)	
5.20	1.8591 (4.5215)	2.8507 (1.6984)				4.1827 (2.6643)
5.21		5.1071 (1.8518)	-1.3278 (3.7747)			
Average	9.4915 17.1239[a]	4.4760	-3.8379	0.3128	-0.2707	6.9191

[a]Coefficient in relation 5.16 only.

Table 17 (Continued)

Equation number	$x^R_{92}(t)$ Supply of fertilizer	$y^R_{206}(t)$ Ratio of orange price to wages	$y^R_{508}(t)$ Orange-cotton lint price ratio	$y^R_{714}(t)$ Orange-grapes price ratio	$x^R_{902}(t)$ Orange acreage
5.16	0.2811 (2.3218)	-266.2019 (602.6860)	66.2314 (174.7551)	289.3590 (407.2204)	
5.17		-11.7579 (33.3220)	-18.4424 (22.4382)		4.9476 (5.0083)
5.18			-20.7297 (13.7034)	-22.1737 (92.3590)	
5.19	0.2631 (0.2426)	-28.7254 (10.1106)			5.9072 (3.6127)
5.20	0.1817 (0.1552)	-34.0599 (17.7583)			
5.21	0.1592 (0.2296)	-4.8587 (20.9343)		-107.3080 (90.3697)	2.8866 (3.6266)
Average	0.2212	-19.8507	-19.5861	-64.7405	4.5804

Table 17 (Continued)

Equation number	$x^R_{96}(t)$ Time	$x^R_{97}(t)$ Square of time	$x^R_{98}(t)$ Dummy variable for war effect	$x^R_{99}(t)$ Dummy variable for cotton program	x_0 Intercept	R^2
5.16	-202.5246 (684.1895)	-1.8447 (2.5289)		1,190.2595 (1,382.4283)		0.842
5.17	80.5780 (39.5340)	-1.8841 (0.8748)	275.4975 (131.3459)	-124.6741 (243.7958)	-173.3930 (1,335.4562)	0.830
5.18	114.3740 (17.9885)	-2.3553 (0.3438)	278.5980 (154.9122)	-77.7159 (172.7768)	423.1438 (229.8428)	0.815
5.19					227.7500 (113.7013)	0.786
5.20	79.4611 (16.6525)	-1.6148 (0.5870)			814.4519 (337.8018)	0.828
5.21	75.9918 (30.1453)	-1.3621 (0.7206)			114.4068 (740.6468)	0.817
Average	87.6012	-1.6122	277.0477	-101.1950	394.9381	

Table 18. Region II, Western States (1921-1939), $y^R_{201}(t)$: Estimated unit effects of variables in selected equations explaining $y^R_{201}(t)$, the regional total production of oranges

Equation number	$y^R_{203}(t)$ Current orange price	$x^R_{204}(t)$ Lagged orange price	$x^R_{205}(t)$ Five-year moving average of orange prices	$x^R_{21}(t)$ Supply of apples	$x^R_{22}(t)$ Lagged supply of apples	$x^R_{25}(t)$ Current price of apples
5.22		7.1207 (6.4572)		1.6190 (1.4932)		
5.23		4.1517 (1.7205)				
5.24		1.2317 (2.5827)	0.2102 (5.8050)		-0.6548 (0.9998)	
5.25	4.7360 (8.2127)	5.2660 (5.0912)				7.3084 (5.8029)
5.26		4.0407 (5.1992)	-2.2761 (6.6545)			
Average[a]	4.7360	4.3621	-2.2761	1.6190	-0.6548	7.3084

[a]Average coefficient is based on the at least significant coefficients.

Table 18 (Continued)

Equation number	$x^R_{92}(t)$ Supply of fertilizer	$y^R_{206}(t)$ Ratio of orange price to wages	$y^R_{508}(t)$ Orange-cotton lint price ratio	$y^R_{714}(t)$ Orange-grapes price ratio	$x^R_{902}(t)$ Orange acreage
5.22	17.4992 (11.3020)	-69.9995 (34.2114)	1.7256 (7.3507)		-56.6041 (33.0136)
5.23			-6.9096 (6.8200)	-32.6287 (45.4504)	
5.24	2.7884 (4.3854)	-27.7680 (9.4780)			-17.3380 (19.8797)
5.25	5.1721 (8.0284)	-11.0823 (46.3460)			
5.26	12.3963 (9.4238)	-62.1185 (35.8192)		-54.4209 (81.8609)	-36.4422 (25.2814)
Average[a]	9.4640 3.9802[b]	-42.7421	-6.9096	-43.5248	-36.7947

[b]Computed from relations 5.24 and 5.25 only.

Table 18 (Continued)

Equation number	$x^R_{96}(t)$ Time	$x^R_{97}(t)$ Square of time	$x^R_{99}(t)$ Dummy variable for cotton program	x_0 Intercept	R^2
5.22	303.1956 (134.2907)	-12.6675 (7.5878)	-108.7157 (217.8369)	9,991.1484 (5,403.3106)	0.888
5.23	74.3080 (35.7176)	-0.5170 (2.0769)	-111.0414 (186.1086)	375.5647 (190.9479)	0.827
5.24				-3,520.7004 (1,704.7618)	0.862
5.25	43.5381 (53.5206)	-3.1133 (6.9643)		481.3911 (377.2660)	0.868
5.26	220.7632 (105.9138)	-9.4642 (6.6517)		7,140.3047 (4,250.8923)	0.878
Average[a]	160.4512 58.9230[c]	-8.4150	-109.8785	428.4779	

[c]Computed from relations 5.23 and 5.25 only.

Table 19. Region II, Western States (1948-1965), $y^R_{201}(t)$: Estimated unit effects of variables in selected equations explaining $y^R_{201}(t)$, the regional total production of oranges

Equation number	$y^R_{203}(t)$ Current orange price	$x^R_{204}(t)$ Lagged orange price	$x^R_{205}(t)$ Five-year moving average of orange prices	$x^R_{21}(t)$ Supply of apples	$x^R_{22}(t)$ Lagged supply of apples	$x^R_{25}(t)$ Current price of apples
5.27		0.1434 (4.8969)		0.5353 (2.0526)		
5.28		1.8234 (3.9059)				
5.29		2.9158 (5.4054)	-3.2693 (8.4946)		0.7852 (1.8105)	
5.30	-68.6688 (137.3828)	2.3649 (4.6275)				1.2475 (8.1042)
5.31		4.2603 (9.3242)	-15.1946 (29.3854)			
Average	-68.6688	2.8411	-9.2319	0.5353	0.7852	1.2475

Table 19 (Continued)

Equation number	$x^R_{92}(t)$ Supply of fertilizer	$y^R_{206}(t)$ Ratio of orange price to wages	$y^R_{508}(t)$ Orange-cotton lint price ratio	$y^R_{714}(t)$ Orange-grapes price ratio	$x^R_{902}(t)$ Orange acreage
5.27	0.3612 (0.8336)	129.9190 (351.3057)	-171.9871 (229.5490)		1.7723 (7.0330)
5.28			-71.0958 (44.1739)	-98.8525 (243.0628)	
5.29	0.1911 (0.3641)	114.3587 (70.8212)			3.5407 (6.5071)
5.30	0.3391 (0.8330)	537.5188 (1,330.3502)			
5.31	0.5548 (0.6027)	344.9925 (277.3371)		-74.2566 (93.1563)	16.0741 (15.7697)
Average	0.3616	281.6972	-121.5414	-86.5545	7.1290 2.6565[a]

[a]Computed from relations 5.27 and 5.29 only.

Table 19 (Continued)

Equation number	$x_{96}^R(t)$ Time	$x_{97}^R(t)$ Square of time	x_0 Intercept	R^2
5.27	-468.1218 (862.2500)	6.0143 (10.7301)	10,923.5898 (14,186.8103)	0.739
5.28	-45.0284 (148.1630)	7.2270 (2.0032)	2,921.2197 (2,735.2295)	0.711
5.29			2,326.7180 (3,449.5378)	0.713
5.30	-513.2535 (1,336.4563)	7.3076 (19.0800)	9,889.2773 (20,971.4691)	0.701
5.31	-759.0703 (1,143.3913)	9.5169 (14.9484)	7,551.4180 (8,152.9413)	0.728
Average	-580.1485	7.5164	6,722.4445	

production, at least for the period under study. It is not surprising then that, in terms of average mean elasticities, the estimated response to changes in the current orange price is larger for Region I. The magnitude of the regional elasticity estimates is directly related to the proportion of the value of citrus fruits in the region's total value of agricultural production.

2. Lagged orange price, $x^R_{204}(t)$

In the short run, the b_{204}-coefficients are expected to be positive; in the longer run and/or under the assumption of a widespread notion of a "normal" price range, however, these coefficients are expected to be negative. For Region I, the b_{204}-values are negative (except in relation 5.8) and lowly significant in all relations for the prewar period and the entire study period. The coefficients for the postwar period are positive and significant or lowly significant. A comparison between the coefficients of $y^R_{203}(t)$ and $x^R_{204}(t)$ reveals that lagged orange price is becoming very important (at the expense of current orange price) in short-run decisions concerning orange harvesting and marketing in Region I, the Southern States.

In Region II, b_{204} is highly significant, significant or lowly significant according to the relation considered. For each of the three periods under study, the values of

b_{204} are positive (except in relation 5.16). This implies that traditionally grove owners in the Western States have considered lagged orange price rather than the current orange price as one of the important factors affecting (short-run) orange production plans.

3. Five-year moving average of orange prices, $x^R_{205}(t)$

The coefficient b_{205} is positive in all relations and for all time periods for Region I. The coefficient is significant or lowly significant. For Region II, on the other hand, the b_{205}-values are negative and are also significant or lowly significant.

4. Supply of grapefruit, $x^R_{51}(t)$, and supply of apples, $x^R_{21}(t)$

As already pointed out, grapefruit substitutes for oranges in the Southern States when the relative price of oranges goes up. In the Western States apples substitute for oranges when similar price changes occur. The variables $x^R_{51}(t)$ and $x^R_{21}(t)$ are therefore the logical equivalents of $x_{21}(t)$ at the regional level.

Grapefruit and apples compete with oranges for the consumer's income, so that in the short run positive values of b_{51} and b_{21} are expected. These are obtained in all selected equations containing $x^R_{51}(t)$ or $x^R_{21}(t)$. The b_{51}-values of Region I are significant or lowly significant, while the

b_{21}-values of Region II are lowly significant. The b_{21}-values are generally larger than those for b_{51}.

5. Lagged supplies of grapefruit, $x_{51}^{R}(t)$, and apples, $x_{22}^{R}(t)$

Lagged supply of apples is not significant as a factor affecting the production of oranges in Region II. The b_{72}-values are all in the neighborhood of zero and in fact are statistically not significant from zero. Lagged grapefruit price, $x_{22}^{R}(t)$, on the other hand, is significant in Region I at a probability of type I error of less than 0.25. The positive b_{52}-values indicate that, as expected, an increase in last year's supply of grapefruit would stimulate orange production this year.

6. Current prices of grapefruit, $x_{55}^{R}(t)$, and of apples, $x_{25}^{R}(t)$

Since grapefruit and oranges are competitive products, changes in the current price of grapefruits will, via supply analysis, lead to changes in orange production, $y_{201}^{R}(t)$, in the opposite direction. That is, negative values of coefficient b_{55} are expected. Such values are indeed obtained for the grapefruit coefficients b_{55} of Region I. These estimates are significant or lowly significant in one-sided tests.

The relationship between orange production, $y_{201}^{R}(t)$, and apple prices, $x^R_{25}(t)$, is one more of demand analysis than of supply analysis; and hence the b_{75}-coefficients are expected to be positive, which in fact they are (for Region II).

7. Supply of fertilizer, $x^R_{92}(t)$

All selected estimates are positive as expected, since fertilizer is an important input in orange production. The b_{92}-coefficients are at least lowly significant in one-sided tests for both regions; the significance levels are relatively unsatisfactory for Region II. The magnitude of the elasticity estimates is approximately twice as large for Region I as for Region II. This difference in magnitude can be attributed to the relatively high fertilizer cost as a proportion of total cost of orange production in Region I.

8. Ratio of orange price to wages, $y^R_{206}(t)$

The coefficient c_{206} of the ratio of regional orange price to regional average wages received by hired day laborer is negative for the prewar period and the entire study period for both regions. Also, for both Regions I and II the postwar values of c_{206} are positive. All the c_{206}-coefficients (positive and negative) are at least lowly significant, with about five being highly significant. Once again, the significance levels are relatively better for Region I than for Region II for this second input. The positive postwar values are in conformity with short run economic theory. The negative values of c_{206} can be meaningfully interpreted within the long run framework, but are mainly nonsignificant.

9. <u>Orange-cotton lint price ratio, $y^R_{508}(t)$</u>

The production of cotton lint is an enterprise that competes with the production of oranges for farm space and other resources. Consequently, if the price of cotton lint received by farmers should go up in the short run, one would expect to find changes in $y^R_{201}(t)$ in the opposite direction. This means that a change in the reciprocal of cotton lint price will change $y^R_{201}(t)$ in the same direction. Thus for short run analysis, it is clear that the values of c_{508} will be positive, if the coefficient c_{203} is positive.

The evaluation of the c_{208}-coefficient in terms of microeconomic theory is difficult because both $y^R_{508}(t)$ and $y^R_{201}(t)$ are jointly dependent endogenous macrovariables. There is therefore no clear-cut unidirectional cause-effect relationship.

In the short run, farmers will generally increase orange supply if the orange-cotton price ratio goes up. Hence, the positive c_{508}-values of Tables 14 and 15--representing the $y^R_{508}(t)$ variable for Region I for the entire study period and the prewar period, respectively--are appropriately explained in terms of the short run. Also for the postwar period, the negative c_{508}-coefficients of Region I can be meaningfully considered in the short run framework, since the current orange price has negative coefficients.

With respect to the negative c_{508}-coefficients of Region II for all three time periods, we can employ the concept of a "widespread normal price range" for oranges to explain their occurrence as a long run phenomenon. This relationship is reflected in the magnitudes of the mean elasticity estimates.

The difference in the magnitude and the signs of the elasticity estimates for the regional ratio $y^R_{508}(t)$ may be associated with an increasing number of competing enterprises. Region I has a smaller number of competing enterprises and also the region's resources of production are generally less specialized and hence can be more easily transferred from one enterprise to another.

10. Orange-vegetable price ratio, $y^R_{509}(t)$, and orange-grapes price ratio, $y^R_{714}(t)$

Grape production competes with orange production for resources mainly in Region II. Therefore the effect of changes in the current regional price of grapes upon the regional total production of oranges is investigated only for this region. Similarly, the effect of current regional vegetable price upon $y_{201}^{R}(t)$ is studied for Region I alone.

For each period and for each region, the coefficients c_{509} and c_{714} have the same signs as those of c_{508} of $y_{508}^{R}(t)$ discussed above. Therefore, the signs may be interpreted in the same manner as is done above. The level of significance is slightly better for the values of c_{509} than for the values of c_{714}.

11. Orange acreage, $x_{902}^{R}(t)$

For a short run analysis, the b_{902}-coefficients are expected to be equal to or larger than zero. The sign of the estimated coefficient is positive as expected in all selected equations for Region I. In this region, acreage is very important in decisions concerning orange production. This can be inferred from the level of significance of the b_{902}-coefficients. These coefficients for Region I are either highly significant or significant.

For Region II, the b_{902}-values are also positive for the total study period and the postwar period, but negative for the prewar period. The positive coefficients are significant or lowly significant. The negative b_{902}-coefficients are of little explanatory value since they all have "low" significance levels.

Expressed in average mean elasticities, the estimated response to changes in the orange acreage for Region I is about three times as large as that for Region II.

12. Time, $x^R_{96}(t)$, and square of time $x^R_{97}(t)$

The variable time has both positive and negative coefficients b_{96} for the prewar period and the total study period in each region. The positive b_{96}-coefficients are at least significant, while the negative values tend to be lowly significant. For these two periods, the average tends to be negative for Region I and positive for Region II. This order is reversed when we consider the postwar period: Region I has b_{902}-coefficients which are all positive and Region II has all negative coefficients. Interpreting $x^R_{96}(t)$ as a proxy for the regional changes in the level of production technology, the b_{96}-coefficient is expected to be positive. The statistical results seem to suggest that the cross elasticity of supply for oranges has moved in opposite directions in Regions I and II during the period studied. The cross elasticity has increased for Region I, while the direction of the predicted change becomes plausible only if the cross elasticity has decreased.

