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Factor demand in the United States agriculture: econometric simulation

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I. INTRODUCTION AND OBJECTIVES

A. Introduction

This study is an investigation of the aggregate demand for investment expenditure on farm machinery and farm buildings. The demand for farm labor is also included. The study includes the econometric analysis of the investment demand for above-mentioned factors and the related underlying variables affecting those demands. The data used in the study are aggregate times series data from 1924 to 1965 for national analysis and from 1946 to 1965 for regional analysis.

The usefulness of the study is obvious: The problem of overcapacity and low incomes in agriculture has been one of the major problems in U.S. society over the three decades. The problems of agriculture have been somewhat reflected in a large supply of crop and livestock products and low level of farm incomes as compared to those in non-farm sectors.

Although the problems of agriculture are directly those of commodity supply and price, fundamentally they are problems of resource demand and supply. More basically, the farm problems stem from economic growth which is reflected in the relatively stable price for non-farm produced items and increasing productivity of resources.

Through economic growth, capital has increased in