The square of time, $x^R_{97}(t)$, was more important in the prewar period than in the postwar period. It is also more important as a variable affecting $y^R_{201}(t)$ for Region I than for Region II.

13. War effect, $x_{98}^{R}(t)$

Positive b_{98}-coefficients are obtained for both regions. The coefficients are lowly significant for Region I but are significant for Region II. This implies that orange production was affected less by wartime prices in Region I than in Region II. This relationship is also reflected in the magnitudes of the mean elasticity estimates, which indicate that orange production in Region II responded to the wartime conditions by about twice the response in Region I.

14. Cotton acreage allotment program, $x_{99}^{R}(t)$

Positive b_{99}-coefficients are to be expected since the land released from cotton production can be wholly or partially cultivated to orange to increase orange supply. Contrary to such an expectation, the effect of the wartime policy on $y_{201}^{R}(t)$ is positive in only one relation (relation 5.16).

The negative values are all lowly significant for Region II but significant at an acceptable level for Region I. The response of $y_{201}^{R}(t)$ to changes in $x_{99}^{R}(t)$ is higher for Region I than for Region II.

15. Intercept, x_0

The estimated intercept coefficient, b_0 is positive and significant in both regions and for all three time periods considered, except for Region I during the postwar period. In the latter period, b_0 is negative and highly significant or significant.

16. Summary

Quite a large number of variables exert some influence on $y^R_{201}(t)$, the regional total production of oranges, in the two selected regions of the United States. But, as explained elsewhere, not all of these variables can be included in an equation at the same time without greatly reducing the significance levels of the individual coefficients, though the value of R^2 may actually increase. The differences among the two regions in the magnitude of the predicted response are associated principally with the varying degree of specialization of resources. California production is highly commercialized, so that higher price responsiveness and speculative behavior is not surprising for Region II. The R^2-values for most selected relations are between 0.83 and 0.96 for Region I and between 0.70 and 0.88 for Region II.

C. Variables in Equations Explaining $y^R_{301}(t)$, the Regional Total Production of Grapefruits

1. Current grapefruit price, $y^R_{303}(t)$

This regional analysis was restricted to Region I only because, as already pointed out, Florida and the other

Southern States produce about 90 per cent of the total production of the United States grapefruits. Only about 9 per cent of the United States grapefruit production activity is undertaken in the Western States. The other one per cent is produced in scattered areas throughout the United States.

The coefficient b_{303} of current grapefruit price received by growers in the Southern States is uniformly positive for all the three time periods. The b_{303}-coefficients are all lowly significant. In terms of mean elasticities, the estimated response to changes in the current grapefruit price is largest for the prewar period and smallest for the postwar period. This indicates that the price elasticity of grapefruit supply in Region I has decreased during the period studied.

2. Lagged grapefruit price, $x^R_{304}(t)$

Positive b_{304}-coefficients are obtained in all relations for each of the three time periods. They are significant or lowly significant according to the relation considered. If the lagged grapefruit price in Region I increases (decreases), ceteris paribus, the regional total production of grapefruits will increase (decrease). The direction of the predicted change is in agreement with short run theory of production.

3. Five-year moving average of grapefruits, $x^R_{305}(t)$

The b_{305}-coefficients are expected to be greater than or equal to zero. The sign of the estimated coefficient is positive as expected in all selected equations. The coefficient is generally lowly significant. The estimated response of the effect of $x^R_{305}(t)$ on the grapefruit production in Region I seems to increase with time. This remark is based on the fact that the elasticity of grapefruit supply in this region with respect to the variable $x^R_{305}(t)$ is greater for the postwar period than for the prewar period.

4. Current orange supply, $x^R_{31}(t)$

In the short run, the expected effect of the current orange supply upon the regional total production of grapefruits is positive. The estimated unit effects have the expected sign in the selected equations. However, as the sampling error shows, this coefficient is not significant, and hence it is of very little (if any) explanatory value.

5. Lagged orange supply, $x^R_{32}(t)$

Unlike the current supply of oranges, the lagged orange supply $x^R_{32}(t)$ has coefficients which are highly significant or significant. The coefficient is positive, as expected. The value of $x^R_{32}(t)$ as a variable explaining the variation in grapefruit production in Region I has decreased over the

Table 20. Region I, Southern States (1921-1965), $y_{301}^{R}(t)$: Estimated unit effects of variables in selected equations explaining $y_{301}^{R}(t)$, the regional total production of grapefruits

Equation number	$y_{303}^{R}(t)$ Current grapefruit price	$x_{304}^{R}(t)$ Lagged grapefruit price	$x_{305}^{R}(t)$ Five-year moving average of grapefruit prices	$x_{31}^{R}(t)$ Current orange supply	$x_{32}^{R}(t)$ Lagged orange supply	$x_{35}^{R}(t)$ Current orange price
5.32		2.6308 (3.5277)		0.1682 (0.1116)		
5.33		2.7221 (3.0409)				
5.34		10.3218 (4.2611)	0.8456 (6.8532)		0.3904 (0.0823)	
5.35	21.3786 (28.6428)	5.4335 (3.5986)				-38.6160 (19.2410)
5.36		6.7080 (4.1509)	8.3443 (7.6010)			
Average[a]	21.3786	4.3733	8.3443	0.1682	0.3904	-38.6160

[a]Average coefficient is based on the at least significant coefficients.

Table 20 (Continued)

Equation number	$x_{92}^{R}(t)$ Supply of fertilizer	$y_{306}^{R}(t)$ Ratio of grapefruit price to wages	$y_{608}^{R}(t)$ Grapefruit-cotton lint price ratio	$y_{309}^{R}(t)$ Grapefruit-vegetable price ratio	$x_{903}^{R}(t)$ Grapefruit acreage
5.32	0.2091 (0.2764)	42.5740 (38.3200)	-101.2612 (59.0795)		6.6864 (2.4990)
5.33			-94.0566 (18.9647)	102.4377 (43.6900)	
5.34	0.4952 (0.2331)	-15.7633 (11.4157)			9.7939 (1.1969)
5.35	0.0648 (0.5433)	-127.4524 (23.3308)			
5.36	0.1876 (0.3486)	-120.0831 (25.4844)		292.6059 (78.2529)	4.1842 (1.8875)
Average[a]	0.2973	-123.7677	-97.6589	197.5218	6.8881

Table 20 (Continued)

Equation number	$x^R_{96}(t)$ Time	$x^R_{97}(t)$ Square of time	$x^R_{98}(t)$ Dummy variable for war effect	$x^R_{99}(t)$ Dummy variable for cotton program	x_0 Intercept	R^2
5.32	64.9284 (38.1926)	-1.1140 (0.5259)	531.5026 (139.6977)	-625.2977 (374.8908)	-435.9651 (427.7886)	0.924
5.33	106.2349 (16.6825)	-1.6014 (0.3061)	604.1758 (122.7069)	-249.9202 (166.7440)	160.2689 (226.7288)	0.917
5.34					3,139.6040 (1,063.4462)	0.894
5.35	88.6049 (14.5423)	-2.9350 (1.0106)			1,315.7082 (390.7654)	0.904
5.36	33.9623 (27.5181)	-0.6527 (0.6193)			923.6440 (483.7037)	0.888
Average[a]	73.4326	-1.5757	567.8392	-437.6089	1,384.8062	

Table 21. Region I, Southern States (1921-1939), $y^R_{301}(t)$: Estimated unit effects of variables in selected equations explaining $y^R_{301}(t)$, the regional total production of grapefruits

Equation number	$y^R_{303}(t)$ Current grapefruit price	$x^R_{304}(t)$ Lagged grapefruit price	$x^R_{305}(t)$ Five-year moving average of grapefruit prices	$x^R_{31}(t)$ Current orange supply	$x^R_{32}(t)$ Lagged orange supply	$x^R_{35}(t)$ Current orange price
5.37		1.5673 (2.4162)		0.3752 (0.4993)		
5.38		3.2329 (2.5331)				
5.39		6.6760 (4.1596)	1.2626 (7.9345)		0.7650 (0.3469)	
5.40	19.5126 (13.4961)	1.3524 (2.3391)				-3.8481 (2.9247)
5.41		1.1902 (2.6309)	1.7098 (6.3641)			
Average	19.5126	2.8057	1.4862	0.3752	0.7650	-3.8481

Table 21 (Continued)

Equation number	$x^R_{92}(t)$ Supply of fertilizer	$y^R_{306}(t)$ Ratio of grapefruit price to wages	$y^R_{608}(t)$ Grapefruit-cotton lint price ratio	$y^R_{309}(t)$ Grapefruit-vegetable price ratio	$x^R_{903}(t)$ Grapefruit acreage
5.37	0.1281 (0.3313)	-8.8324 (11.3520)	-2.5790 (13.8867)		5.9005 (7.2548)
5.38			-2.3042 (9.8733)	30.7313 (36.7317)	
5.39	0.4809 (0.3302)	-11.1962 (5.4812)			3.7068 (2.2935)
5.40	0.1140 (0.3013)	-49.2562 (20.8574)			
5.41	0.2189 (0.3762)	-21.9455 (23.0774)		42.8171 (80.9155)	4.4795 (5.0006)
Average	0.2354	-22.8075	-2.4416	36.7742	4.6956

Table 21 (Continued)

Equation number	$x_{96}^{R}(t)$ Time	$x_{97}^{R}(t)$ Square of time	$x_{99}^{R}(t)$ Dummy variable for cotton program	x_0 Intercept	R^2
5.37	-8.6887 (34.7414)	5.4499 (2.9275)	-71.2183 (168.5244)	587.6516 (600.4535)	0.950
5.38	-39.5620 (22.1439)	4.9207 (1.2661)	-180.7181 (148.1556)	388.0605 (169.7395)	0.916
5.39				473.0347 (1,333.0788)	0.907
5.40	-17.7490 (27.6529)	2.2322 (9.9770)		345.8174 (165.2921)	0.958
5.41	-7.9434 (24.8281)	4.5297 (1.7258)		418.0703 (472.2401)	0.950
Average	-18.4857 -11.4603[a]	4.2831	-125.9682	442.5268	

[a]Computed without the coefficient of relation 5.38.

Table 22. Region I, Southern States (1948-1965), $y^R_{301}(t)$: Estimated unit effects of variables in selected equations explaining $y^R_{301}(t)$, the regional total production of grapefruits

Equation number	$y^R_{303}(t)$ Current grapefruit price	$x^R_{304}(t)$ Lagged grapefruit price	$x^R_{305}(t)$ Five-year moving average of grapefruit prices	$x^R_{31}(t)$ Current orange supply	$x^R_{32}(t)$ Lagged orange supply	$x^R_{35}(t)$ Current orange price
5.42		9.0245 (4.3940)		0.1811 (0.2492)		
5.43		3.1842 (4.8905)				
5.44		4.9456 (5.5271)	10.6555 (23.9716)		0.1841 (0.1529)	
5.45	22.8508 (21.4009)	10.8689 (4.2510)				-5.7337 (4.8399)
5.46		8.0086 (4.3391)	70.6667 (74.0011)			
Average	22.8508	7.2063	40.6611	0.1811	0.1841	-5.7337

Table 22 (Continued)

Equation number	$x^R_{92}(t)$ Supply of fertilizer	$Y^R_{306}(t)$ Ratio of grapefruit price to wages	$Y^R_{608}(t)$ Grapefruit-cotton lint price ratio	$Y^R_{309}(t)$ Grapefruit-vegetable price ratio	$x^R_{903}(t)$ Grapefruit acreage
5.42	-1.1404 (0.7224)	-42.0630 (58.6786)	-41.9708 (82.0139)		
5.43			-32.5504 (67.8632)	-93.5695 (75.2696)	
5.44	-1.2689 (0.6600)	-46.0869 (38.2953)			0.7401 (6.2279)
5.45	-0.9065 (0.3554)	-21.0029 (97.6064)			
5.46	-1.2200 (0.7260)			-85.2929 (77.6014)	3.6013 (5.6969)
Average	-1.1339	-36.3842	-37.2606	-89.4312	3.6013

Table 22 (Continued)

Equation number	$x_{96}^{R}(t)$ Time	$x_{97}^{R}(t)$ Square of time	x_0 Intercept	R^2
5.42	-337.4242 (604.0417)	5.6323 (8.6180)	8,163.4101 (11,871.2965)	0.830
5.43	-142.3386 (162.5800)	1.7879 (2.3593)	4,732.8242 (2,867.2159)	0.605
5.44			2,638.9270 (2,174.2903)	0.848
5.45	-243.9518 (117.3361)	4.4038 (1.7830)	6,704.3008 (2,097.0876)	0.819
5.46			1,660.1941 (1,718.6976)	0.841
Average	-241.2382	3.9413	4,779.9312	

years: the average mean elasticity for the postwar period is about one-fifth the prewar value.

6. Current orange price, $x^R_{35}(t)$

Orange is the principal substitute in production for grapefruit in the Southern States. Consequently, we would expect the b_{35}-coefficients to be negative in the short run. They are indeed negative and at least lowly significant in the selected relations. The magnitude of the estimates of the cross elasticity of grapefruit supply with respect to orange price has not changed much during the study period.

7. Supply of fertilizer, $x^R_{92}(t)$

The coefficient b_{92} is positive as expected for the entire study period and the prewar period, but is negative for the postwar period. The coefficients are at least lowly significant. The negative b_{92}-values of the postwar period may be explained as follows:

The supply of fertilizer has a correlation coefficient of 0.9629 and 0.9715 with time, $x^R_{96}(t)$, and the square of time, $x^R_{97}(t)$, respectively, during the postwar period. These values compare with 0.4931 and 0.4796, respectively, of the prewar period. This implies that in the postwar period, the normal positive effect of the supply of fertilizer was counted as part of the influence of the time variables upon grapefruit production. That is, for this period, supply of fertilizer cannot be considered as an independent variable.

8. Ratio of grapefruit price to wages, $y^R_{306}(t)$

If interpreted in the longer run as in Chapter IV, the c_{306}-coefficients are expected to be negative. The estimated coefficients are negative in all selected relations but one, viz., relation 5.32. The coefficient is highly significant, significant or lowly significant. The significance levels are relatively unsatisfactory for the postwar period, better for the prewar period, and best for the entire study period. The magnitude of the regional elasticity estimates is directly related to the significance levels.

9. Grapefruit-cotton lint price ratio, $y^R_{608}(t)$

The remark in subsection B.9 is also pertinent here: there is no clear-cut unidirectional cause-effect relationship between $y^R_{301}(t)$ and $y^R_{608}(t)$. The negative c_{608}-coefficients become plausible if we accept that farmers hold some notion of "normal" price and/or if they are interpreted in the long run context.

10. Grapefruit-vegetable price ratio, $y^R_{309}(t)$

Vegetables compete with grapefruit production for farm resources. Like c_{608}, the expected sign of c_{309} is positive or negative depending upon the length of the period considered. If grapefruit growers in the Southern States interpret an increase (decrease) in the ratio $y_{309}^{R}(t)$ as a short run phenomenon, they will tend to increase (decrease) the production of grapefruit. Hence, in the short run the c_{309}-coefficient should be positive. The positive c_{309}-values for the entire study period and the prewar period are interpreted in this way. The negative values of c_{309} for the postwar period are lowly significant and may be interpreted as indicating the acceptance of a "normal" price and/or long run developments.

11. Grapefruit acreage, $x_{903}^{R}(t)$

The sign (positive) of the coefficient b_{903} of grapefruit acreage is as expected. The estimated response to changes in grapefruit acreage in Region I is greatest for the entire study period and smallest for the postwar period.

12. Time, $x_{96}^{R}(t)$, and square of time, $x_{97}^{R}(t)$

Taken together, these two time variables are expected to indicate the trend of the regional grapefruit production. The grapefruit supply curve for Region I is plotted in Figure 5. A look at the relevant graph leads one to expect that for the entire study period (1921-1965) a quadratic curve, convex to the origin, will give a good fit; and that

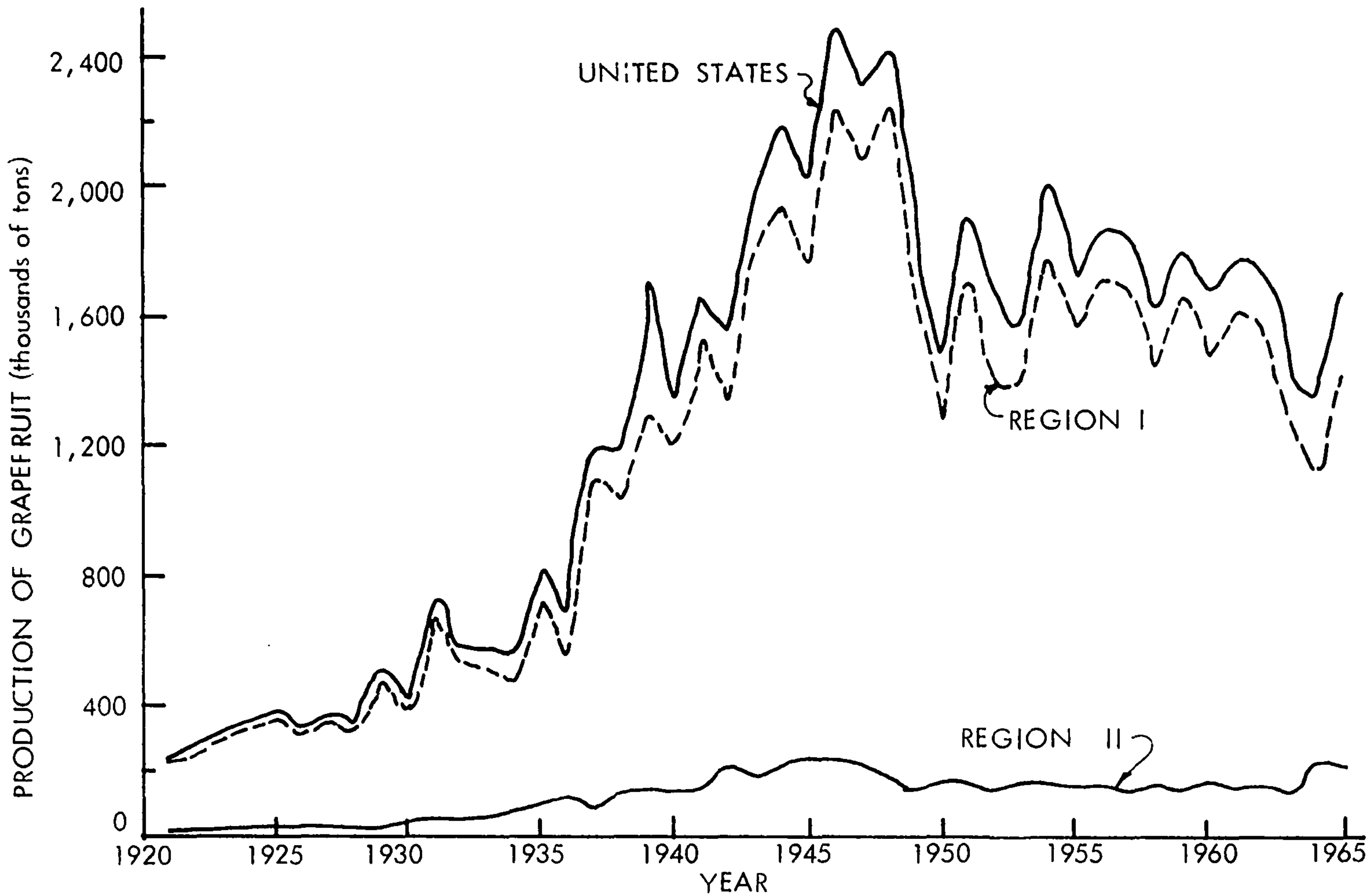

Figure 5. The grapefruit supply cycle, U.S.A. and by regions, 1921-1965

the prewar and the postwar periods could also be fitted by quadratic curves which are concave to the origin. In other words, we would expect b_{96} to be positive and b_{97} negative for the entire study period, and negative b_{96}-values and positive b_{97}-values for the two subperiods. The signs of the estimated coefficients do tally with the expected ones. The b_{96} and b_{97}-coefficients are highly significant, significant or lowly significant in one-sided t-tests.

In addition to reflecting the influence of production technology on $y^R_{301}(t)$, the time variables also reflect the effect of fertilizer supply on $y^R_{301}(t)$ during the postwar period.

13. War effect, $x^R_{98}(t)$

The war had a significant impact on grapefruit production in the Southern States. The coefficient b_{98} is positive as expected and highly significant. The war effect alone was responsible for about 45 per cent of the tremendous increase in grapefruit production that occurred between 1939 and 1948.

14. Cotton acreage allotment program, $x^R_{99}(t)$

The cotton acreage control program was started in 1934 so that given the five-year lag between planting and first commercial harvesting of grapefruits, this program could not have affected orange supply to any appreciable degree during the prewar years. This is borne by the nonsignificant values of c_{99} for this period (Table 21). For the total study period, however, the effect of the cotton program on $y^R_{301}(t)$ is significant. The negative coefficient c_{99} indicates that the government cotton acreage control program has resulted in a reduction in grapefruit production in Region I.

15. Intercept, x_0

The intercept coefficient is highly significant or significant. The magnitudes of the estimated b_0-coefficients are consistent with what one might expect by inspecting the graph of grapefruit production in Region I (see Figure 5).

16. Summary

The major factors affecting grapefruit production in Region I are lagged grapefruit price, $x^R_{304}(t)$, the supply of fertilizer, $x^R_{92}(t)$, and $y^R_{309}(t)$, and the time variables. Thus, grapefruit production is affected not only by the cost and revenue factors but also by the level of production technology.

D. Variables in Equations Explaining $y^R_{401}(t)$, the Regional Total Production of Lemons

1. Current lemon price, $y^R_{403}(t)$

In the introduction to this Chapter, it was pointed out that California and Arizona produce nearly 99 per cent of the entire lemon supply of the United States. The Southern States produce only negligible quantity of lemon. The regional analysis of lemon production is therefore restricted to Region II, the Western States, alone.

The coefficient c_{403} of the regional current lemon price $y^R_{403}(t)$ is negative for the entire study period and the prewar period, but positive for the postwar period. However, in a one-sided test of significance none of these c_{403}-values is significantly different zero. Hence, the regional analysis reveals that the current lemon price does not help us much in our search to explain the variability in $y^R_{401}(t)$, the total production of lemons in Region II.

2. Lagged lemon price, $x^R_{404}(t)$

The estimated response of $y^R_{401}(t)$ to changes in lagged lemon price has increased during the period studied. It was negative in the prewar period but has been positive during the postwar period. And for the entire study period, the response is positive, as expected. The coefficient b_{404} is at least lowly significant. The significance levels are relatively better for the estimates of the postwar years than for those of the prewar period.

3. Five-year moving average of lemon prices, $x^R_{405}(t)$

The sign of the estimated coefficient is positive in the selected relations. The coefficient b_{405} is significant or lowly significant. The mean elasticity is greater for the postwar period than for the prewar period; this implies that the response of lemon production to the regional variable $x^R_{405}(t)$ has increased during the period studied. The positive sign of coefficient b_{405} is plausible if changes in $x^R_{405}(t)$ are interpreted as short run phenomena.

4. Supply of fertilizer, $x^R_{92}(t)$

In the short run, the b_{92}-coefficient is expected to be positive. It is indeed positive in all the selected relations. The b_{92}-values are significant for the postwar period as well as for the entire study period but lowly significant for the prewar period. This is reflected in the magnitude of the mean elasticity estimates.

5. Ratio of lemon price to wages, $y^R_{406}(t)$

The average c_{406}-coefficient is negative for each of the three time periods. The direction of change is as expected in a long run analysis. The coefficient is highly significant or significant. In two of the relations, namely, 5.47 and 5.56, the c_{406}-values were positive but not significant. For this variable also, the response in the regional

Table 23. Region II, Western States (1921-1965), $y^R_{401}(t)$: Estimated unit effects of variables in selected equations explaining $y^R_{401}(t)$, the regional total production of lemons

Equation number	$y^R_{403}(t)$ Current lemon price	$x^R_{404}(t)$ Lagged lemon price	$x^R_{405}(t)$ Five-year moving average of lemon prices	$x^R_{92}(t)$ Supply of fertilizer	$y^R_{406}(t)$ Ratio of lemon price to wages	$y^R_{808}(t)$ Lemon-cotton lint price ratio
5.47		0.7246 (0.8089)	9.7087 (4.1054)	0.0617 (0.0465)	49.2588 (20.7667)	
5.48	-2.3535 (1.3679)					1.8822 (3.7897)
5.49		0.3127 (0.6836)		0.0179 (0.0300)	-3.1652 (5.4384)	
5.50	-2.9013 (1.0241)					1.8558 (1.7699)
5.51	-1.4631 (1.5238)			0.0999 (0.1162)	-3.8161 (11.1831)	2.5691 (3.7182)
Average	-2.2393	0.5186	9.7087	0.0599	-3.4906	2.1023

Table 23 (Continued)

Equation number	$y^R_{815}(t)$ Lemon-hay price ratio	$x^R_{904}(t)'$ Lemon acreage	$x^R_{96}(t)$ Time	$x^R_{98}(t)$ Dummy variable for war effect	$x^R_{99}(t)$ Dummy variable for cotton program	x_0 Intercept	R^2
5.47	-133.7853 (49.7410)	28.4182 (13.9411)	-2.2897 (6.4941)	27.1414 (49.1108)		-1,938.9541 (1,090.3969)	0.864
5.48	-29.2076 (26.7404)		8.9035 (2.1182)	33.7532 (48.7711)	21.5993 (38.5298)	457.3605 (91.6671)	0.866
5.49		3.5006 (4.8308)	8.8838 (3.2233)			132.9380 (326.5534)	0.835
5.50			9.9828 (1.5340		38.0940 (37.8877)	400.5464 (741.2573)	0.844
5.51		3.8328 (7.1701)	23.0571 (11.6138)		30.3603 (88.3387)	1,445.0083 (762.0494)	0.871
Average	-81.4964	3.6667	9.2567	30.4473	30.0178	330.2816	

Table 24. Region II, Western States (1921-1939), $y^R_{401}(t)$: Estimated unit effects of variables in selected equations explaining $y^R_{401}(t)$, the regional total production of lemons

Equation number	$y^R_{403}(t)$ Current lemon price	$x^R_{404}(t)$ Lagged lemon price	$x^R_{405}(t)$ Five-year moving average of lemon prices	$x^R_{92}(t)$ Supply of fertilizer	$y^R_{406}(t)$ Ratio of lemon price to wages	$y^R_{808}(t)$ Lemon-cotton lint price ratio
5.52		-0.8022 (0.8038)	2.4290 (3.8235)	1.0765 (1.0937)	-5.3864 (6.5034)	
5.53	-2.1000 (1.6087)	-1.4261 (1.3631)				6.3408 (5.4285)
5.54		-0.6789 (0.7216)		0.8305 (0.8874)	-8.6150 (4.3181)	
5.55	-1.3634 (1.0919)					4.1883 (2.2762)
Average	-1.7317	-0.9690	2.4290	0.9535	-7.0007	5.2645

Table 24 (Continued)

Equation number	$y^R_{815}(t)$ Lemon-hay price ratio	$x^R_{904}(t)$ Lemon acreage	$x^R_{96}(t)$ Time	$x^R_{99}(t)$ Dummy variable for cotton program	x_0 Intercept	R^2
5.52	-16.7326 (23.3641)	-11.6075 (9.7494)	8.8872 (6.9494)		638.3528 (507.2817)	0.771
5.53	-31.4446 (21.2761)			45.2940 (57.5725)	502.8625 (218.5335)	0.758
5.54		-11.6303 (9.0934)	10.2992 (5.6947)		787.7695 (429.9006)	0.760
5.55			7.5856 (6.2549)	19.0272 (49.4701)	265.6475 (71.4079)	0.712
Average	-24.0886	-11.6189	8.9240	32.1607	548.6580	

Table 25. Region II, Western States (1948–1965), $y^R_{401}(t)$: Estimated unit effects of variables in selected equations explaining $y^R_{401}(t)$, the regional total production of lemons

Equation number	$y^R_{403}(t)$ Current lemon price	$x^R_{404}(t)$ Lagged lemon price	$x^R_{405}(t)$ Five-year moving average of lemon prices	$x^R_{92}(t)$ Supply of fertilizer	$y^R_{406}(t)$ Ratio of lemon price to wages	$y^R_{808}(t)$ Lemon-cotton lint price ratio
5.56		8.1796	7.6652	0.3411	349.4889	
		(14.4552)	(21.2798)	(1.0706)	(808.5249)	
5.57	3.6031	3.2964				-2.8263
	(6.5223)	(1.3011)				(12.8531)
5.58		1.9641		0.1014	-25.8059	
		(0.8102)		(0.0864)	(13.7202)	
5.59	1.5945					-12.5238
	(2.8155)					(16.8976)
5.60	1.1051			0.5318	-68.7258	-18.8504
	(0.3734)			(1.8862)	(22.8499)	(6.3530)
Average	2.1009	4.4800	7.6652	0.3246	-47.2668	-11.4001

Table 25 (Continued)

Equation number	$y^R_{815}(t)$ Lemon-hay price ratio	$x^R_{904}(t)$ Lemon acreage	$x^R_{96}(t)$ Time	x_0 Intercept	R^2
5.56	-1,201.0031 (2,864.4555)	5.6226 (12.8411)	125.1500 (341.5353)	-3,673.8367 (8,441.7247)	0.788
5.57	-223.6920 (136.9282)		6.0774 (2.6231)	562.7756 (157.1801)	0.786
5.58		2.6139 (4.5590)	16.3818 (14.3499)	862.4243 (287.3146)	0.780
5.59			6.9708 (2.7497)	568.7988 (142.8605)	0.670
5.60	-384.2858 (142.2053)	8.1292 (2.9200)	8.4411 (2.6935)	369.8846 (134.6517)	0.896
Average	-303.9889	5.4552	7.1631	590.9708	

lemon production is greater for the postwar period than for the prewar period.

6. Lemon-cotton lint price ratio, $y^R_{808}(t)$

The positive c_{808}-coefficient for the entire study period and the prewar period suggests that lemon producers in the Western States interpret an increase in the regional lemon-cotton price ratio as a short run phenomenon. If the producers consider changes in the ratio $y^R_{808}(t)$ as representing longer run phenomena, they will tend to embark on general renovation and new planting activities--these activities will lead to temporary cutback in lemon production followed by a greatly increased supply. Thus, in the longer run framework, c_{808}-coefficient is expected to be negative. The lowly significant coefficient c_{808} of the postwar period may be explained in this light.

7. Lemon-hay price ratio, $y^R_{815}(t)$

Hay production, like cotton production, competes with lemon orcharding for farm space and other farm resources. Consequently, if interpreted in the longer run context, the c_{815}-coefficients are expected to be negative. The estimated coefficient c_{815} is negative for each of the three periods under study (Tables 23 through 25). The c_{815}-values are significant or lowly significant. The levels of significance are better for the postwar period than for the prewar period; and this reflects itself in the response of lemon production to changes in the ratio $y^R_{815}(t)$.

8. Lemon acreage, $x^R_{904}(t)$

The coefficient b_{904} of acreage planted to lemon in the Western States is positive as expected, except for the prewar period. The positive b_{904}-values are significant or lowly significant. The average coefficient $b_{904} = 3.6667$ indicates that if lemon acreage increases (decreases) by one thousand acres, *ceteris paribus*, lemon production in the Western States will increase (decrease) by about 3,667 tons. The negative coefficients of the prewar period are not significantly different from zero at an acceptable level of significance, and hence are of very little explanatory value.

9. Time, $x^R_{96}(t)$

The factors comprising the variable "time" are expected to affect lemon production positively. Hence the b_{96}-coefficient is expected to be greater than or equal to zero. The estimated b_{96}-values are indeed positive in all the selected relations except one, viz., relation 5.47 of Table 23. The b_{96}-coefficients are highly significant or significant, but the negative coefficient is only lowly significant. The negative sign and the low significance level of the b_{96}-

value in relation 5.47 may be the result of there being "too many" explanatory variables in this particular relation. The degree of response of lemon production in the Western States to changes in $x_{96}^{R}(t)$ is about the same in the three periods.

10. War effect, $x_{98}^{R}(t)$

The response of lemon production in the Western States to the inflated land values and high prices of war years was moderate and in the expected direction, that is, the estimated coefficient b_{98} is positive. The coefficient is only lowly significant. The average coefficient b_{98} - 30.5573 indicates that the conditions created by the outbreak of the Second World War were responsible for about 18 per cent of the total increase in lemon production between 1939 and 1947.

11. Cotton acreage allotment program, $x_{99}^{R}(t)$

The coefficient b_{99} is positive as expected but the level of significance is quite poor for all the selected relations. Thus though the response of lemon production in the Western States to the cotton acreage control program is decidedly in the positive direction, it actually is not significantly different from zero. This conclusion is valid for the prewar period as well as the postwar period.

12. Intercept, x_0

The intercept change is positive as expected from an inspection of the data. The coefficient b_0 is highly significant or significant, which suggests that probably some of the factors thrown into the intercept term should be isolated and included in the analysis as a means of improving the predictive power of our models.

13. Summary

The variables that significantly influence the lemon supply cycle in the Western States are lagged lemon price, $x^R_{404}(t)$, wages to hired day labor as reflected in the ratio $y^R_{406}(t)$, acreage, $x^R_{904}(t)$, and time, $x^R_{96}(t)$. Once again, we find that cost and revenue factors as well as the general level of farm technology are the principal actors in the development of the lemon cycle. The addition of other explanatory variables, including dummy variables, leads to only modest increases in the values of R^2 while at the same time reducing the significance levels of all the variables.

The Durbin-Watson d statistic falls in the inconclusive test range for the relations of orange production in Region I (the Southern States). For all other regional analyses, the d statistic indicates insignificant serial correlation in the disturbances at the 5% significance level.

VI. APPLICATION OF THE MODEL: ACTUAL VALUES COMPARED WITH MODEL RESULTS

A. General Remarks

Friedman (1953) states that "the only relevant test of the validity of a model or an abstract theory is comparison of its predictions with experience. The model or theory is rejected if its predictions are contradicted; it is accepted if its predictions are not contradicted" (p. 9). Thus, the usefulness and validity of the model we have developed in the last three chapters rest in its ability to yield "sufficiently accurate predictions" of changes in production. To test this ability, we have started the model operating with known values of relevant variables (i.e. production data) at the earliest point in time for which we have reliable data and then we compare these with the values generated by the model.

The goodness of fit between observed (actual) and calculated (predicted) values is measured by the residual variance ratio, $\emptyset$. This is the ratio of the residual variance to the variance of the analyzed variable. If we denote the correlation between observed and calculated values by R, the following relation is valid: $R = \sqrt{(1-\emptyset)}$. This means that $\emptyset$ gives the percentage of unexplained variations. The smaller the value of $\emptyset$ the better is the goodness of fit.

B. Comparison of Observed and Calculated Values

The comparisons of actual and calculated values for citrus fruits and the components are shown in the corresponding Figures 6 through 19.

1. Citrus fruits

The study period is from 1921 to 1965. Separate analyses are made for a) the entire study period (see Table 2; Figure 6), b) the prewar period, 1921-1939 (see Table 3; Figure 7), and c) the postwar period, 1948-1965 (see Table 4; Figure 7). The study of citrus fruit production was limited to the national level; that is, no analysis was made for regional (total) production of all citrus fruits.

In general, very good "fit" is obtained by our supply relations. However, as Figures 6 and 7 show, the subperiod analyses yield a much better fit than the entire period analysis. The values of the residual variance ratio, $\emptyset$, for the entire study period are between .035 and .059, as compared with .035 and .049 for the prewar period and .022 and .039 for the postwar period.

2. Oranges

The study period includes the years 1921-1965. A study was made for orange production in the United States as a

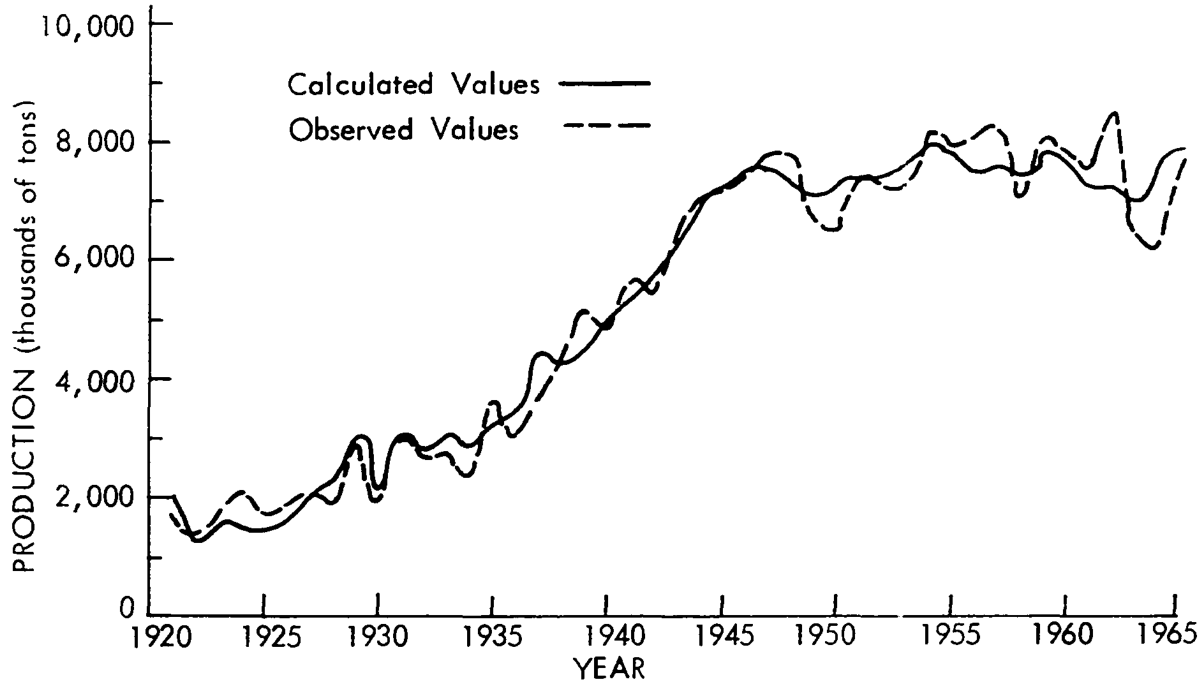

Figure 6. Citrus fruits production, U.S.A.: actual values compared with model estimates, 1921-1965

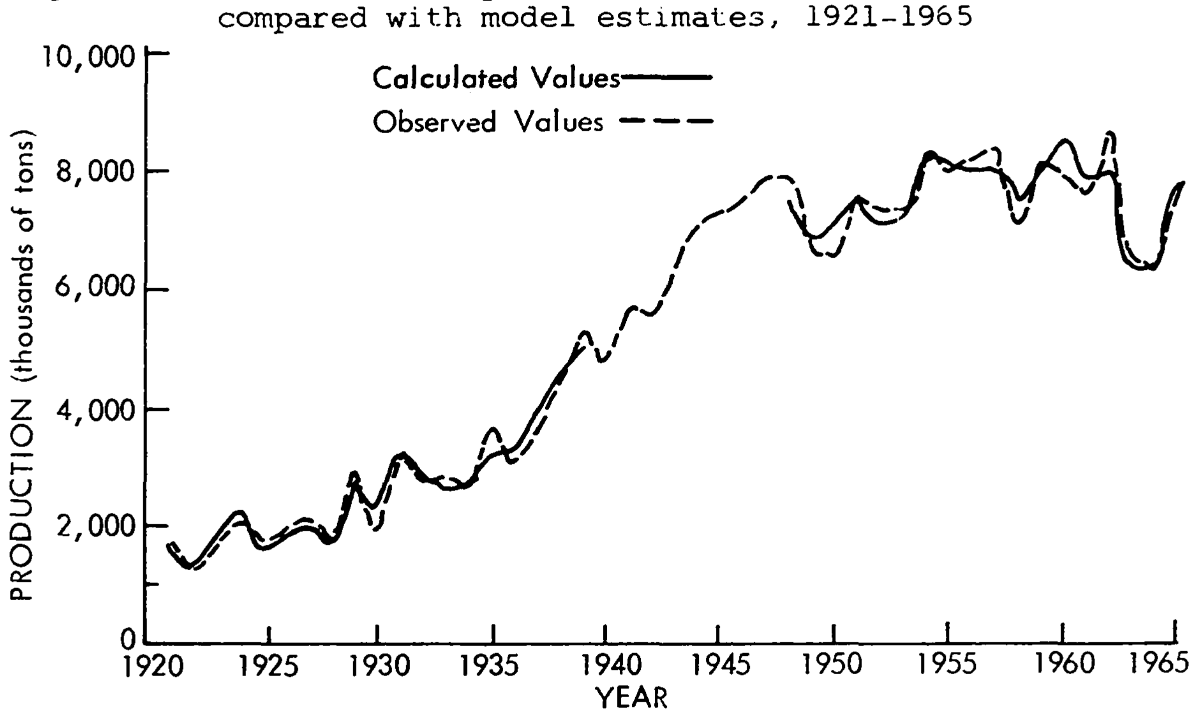

Figure 7. Citrus fruits production, U.S.A.: actual values compared with model estimates, 1921-1939 and 1948-1965

whole, and also for each of the two important orange-producing areas of the nation--the South (Region I) and the West (Region II). The statistical results are recorded in Tables 5 through 7 for the United States, Tables 14 through 16 for the Southern States, and Tables 17 through 19 for the Western States. Figures 8-9, 10-11, and 12-13 show the comparisons of observed and calculated values for the three areas,[1] respectively.

For each of the three areas, the subperiod analyses give better estimates of the actual values (that is, have lower values of Ø) than the analysis for the entire period. This can easily be seen by comparing, say, Figures 8 and 9.

For the three areas, the best fit is obtained for the national (United States) study and the study for the Southern States gives quite satisfactory results. The goodness of fit for the supply relations of the Western States is not bad at all. The Ø values range from .112 to .299. However, the forecasts in quite a number of the cases predict changes in the wrong direction. This is especially true of the entire-period study as shown in Figure 12. It can be seen from the graphs that the wrong predictions occur for the most part in the last ten years of the study period,

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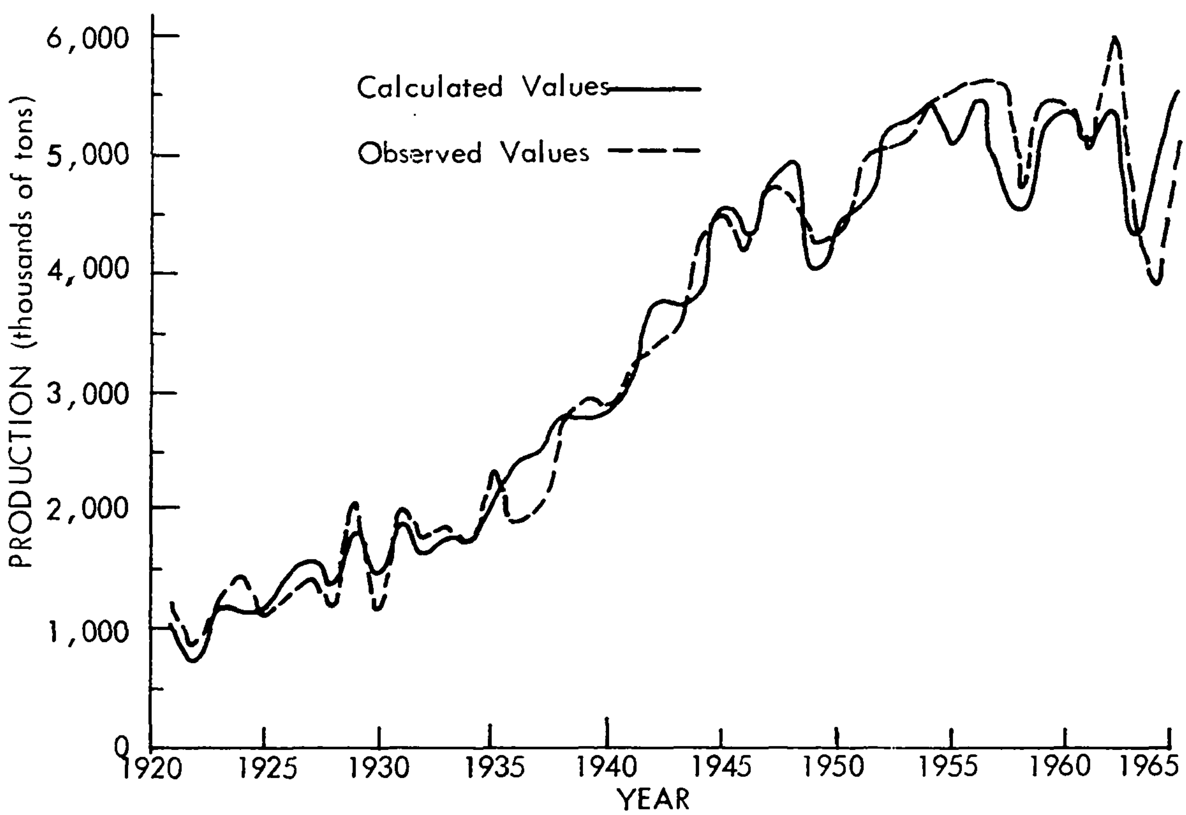
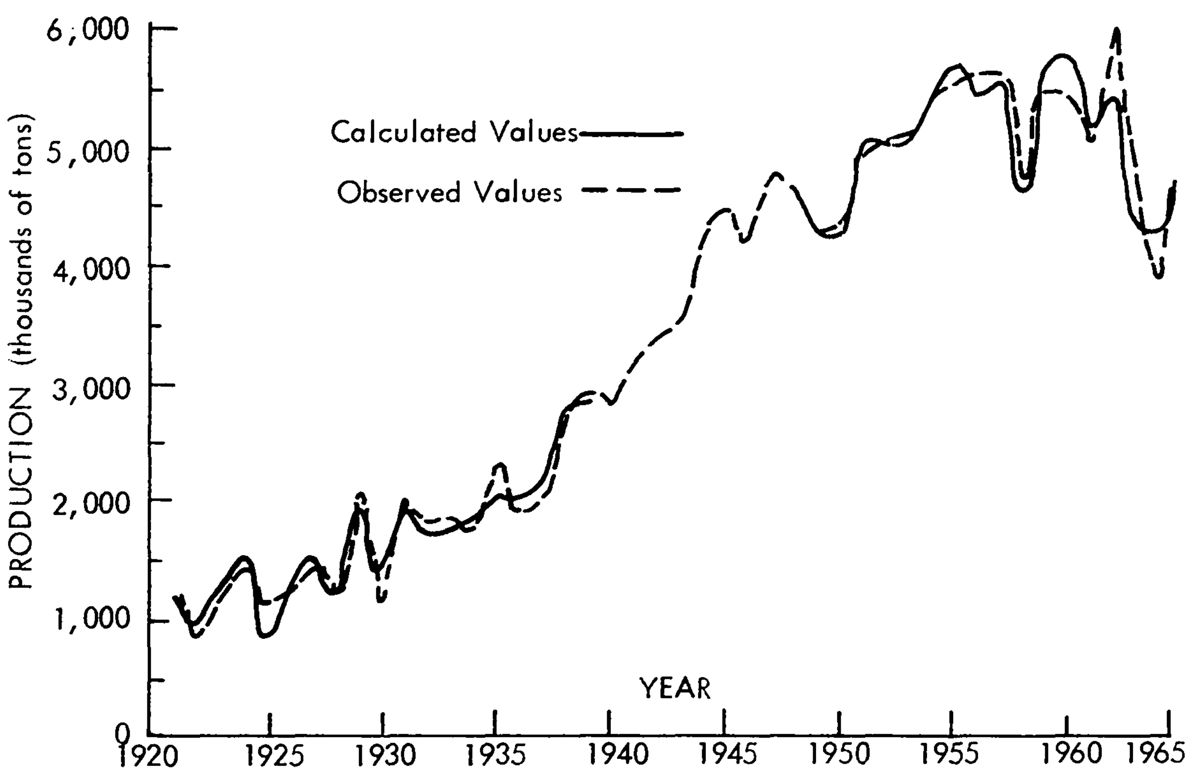
[1]The term "area" refers to either the United States as a whole or to any one of the two selected regions.

Figure 8. Orange production, U.S.A.: actual values compared with model estimates, 1921-1965

Figure 9. Orange production, U.S.A.: actual values compared with model estimates, 1921-1939 and 1948-1965


6,000
5,000
4,000
3,000
2,000
1,000
0
PRODUCTION (thousands of tons)
Calculated Values
Observed Values
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
YEAR


6,000
5,000
4,000
3,000
2,000
1,000
0
PRODUCTION (thousands of tons)
Calculated Values
Observed Values
YEAR
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965

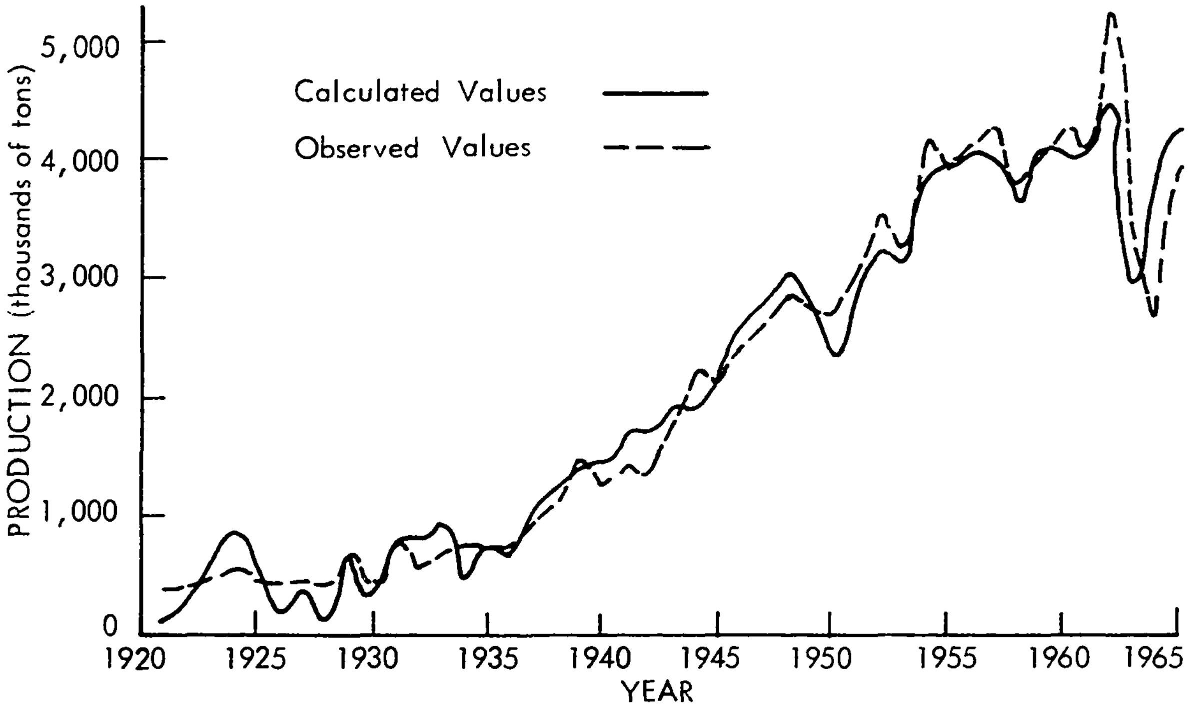


Figure 10. Orange production, Southern States: actual values compared with model estimates, 1921-1965

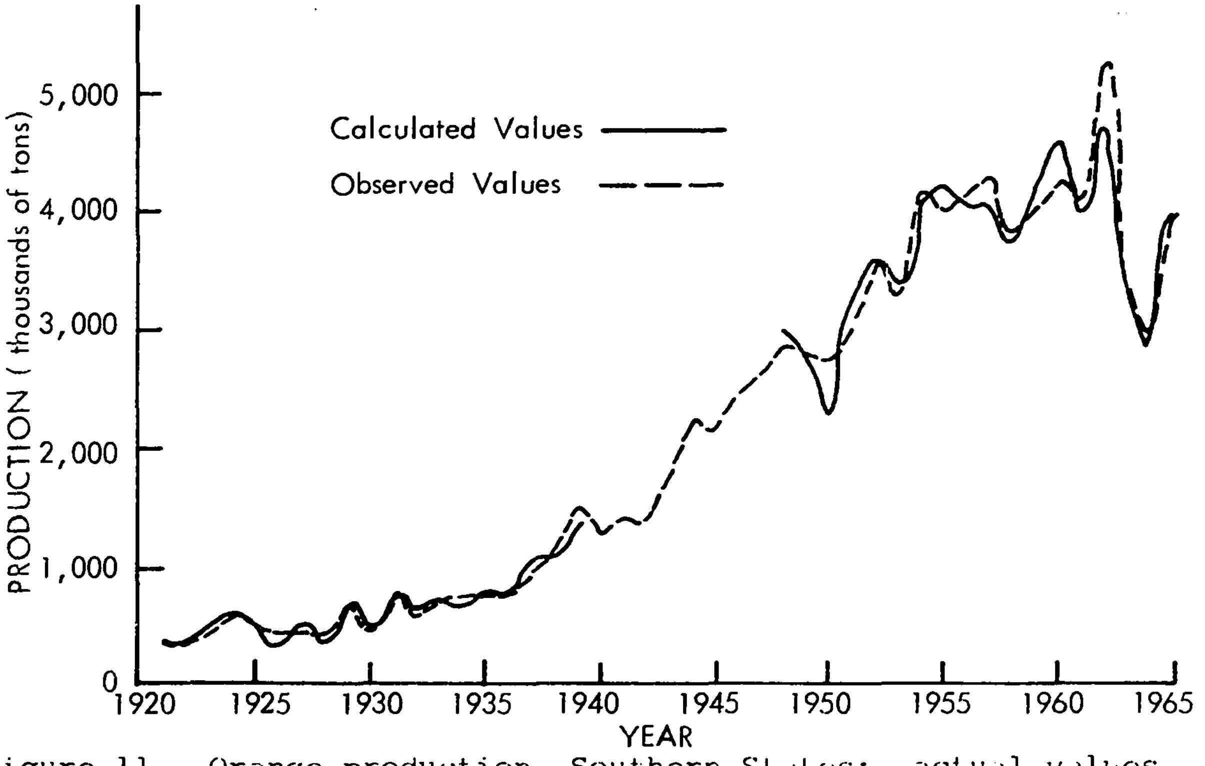


Figure 11. Orange production, Southern States: actual values compared with model estimates, 1921-1939 and 1948-1965

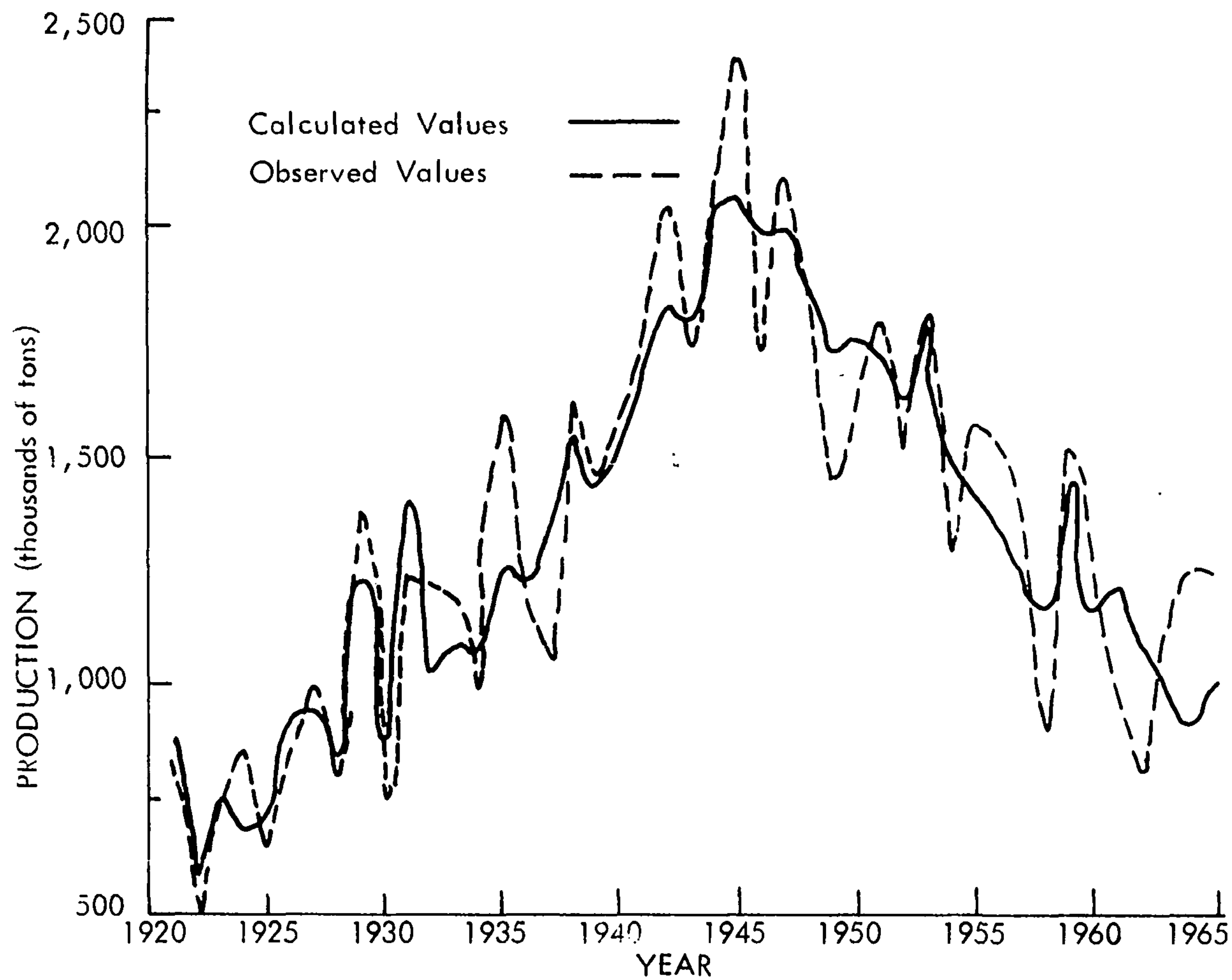


Figure 12. Orange production, Western States: actual values compared with model estimates, 1921-1965

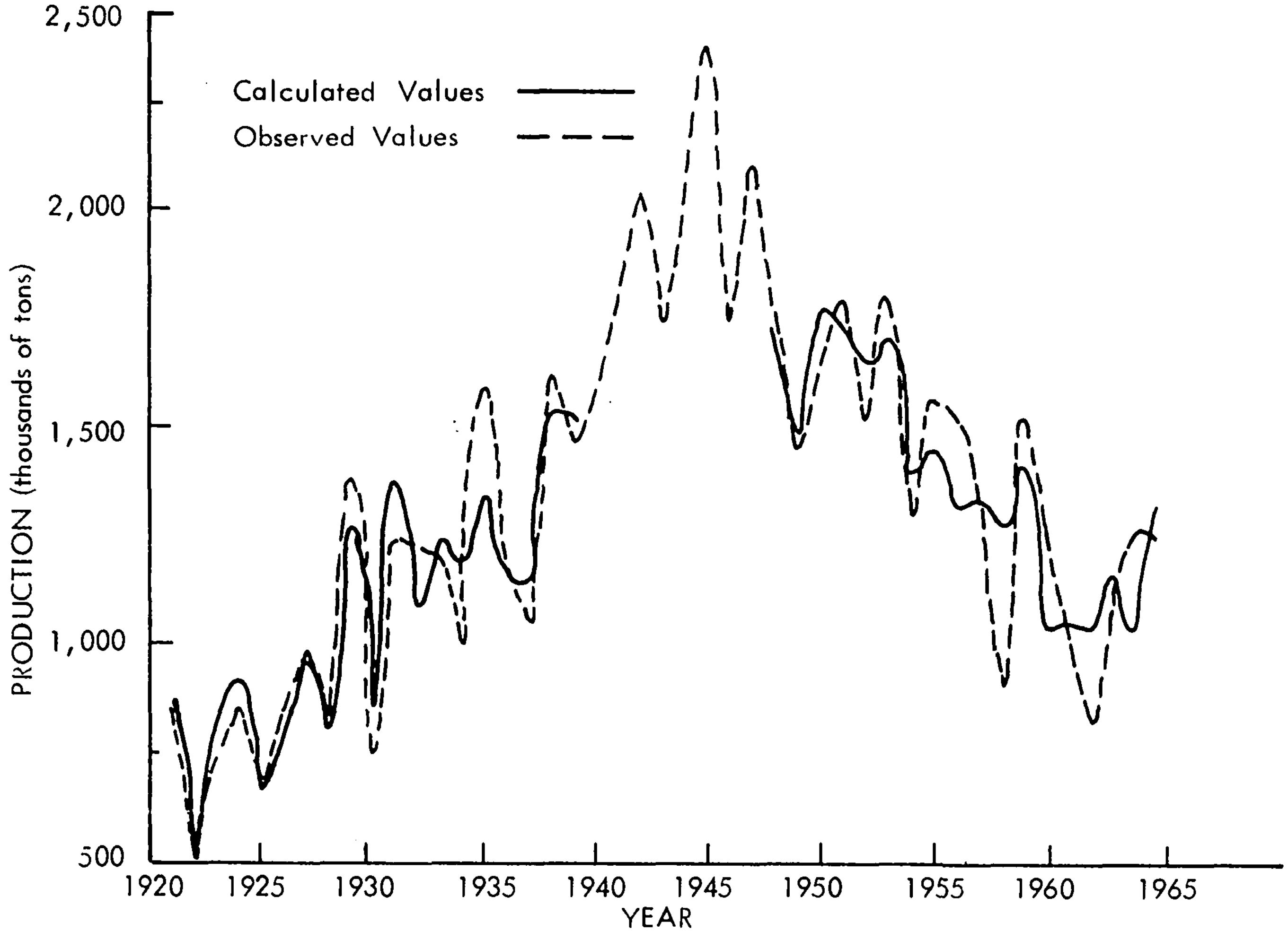


Figure 13. Orange production, Western States: actual values compared with model estimates, 1921-1939 and 1948-1965

while for the prewar and war years the fit is reasonably good. The conclusion is that probably during the last decade, hidden factors were active and changed the functioning mechanism. One such factor may be the irregular fluctuations in the weather. These irregular natural variations upset the regularity of the cycles that would result if production were determined entirely by price and other variables included in the analysis. It is also possible that the data available for this area--the Western States--are deficient.

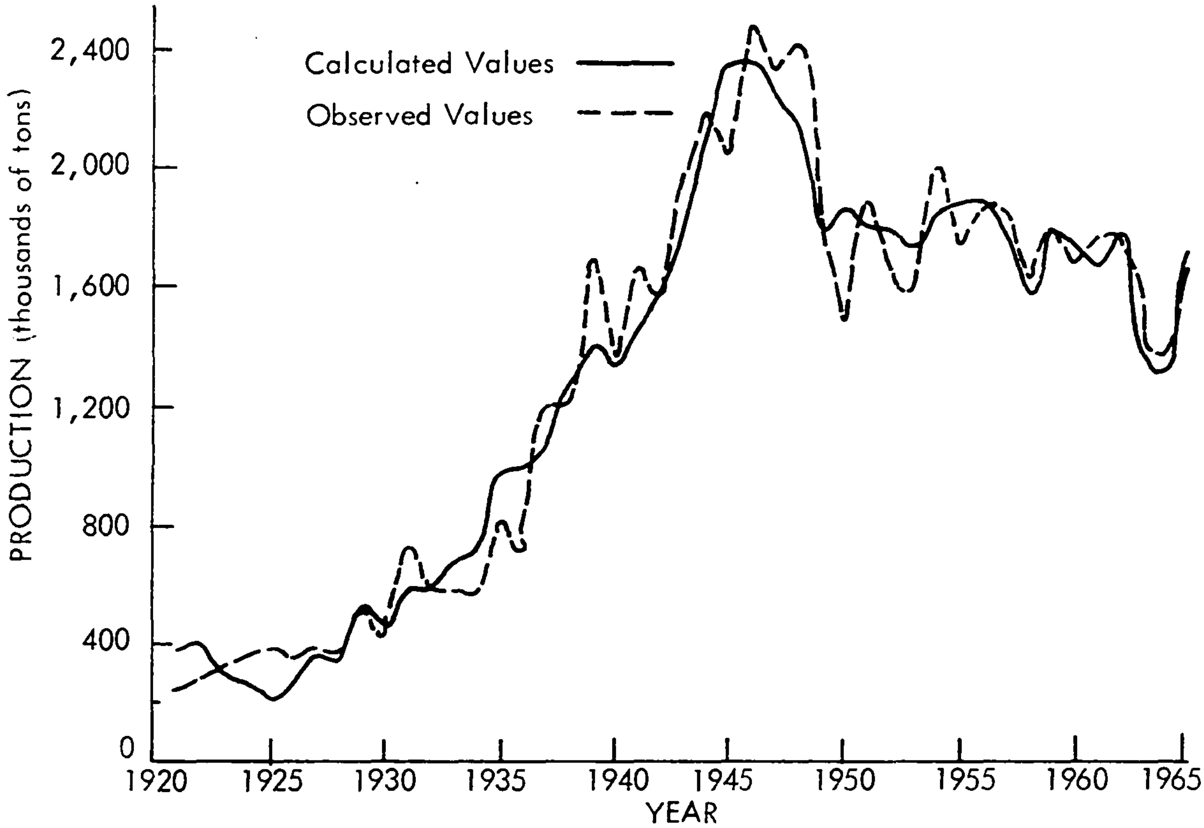
3. Grapefruits

About 90 per cent of all the grapefruit crop of the United States is produced in the Southern States, viz., Florida, Texas and Louisiana. The Western States produce only 9 per cent. Consequently, the study of grapefruit production was limited to only two areas: the United States (see Tables 8-10; Figures 14-15) and the Southern States (see Tables 20-22; Figures 16-17).

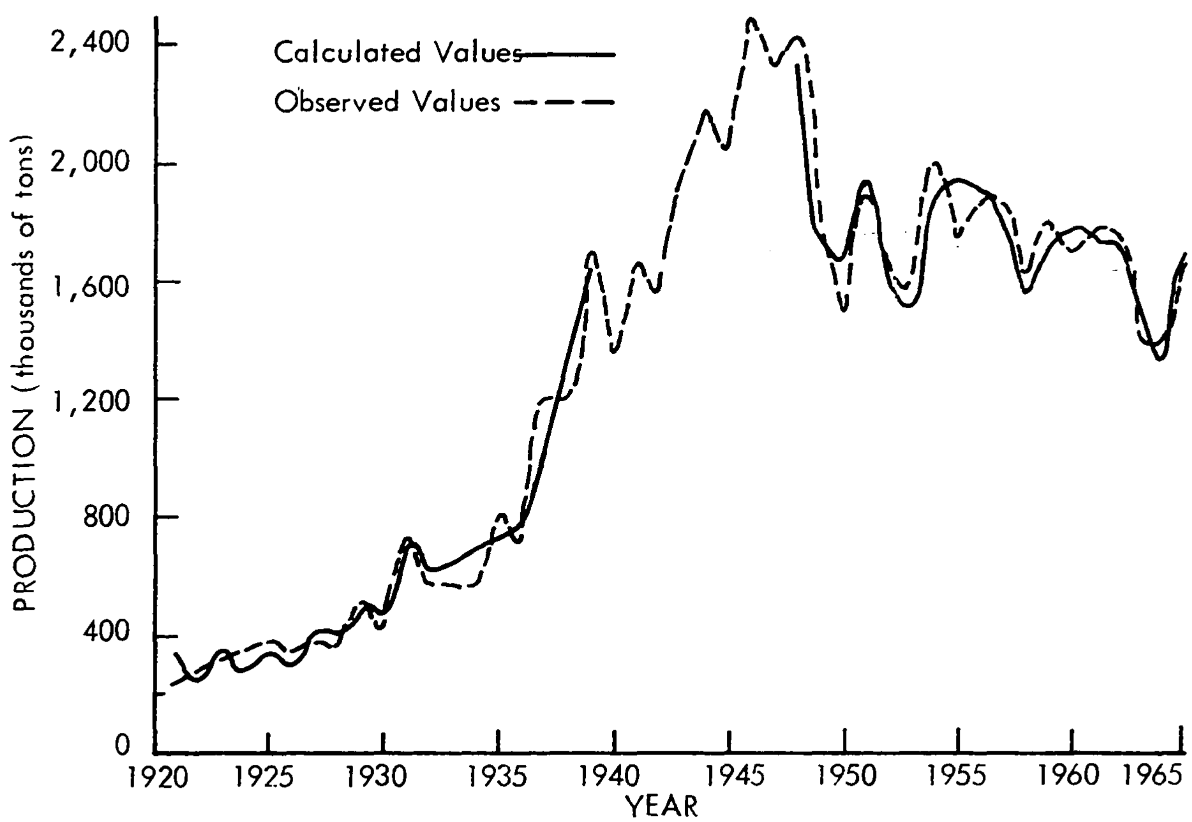
It is also true here that the subperiod analysis give better estimated values than the entire period analysis, and also that the national calculated values are better approximations to the actual values than the regional calculated values are.

Figure 14. Grapefruit production, U.S.A.: actual values compared with model estimates, 1921-1965

Figure 15. Grapefruit production, U.S.A.: actual values compared with model estimates, 1921-1939 and 1948-1965



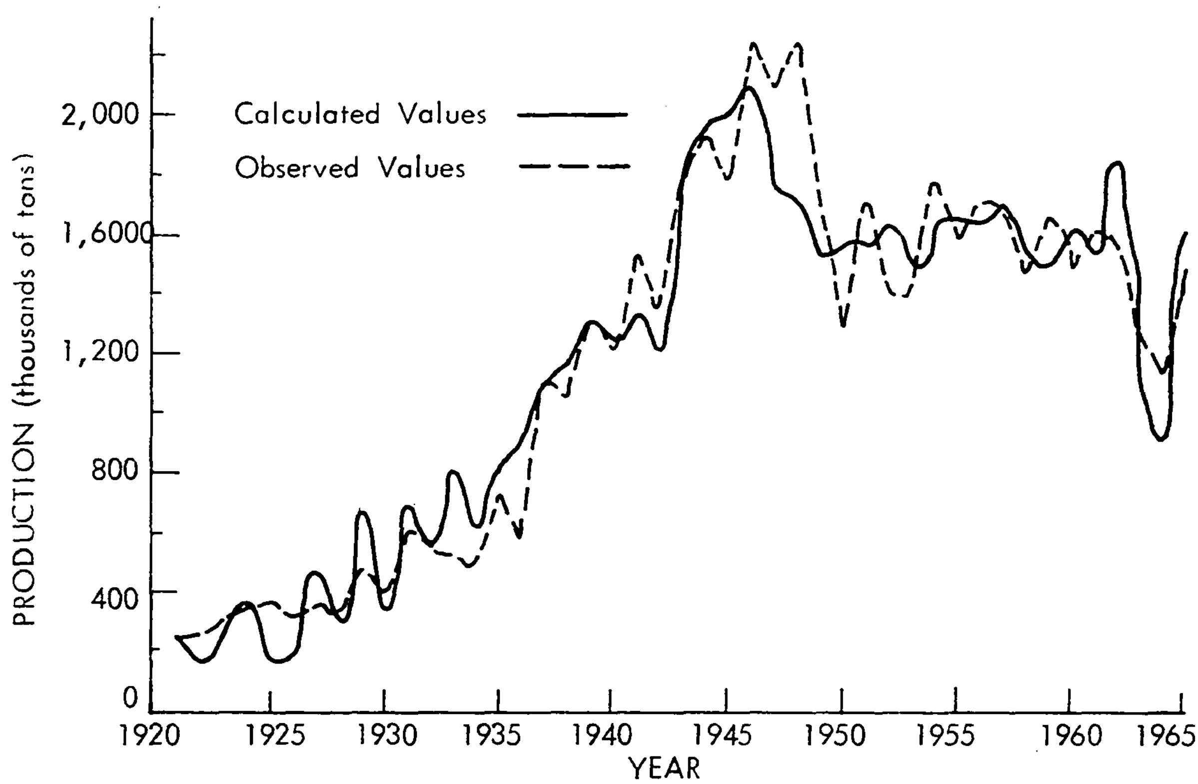
Calculated Values
Observed Values
2,400
2,000
1,600
1,200
800
400
0
PRODUCTION (thousands of tons)
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
YEAR

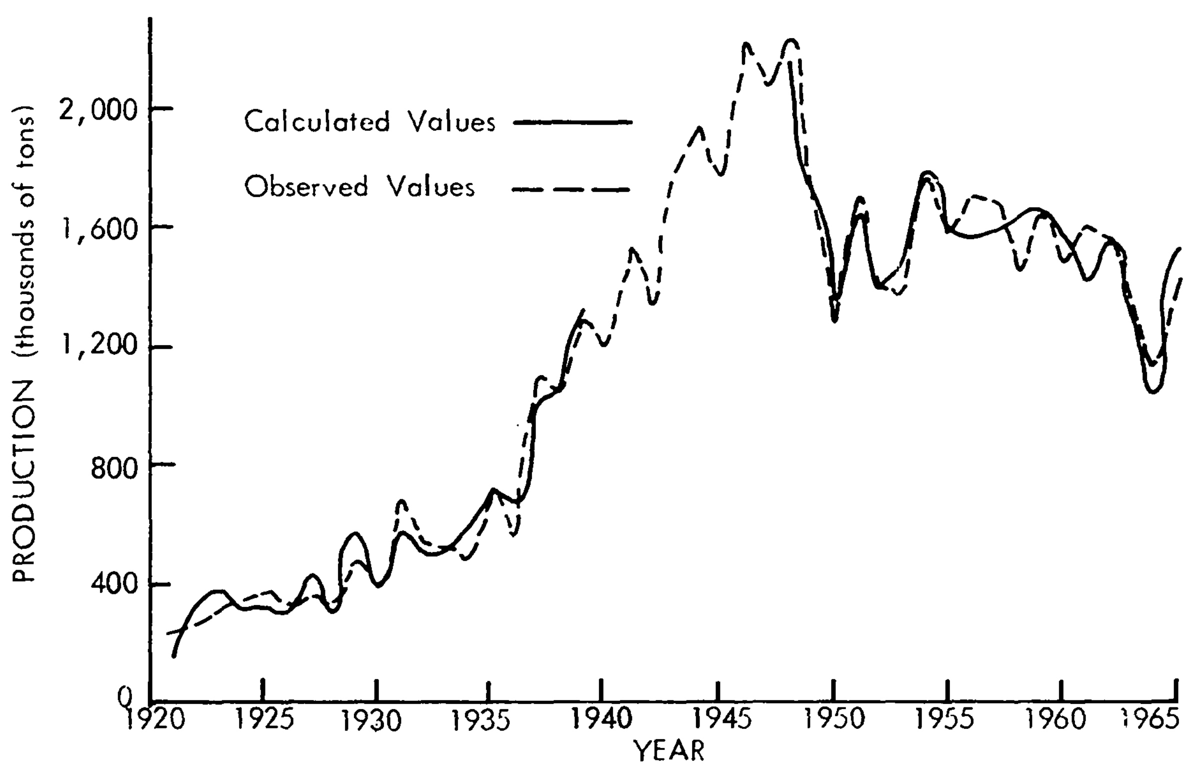


Calculated Values
Observed Values
2,400
2,000
1,600
1,200
800
400
0
PRODUCTION (thousands of tons)
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
YEAR

Figure 16. Grapefruit production, Southern States: actual values compared with model estimates, 1921-1965

Figure 17. Grapefruit production, Southern States: actual values compared with model estimates, 1921-1939 and 1948-1965


Calculated Values
Observed Values
PRODUCTION (thousands of tons)
2,000
1,600
1,200
800
400
0
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
YEAR


Calculated Values
Observed Values
PRODUCTION (thousands of tons)
2,000
1,600
1,200
800
400
0
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
YEAR

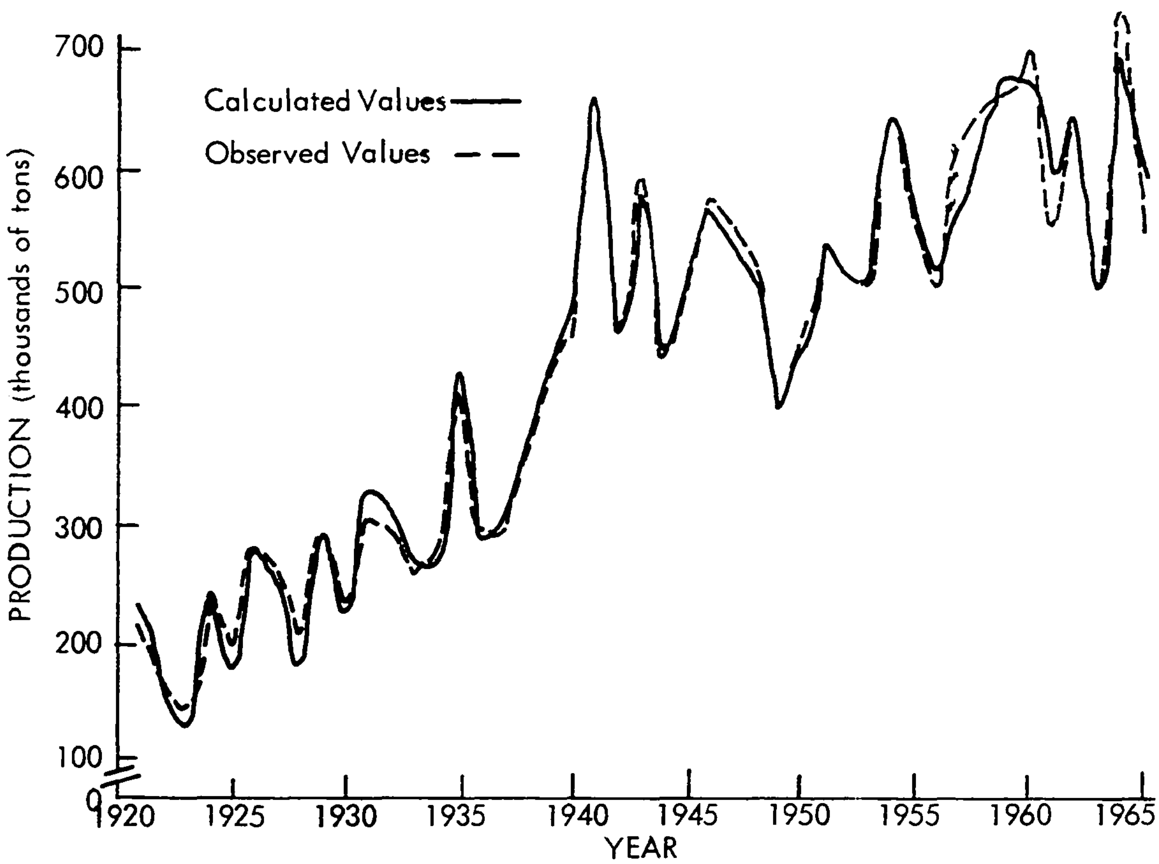
4. Lemons

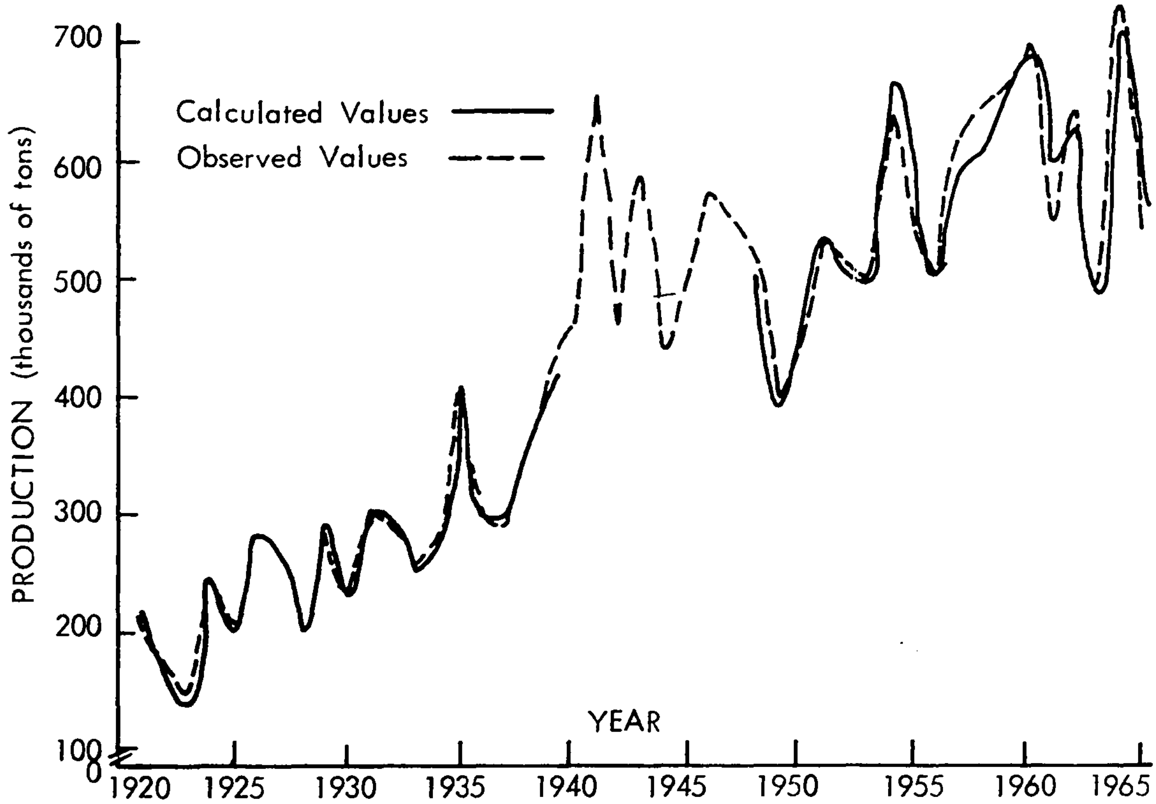
California and Arizona produce almost the entire lemon crop of the United States--about 99 per cent. We, therefore, do not consider a study of lemon production in the Southern States. The study period includes the years 1921-1965. Three analyses--for the entire study period, the prewar period, and the postwar period--are made for each of the two areas: the United States (Tables 11-13; Figures 18-19) and the Western States (Tables 23-25). The results of the regional analysis are not shown graphically because they are very similar to the graphs for the national analysis (Figures 13 and 19).

The results are not much different from those of the other citrus fruit components. The Ø-values are generally lower for the subperiod analyses than for the entire period analysis; and the calculated values for the national analysis "fit" more closely than the calculated values of the regional analysis do to the corresponding actual (observed) values. But there is an added feature to the lemon analysis. Both Figures 18 and 19 show that the estimates of the model tend to fall above or below actual values for extended periods, though the predictions of the model are closely associated with the actual values and both show similar long-run variations. French and Bressler (1962) obtained similar results and surmised that this may be due to the carry-over

Figure 18. Lemon production, U.S.A.: actual values compared with model estimates, 1921-1965

Figure 19. Lemon production, U.S.A.: actual values compared with model estimates, 1921-1939 and 1948-1965


Calculated Values
Observed Values
PRODUCTION (thousands of tons)
700
600
500
400
300
200
100
0
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
YEAR


Calculated Values
Observed Values
PRODUCTION (thousands of tons)
700
600
500
400
300
200
100
0
YEAR
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965

effects of year-to-year acreage changes. There is no apparent tendency for the differences between actual and model results to widen. On the contrary, there is a tendency for these differences to vanish with time.

C. Concluding Remarks

The best fit is obtained for the lemon analysis with an average value of Ø of .015 for all the relations selected. The next in line is the citrus analysis, with Ø of about .037 on the average. Grapefruit analysis gives the "most unsatisfactory" estimates, but even then the goodness of fit is satisfactory. The Ø-value is about .140 on the average, except for the postwar period when the average value of Ø jumps to .172. In all cases studied, the national analyses consistently yield better "fit" than the regional analyses. The subperiod analyses also tend to yield estimates which better fit the observed values than does the entire-period analysis. Again, as between the subperiod analyses, the prewar period generally has better fitting estimates than the postwar period. In almost all cases, this is due to wrong predictions occurring in the last decade or so of the study period. This seems to imply that some hidden factors have come into prominence over the past decade and are now strongly influencing the development of the citrus supply cycle. Two of the important factors that affect citrus fruit production are the weather and technological changes.

Since the model seems to work reasonably well in predicting past production movements, we conclude that it does have some validity and that future projections based on it may serve well as indicators of likely changes in production. Such changes are likely to be cyclical. This study, however, does not include any projections--short run or long run--of future production.

VII. SUMMARY AND CONCLUSION

A. The Objective

The objective of this econometric study is, as stated in the first chapter, the explanation of the citrus supply cycle in the United States and two selected regions. Hence annual time series of the variables which are considered important to the citrus-producing sector of each of the three areas--the United States, the Southern States, and the Western States-- are employed in this dissertation. Each time series covers the period 1921-1965. The objective is accomplished by specifying and estimating policy models of the citrus supply (or production) cycle and by testing hypotheses about their parameters, where it is necessary to do so. Several simultaneous equation models of the following form are constructed:

$$\underline{y}'(t)\underline{\Gamma} + \underline{x}'(t)\underline{B} + \underline{u}'(t) = \underline{0}' \ , \qquad (7.1)$$

where $\underline{y}'(t)$, $\underline{x}'(t)$, and $\underline{u}'(t)$ are the row vectors of the jointly dependent variables, of the predetermined variables, and of the unobserved disturbances in the equations, respectively; $\underline{\Gamma}$ and $\underline{B}$ are the matrices of the coefficients of the jointly dependent variables and of the predetermined variables, respectively; and $0'$ is a row vector of zeros. The estimated parameters (i.e., the estimates of the elements of the coefficient matrices Γ and B) of this econometric investigation are obtained by the method of two-stage least squares. The "Student's" t-tests are used to test the hypotheses.

B. Summary of the Results

1. General remarks

The variables under investigation (i.e., being explained) are:

$y_{101}(t)$ the total production of all citrus fruits;

$y_{201}(t)$ the total production of oranges (excluding tangerines);

$y_{301}(t)$ the total production of grapefruits;

$y_{401}(t)$ the total production of lemons.

On the national level, one set of equations for each of the four "explained variables" above is specified and estimated, and the appropriate hypotheses about the estimated coefficients of the variables in the equations are tested. Three analyses are made for each "explained variable"--an analysis for the entire study period, 1921-1965; for the prewar years 1921-1939; and for the postwar years 1948-1965. The numerical estimates of the coefficients for the variables and the period analyses are presented in Tables 2 through 13 of Chapter IV.

The regional analyses are considered in Chapter V and the regional numerical results are presented in Tables 14 through 25 of that chapter. The regional analyses cover only the last three "explained variables" listed above. The variables of the regional analyses have a superscript R, to differentiate them from the same or similar variables encountered at the national level. But in the discussion below, the superscript R is omitted for brevity.

The following discussion is based on the analyses of the numerical results of the statistical estimation already presented in Chapters IV and V. By "average coefficients" we mean the coefficients that are taken from the "average" row in the respective tables of Chapters IV and V.

2. Equations explaining $y_{101}(t)$, the total production of all citrus fruits

This variable is analyzed at the national level only. The estimated coefficients of almost all variables in the selected equations explaining $y_{101}(t)$ have the correct sign. Most of the coefficients are significant or highly significant. The major variables affecting the development of the citrus supply cycle are lagged citrus price, the cost factors (wages paid to hired day labor and fertilizer price) in the form of $y_{106}(t)$ and $y_{107}(t)$, the level of general production technology (as represented by the "time" variables), and expectation of wartime (high) prices and resource values.

The R^2-values are relatively high--second only to the lemon analysis at the national level. The R^2-values diminish with time--the postwar period relations have much lower R^2-values than do the relations of the prewar period.

3. <u>Equations explaining $y_{201}(t)$, the total production of oranges</u>

At the national level, most of the estimated coefficients of the variables explaining $y_{201}(t)$, the total production of oranges, bear the correct sign. This is also true at the regional level. The effect of $y_{203}(t)$, the current orange price received by farmers, upon $y_{201}(t)$ is negative but not statistically different from zero, at the national level. For Regions I and II, positive or negative c_{203}-coefficients are obtained depending upon the period of time being considered. For Region II, this coefficient is only lowly significant ($\alpha = 0.35$); and for Region I, the significance levels as well as the magnitude of the c_{203}-coefficients decrease from the prewar period to the postwar period.

The effect of $x_{204}(t)$, the lagged orange price received by farmers, upon $y_{201}(t)$ is positive as expected for the U.S.A. as a whole and for Region II. The estimated response in $y_{201}(t)$ due to changes in $x_{204}(t)$ has increased over time for all three areas. In Region II, lagged orange price has traditionally been considered one of the dominant factors in short run decisions concerning orange production. In Region I, before the Second World War, the current orange price was the single most important factor affecting short-run orange production-harvesting decisions. In the postwar period, as a result of processing activity and improved storage facilities, lagged orange price is becoming very important (at the expense of current orange price) in short-run decisions concerning orange production in the Southern States.

Other factors affecting orange production (at both the national and the regional levels) are the prices of rival products, acreage, and resource prices. The prices of the rival products--apples at the national level and in Region II, and grapefruits in Region I--are now featuring greatly in the short-run decision making process. This is inferred from the fact that the cross elasticities of orange supply with respect to a particular rival product has increased during the period studied. The entire period (1921-1965) analyses for the United States and also for Regions I and II show that orange acreage has a significant positive effect upon $y_{201}(t)$. The positive sign is expected under condition of short run profit maximization. For the entire study period (1921-1965), all statistically significant coefficients of $y_{206}(t)$, the ratio of orange price to wages, are negative.

This indicates that both at the national level and at the regional level, orange grove owners tend to interpret annual changes in the product-factor price ratio as longer run developments and tend to adjust the level of production accordingly. Also important in the decision-making process are the general conditions (wartime or peacetime) and the farm production technology in the economy. Differences in the predicted response in Regions I and II are due to the varying degree of specialization of resources and/or the number of competing enterprises.

The R^2-values are highest at the national level and lowest for Region II. And for each of the three areas, the R^2-values decreased over time.

4. Equations explaining $y_{301}(t)$, the total production of grapefruits

At both the national and the regional levels, most of the estimated coefficients of the variables explaining $y_{301}(t)$, the total production of grapefruits, bear the correct sign. But these coefficients have an additional characteristic--a relatively high frequency of sign changes from one period (prewar) to another (postwar).

The effect of $y_{303}(t)$, the current grapefruit price received by farmers, upon $y_{301}(t)$ is positive as expected for both the United States and Region I. No analysis was made for grapefruit production in Region II.[1] For the U.S.A. as a whole, the positive c_{303}-coefficients are significant or lowly significant. For Region I, the positive coefficients are only lowly significant and the response to changes in current grapefruit price has decreased over time. The average elasticities of $y_{301}(t)$ with respect to $y_{303}(t)$ are positive for both the United States and Region I, but the magnitude of the elasticity estimates is larger at the national level.

Also, the effect of $x_{304}(t)$, the one-year lagged grapefruit price, upon $y_{301}(t)$ is positive and significant or lowly significant for both areas studied. In Region I, lagged grapefruit price is apparently the most important factor affecting grapefruit supply.

The other major factors influencing the development of the grapefruit supply cycle are the prices of competing products--oranges and cotton lint, the cost factors--wages paid to hired day labor and the fertilizer supply and price, as well as the general conditions (wartime versus peacetime) and the farm production technology--as represented by "war effect" and the "time" variables, respectively.

The intercept coefficient is positive but not significantly different from zero at the national level. For Region

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[1]For reasons, see section V.A.

I, however, the intercept coefficient is positive and at least significant; the average b_0-value is consistent with the shape of the regional supply curve for grapefruits.

The R^2-values are once again better at the national level than at the regional level, and also better for the prewar period than for the postwar period. The R^2-values for the prewar period are also larger than those for the entire study period analysis at both the national and the regional levels.

5. Equations explaining $y_{401}(t)$, the total production of lemons

Almost the entire lemon supply of the United States is produced in the Western States of Arizona and California. The lemon analyses are therefore confined to the United States and Region II only. The effect of $y_{403}(t)$, the current lemon price received by farmers, upon $y_{401}(t)$ is positive or negative depending upon the particular time period under investigation. However, almost all the c_{403}-coefficients are statistically not significant from zero.

The statistically significant coefficients of $x_{404}(t)$, the one-year lagged lemon price are, for both the United States and Region I, negative for the prewar period but positive for the postwar period. The implication of the sign change is that lemon growers used to interpret the annual changes in the prewar lagged lemon price as indicating long run developments, but in the postwar period the growers now tend to consider the annual changes in lagged lemon price as pointing to short run developments only. Accordingly the response to changes in $x_{404}(t)$, the lagged lemon price, has been different in the postwar years from what it was in the prewar years. Changes in $x_{404}(t)$ now have a more immediate impact on $y_{401}(t)$ via the short-run decision-making apparatus. This change has also manifested itself in the increase in estimated supply elasticity during the postwar period.

The other factors affecting the lemon cycle are the cost factors (wages paid to hired day labor and fertilizer price), lemon acreage, and time. The time trends in all equations reflect trends in relevant variables not included explicitly in the equation. Technological changes are an example of such trend; the expansion of irrigated cropland is another such trend. The intercept coefficient is highly significant or significant, indicating that other factors or variables are important in the development of the lemon cycle and that these variables should be isolated, if possible, and used in the lemon cycle analysis as independent variables. One such "hidden" variable is weather.

A relatively small number of variables explain a large percentage of the variance in $y_{401}(t)$, the total production of lemon. In Region II, this percentage is close to 86, while at the national level about 95 per cent of the variance is thus explained for the entire study period. The difference in the percentage "explained" of the variability of $y_{401}(t)$ between the national analysis and the regional analysis may be the result of the accuracy in the data used. Because of inter-regional or inter-state mobility of resources and products, the regional data may not exactly reflect the true picture of the conditions existing in the particular Region or State. Consequently, the time series data for the United States tends to be more accurate than the data for the Regions.

C. Evaluation and Conclusion

The citrus cycle is said to be well explained by a particular model if the predicted values of the "explained" endogenous variables (that is, "the implications deduced from the estimated model") are in close agreement with the observed or actual values during the period studied. The goodness of fit (i.e., the measure of the closeness of this agreement) in a single equation model or a single equation of a simultaneous equation model is the residual variance ratio, ϕ, which is defined as $R = \sqrt{(1-\phi)}$, where R denotes the correlation between observed and calculated (or predicted) values.

The econometric models developed in this dissertation are rather simplified representation of the complex United States citrus economy, but as long as the value of Ø was considered satisfactory no attempt was made to improve the fit by including additional variables. The number of factors affecting citrus supply is large. Some of them, for example technological progress, are difficult to measure. Many of the factors are intercorrelated, so that the danger of multicollinearity is great. A consequence of this danger is that the model builder may make a compromise by not constructing an absolutely true model, but only one that can be considered as a good approximation, by including only those factors that according to existing theory and experience can be considered main causal factors (Stojkovic, 1963). Since the uncontrolled factors cannot be neutralized by randomization (note that our supply analysis is in the non-experimental field of applied statistical techniques), the consequence can be a special type of error, namely specification error. The model used in this study has followed the principles or specification procedure outlined in Chapter II. The number of "explanatory" variables is kept low to avoid collinearity and the model is intended only as an approximation to the true model. When considered in this way, the results obtained are quite satisfactory. The estimated coefficients possess a reasonable degree of statistical reliability, and judging from the elasticity values and from the percentage of the "explained" variability, which for most of the relations is good, the specification error should not be high.

The Ø-value varies from one type of citrus fruit to another and from relation to relation. In general it can be said that the goodness of fit for the supply relations is satisfactory. In a test against past actual behavior the model generated a historical series of production that closely approximated the actual movement of the production variables (see Chapter VI). Since the model predicts past movements reasonably well, it is potentially fruitful for making projections of possible future changes in the production of citrus fruits. With minor adjustments, therefore, the models could be used to moderate or even stabilize the citrus cycle.

The Durbin-Watson d statistic is generally not significant at the 5% significance level. For the studies involving the United States as a whole (Chapter IV), the d statistic for the many relations ranges from 1.699 to 3.073. For the regional studies also (except for orange production in Region I), the d statistic ranges from 1.737 to 2.852, according to the particular relation considered. These d-values indicate that the hypothesis of serial independence in the residuals (or error terms) is sustained. The d statistic for orange production in Region I falls in the inconclusive test range, with d of about 1.458.

VIII. BIBLIOGRAPHY

Allen, R. G. D. 1938. Mathematical analysis fcr economists. London, England, Macmillan and Corrpany, Ltd.

Allen, R. G. D. 1956. Mathematical economics. London, England, Macmillan and Company, Ltd.

Anderson, T. V. 1950. Estimation of the parameters of a single equation by the limited information maximum likelihood method. In Koopmans, T. C., ed. Statistical inference in dynamic economic models. New York, N.Y., John Wiley and Sons, Inc.

Anderson, T. V. and Rubin, H. 1949. Estimation of the parameters of a single equation in a complete system of stochastic equations. Annals of Mathematical Statistics 20: 46-63.

Bachman, K. L. 1958. Discussion: econometric research in agriculture. Journal of Farm Economics 40: 224-227.

Barker, R. and Stanton, B. F. 1965. Estimation and aggregation of firm supply functions. Journal of Farm Economics 47: 701-712.

Basmann, R. L. 1957. A generalized classical method of linear estimation of coefficients in a structural equation. Econometrica 25: 77-83.

Basmann, R. L. 1960. On finite sample distributions of generalized classical linear identifiability test statistics. American Statistical Association Journal 55: 650-659.

Benedict, M. R. and Kuznets, G. M. 1958. Better basic data for agriculture: some possible approaches. Journal of Farm Economics 40: 208-222.

Brandow, G. E. 1958. A note on the Nerlove estimate of supply elasticity. Journal of Farm Economics 40: 719-722.

Breimyer, Harold F. 1961. Demand and prices for meat. U.S. Department of Agriculture Technical Bulletin 1253.

Bressler, R. G. 1959. Stabilizing the domestic market for fresh lemons. Unpublished report. Los Angeles, California, Lemon Study Committee of Sunkist Growers.

Buse, R. C. 1958. Total elasticities - a predictive device. Journal of Farm Economics 40: 881-891.

Carlson, Sune. 1956. A study on the pure theory of production. New York, N.Y., Kelley and Millman, Inc.

Christ, C. F. 1954. Pitfalls in econometrics. Econometrica 22: 521-522.

Christ, C. F. 1956. Aggregate econometric models. American Economic Review 46: 385-408.

Dean, G. W. and Heady, Earl O. 1958. Changes in supply response and elasticity for hogs. Journal of Farm Economics 40: 845-860.

Durbin, J. and Watson, G. S. 1951. Testing for serial correlation in least-squares regression. II. Biometrica 38: 159-178.

Feller, W. 1957. An introduction to probability theory and its applications. Vol. 1. 2nd ed. New York, N.Y., John Wiley and Sons, Inc.

Fisher, F. M. 1959. Generalization of the rank and order conditions for identifiability. Econometrica 27: 431-447.

Fisher, F. M. 1961. On the cost of approximate specification in simultaneous equation estimation. Econometrica 29: 139-170.

Fox, Karl A. 1953. The analysis of demand for farm products. U.S. Department of Agriculture Technical Bulletin 1081.

Fox, Karl A. 1958. Econometric analysis for public policy. Ames, Iowa, Iowa State University Press.

Fox, K. A., Sengupta, J. K., and Thorbecke, E. 1966. The theory of quantitative economic policy with applications to economic growth and stabilization. Chicago, Illinois, Rand McNally and Company.

French, Ben C. and Bressler, R. G. 1962. The lemon cycle. University of California [Berkeley] Giannini Foundation Paper 229.

Friedman, M. 1953. Essays in positive economics. Chicago, Illinois, University of Chicago Press.

Frisch, R. and Waugh, F. V. 1933. Partial time regression as compared with individual trends. Econometrica 1: 387-400.

Fuller, W. A. and Ladd, G. W. 1961. A dynamic quarterly model of the beef and pork economy. Journal of Farm Economics 43: 797-812.

Gale, D. 1960. The theory of linear economic models. New York, N.Y., McGraw-Hill Book Company, Inc.

Girshick, M. A. and Haavelmo, T. 1953. Statistical analysis of the demand for food: examples of simultaneous estimation of structural equations. Cowles Commission Monograph 14: 92-111.

Goldberger, A. S. 1964. Econometric theory. New York, N.Y., John Wiley and Sons, Inc.

Griliches, Z. 1957. Specification bias in estimates of production functions. Journal of Farm Economics 39: 8-20.

Griliches, Z. 1960. Are farmers irrational? Journal of Political Economics 48: 68-71.

Gruber, J. 1965. Econometric simultaneous equation models of the cattle cycle in the United States and three selected regions. Unpublished Ph.D. thesis. Ames, Iowa, Library, Iowa State University.

Haavelmo, T. 1943. The statistical implications of a system of simultaneous equations. Econometrica 11: 1-12.

Haavelmo, T. 1958. The role of the econometrician in the advancement of economic theory. Econometrica 26: 1-12.

Heady, Earl O. 1952. Economics of agricultural production and resource use. Englewood Cliffs, New Jersey, Prentice-Hall.

Heady, Earl O. 1962. Agricultural policy under economic development. Ames, Iowa, Iowa State University Press.

Heady, E. O., Baker, C. B., Diesslin, H. G., Kehrberg, E., and Staniforth, S., eds. 1961. Agricultural supply functions. Ames, Iowa, Iowa State University Press.

Heady, E. O. and Dillon, J. L. 1961. Agricultural production functions. Ames, Iowa, Iowa State University Press.

Henderson, J. M. and Quandt, R. E. 1958. Microeconomic theory. New York, N.Y., McGraw-Hill Book Company, Inc.

Hicks, J. R. 1939. Value and capital. London, England, Oxford University Press.

Hood, W. C. and Koopmans, T. C., eds. 1953. Studies in econometric method. Cowles Commission Monograph 14.

Hoos, S. 1955. Price elasticities of fresh and processed lemons. University of California [Berkeley] Giannini Foundation.

Hoos, S. S. and Kuznets, G. M. 1962. Impacts of lemon products imports on domestic lemon markets. University of California [Berkeley] Giannini Foundation Research Report 254.

Hoos, S. S. and Seltzer, R. C. 1952. Lemons and lemon products - changing economic relationships, 1951-52. Calif. (Berkeley) Agric. Expt. Sta. Bul. 729.

Hopp, H. and Foote, R. J. 1955. A statistical analysis of factors that affect prices of coffee. Journal of Farm Economics 37: 429-438.

Houthakker, H. S. 1953. The specification problem in regression analysis. Econometrica 21: 488-489.

Johnston, J. 1963. Econometric methods. New York, N.Y., McGraw-Hill Book Company, Inc.

Kemeny, J. G. and Snell, J. L. 1962. Mathematical models in the social sciences. Boston, Massachusetts, Ginn and Company.

Klein, L. R. 1953. A textbook of econometrics. Evanston, Illinois, Row, Peterson.

Klein, L. R. 1960. Single equation versus equation system methods of estimation in econometrics. Econometrica 28: 866-871.

Klein, L. R. and Goldberger, A. S. 1955. An econometric model of the United States 1929-1952. Amsterdam, Holland, North-Holland Publishing Company.

Kloek, T. and Mennes, L. B. M. 1960. Simultaneous equations estimation based on principal components of predetermined variables. Econometrica 28: 45-61.

Koopmans, T. C., ed. 1950. Statistical inference in dynamic economic models. Cowles Commission Monograph 10.

Koopmans, T. C. 1951. Analysis of production as an efficient combination of activities. Cowles Commission Monograph 13: 33-97.

Koopmans, T. C. 1953a. Activity analysis and its applications. American Economic Review 43: 406-414.

Koopmans, T. C. 1953b. Identification problems in economic model construction. Cowles Commission Monograph 14: 27-48.

Koopmans, T. C. 1957. Three essays on the state of economic science. New York, N.Y., McGraw-Hill Book Company, Inc.

Koopmans, T. C. and Bausch, A. F. 1959. Selected topics in economics involving mathematical reasoning. SIAM Review 1: 79-148.

Koopmans, T. C. and Hood, W. C. 1953. The estimation of simultaneous linear economic relationships. Cowles Commission Monograph 14: 112-199.

Kuenne, R. E. 1963. The theory of general economic equilibruim. Princeton, New Jersey, Princeton University Press.

Kuznets, G. M. and Klein, L. R. 1943. A statistical analysis of the domestic demand for lemons 1921-1941. University of California [Berkeley] Giannini Foundation Mimeographed Report 84.

Ladd, G. W. 1956. Effects of shocks and errors in estimation: an empirical comparison. Journal of Farm Economics 38: 485-495.

Lyttkens, E. 1963. Some notes on econometric models. In Wold, Herman, ed. 1964. Econometric model building: essays on the causal chain approach. Pp. 322-340. Amsterdam, Holland, North-Holland Publishing Company.

Marschak, J. 1953. Economic measurements for policy and prediction. Cowles Commission Monograph 14: 1-26.

McCorkle, C. O. and Mundlak, Y. 1955. Statistical analysis of supply response in late spring potatoes in California. Hilgardia 24: 455-493. 1956.

Mood, A. M. and Graybill, F. A. 1963. Introduction to the theory of statistics. 2nd ed. New York, N.Y., McGraw-Hill Book Company, Inc.

Nerlove, Marc. 1956. Estimates of elasticities of supply of selected agricultural commodities. Journal of Farm Economics 38: 496-509.

Nerlove, Marc. 1958a. The dynamics of supply: estimation of farmers' response to price. Baltimore, Maryland, The John Hopkins Press.

Nerlove, Marc. 1958b. On the Nerlove estimate of supply elasticity: a reply. Journal of Farm Economics 40: 723-728.

Nerlove, Marc and Backman, K. L. 1960. The analysis of changes in agricultural supply: problems and approaches. Journal of Farm Economics 42: 531-554.

Nerlove, Marc and Waugh, F. V. 1961. Advertising without supply control: advertising of oranges. Journal of Farm Economics 43: 813-837.

Parsons, Ph. S. and McCorkle, C. O. 1963. A statistical picture of California's agriculture. California [Berkeley] Agricultural Experiment Station Circular 459.

Popper, K. R. 1962. Conjections and refutations. New York, N.Y., Basic Books.

Powell, L. A. and Godwin, M. R. 1955. Economic relationships involved in retailing citrus products. Florida [Gainesville] Agricultural Experiment Station Bulletin 567.

Pubols, Ben H. 1950. Citrus fruit during world war II. U.S. Department of Agriculture Monograph 3.

Shear, S. W. and Blair, R. E. 1958. California fruit statistics and related data. California [Berkeley] Agricultural Experiment Station Bulletin 763.

Stojkovic, George. 1963. Market models for agricultural products. In Wold, H., ed. 1964. Econometric model building: essays on the causal chain approach. Pp. 386-419. Amsterdam, Holland, North-Holland Publishing Company.

Stout, Roy G. 1962. Estimating citrus production by use of frame count survey. Journal of Farm Economics 44: 1037-1049.

Suitts, D. B. 1954. An econometric model of the watermelon market. Journal of Farm Economics 37: 237-251.

Suitts, D. B. and Koizumi, S. 1956. The dynamics of the onion market. Journal of Farm Economics 38: 475-484.

Theil, H. 1953. Estimation and simultaneous correlation in complete equation systems. The Hague, Holland, Centraal Planbureau.

Theil, H. 1954. Linear aggregation of economic relations. Amsterdam, Holland, North-Holland Publishing Company.

Theil, H. 1957. Specification errors and the estimation of economic relationships. Review of the International Statistics Institute 25: 41-51.

Theil, H. 1958. Economic forecasts and policy. Amsterdam, Holland, North-Holland Publishing Company.

Theil, H. and Kloek, T. 1960. The operational implications of imperfect models. In Arrow, K. J., Karlin, S., and Suppes, P., eds. Mathematical methods in the social sciences, 1959. Pp. 105-128. Stanford, California, Stanford University Press.

Theil, H. and Nager, A. L. 1961. Testing the independence of regression disturbances. American Statistical Association Journal 56: 793-806.

Tinbergen, Jan. 1939. Statistical testing of business cycle theories. Geneva, Switzerland, League of Nations.

Tinbergen, Jan. 1940. Econometric business cycle research. Review of Economic Studies 7: 73-90.

Tintner, G. 1952. Econometrics. New York, N.Y., John Wiley and Sons, Inc.

Tintner, G. 1953. The definition of econometrics. Econometrica 21: 31-40.

Tintner, G. 1954. The use of mathematical methods in econometrics and economic statistics. International Social Science Bulletin 6: 640-651.

Tsiang, S. C. 1955. Experimental selection of explanatory variables and the significance of correlation. Econometrica 23: 330-331.

Tyner, F. H. and Tweeten, L. G. 1965. A methodology for estimating production parameters. Journal of Farm Economics 47: 1462-1467.

U.S. Census Bureau. 1960. Historical statistics of the United States, colonial times to 1957. Washington, D.C., U.S. Government Printing Office.

U.S. Census Bureau. 1964. Statistical Abstract of the United States, 1964.

U.S. Congress. 1948. Problems of the citrus-fruit industry: hearings before a subcommittee of the committee on agriculture and forestry, U.S. Senate. Washington, D.C., Government Printing Office.

U.S.D.A. 1945a. Citrus fruits, production, farm disposition, value, and utilization of sales, crop seasons 1909-10 - 1943-44. Washington, D.C., Bureau of Agricultural Economics, U.S. Department of Agriculture.

U.S.D.A. 1945b. Surveys of wages and wage rates in agriculture. U.S. Department of Agriculture Report 1.

U.S.D.A. 1949. Fruits and nuts: bearing acreage, 1919-1946. U.S. Department of Agricultural Commodity Statistics 32.

U.S.D.A. 1952a. Citrus fruits, production, farm disposition, value and utilization of sales, crop seasons 1944-45 - 1949-50. Washington, D.C., Bureau of Agricultural Economics, U.S. Department of Agriculture.

U.S.D.A. 1952b. Fruits (noncitrus): production, farm disposition, value, and utilization of sales, 1944 - 1949. U.S. Department of Agricultural Statistical Bulletin 114.

U.S.D.A. 1956. Fruits (noncitrus), by states, 1949-1955. U.S. Department of Agricultural Statistical Bulletin 192.

U.S.D.A. 1957a. Agricultural Statistics, 1957.

U.S.D.A. 1957b. Citrus fruits, by states, 1949-50 - 1955-56. U.S. Department of Agricultural Statistical Bulletin 201.

U.S.D.A. 1958. Labor used for fruits and tree nuts. U.S. Department of Agricultural Statistical Bulletin 232.

U.S.D.A. 1962. Agricultural Statistics, 1962.

U.S.D.A. 1963a. Agricultural Situation 47, No. 4.

U.S.D.A. 1963b. The Fruit Situation 147.

U.S.D.A. 1966a. Agricultural Statistics, 1966.

U.S.D.A. 1966b. Consumption of commercial fertilizers and primary plant nutrients. U.S. Department of Agricultural Statistical Bulletin 375.

U.S.D.A. 1966c. The Vegetable Situation 161.

U.S.D.A. 1967a. Citrus fruits, production, use, and value, by states, 1909-10 - 1964-65. U.S. Department of Agricultural Statistical Bulletin 380.

U.S.D.A. 1967b. Fruits (noncitrus), by states, 1959-1964. U.S. Department of Agricultural Statistical Bulletin 407.

Van de Wetering, H. 1964. Supply response models of livestock products: a national and regional analysis. Unpublished Ph.D. thesis. Ames, Iowa, Library, Iowa State University.

Wagner, H. M. 1959. Linear programming techniques for regression analysis. American Statistical Association Journal 54: 206-212.

Watts, H. W. 1958. Discussion: econometric research in agriculture. Journal of Farm Economics 40: 313-314.

Whittle, P. 1963. Prediction and regulation by linear least square methods. Princeton, New Jersey, Van Nostrand.

Wilcox, W. W. 1947. The farmer in the second world war. Ames, Iowa, Iowa State College Press.

Wold, H. 1955. Possibilites et limation des systemes a chaines causal. Cahier du seminaire d'econometric de R. Roy 3: 81-97.

Wold, H. 1959. Ends and means in econometric model building. In Grenander, U., ed. 1960. Probability and statistics: the Harald Cramer volume. Pp. 355-434. New York, N.Y., John Wiley and Sons, Inc.

Wold, H. 1960. A generalization of causal chain models. Econometrica 28: 443-463.

Wold, H. 1961. Unbiased predictors. Fourth Berkeley Symposium of Mathematical Statistics and Probability Proceedings 1: 719-761.

Wold, H., ed. 1964. Econometric model building: essays on the causal chain approach. Amsterdam, Holland, North-Holland Publishing Company.

Zellner, A. and Theil, H. 1962. Three-stage least squares: simultaneous estimation of simultaneous relations. Econometrica 30: 54-78.

Zusman, P. 1961. Econometric analysis of the market for California early potatoes. Hilgardia 33: 539-668. 1962.

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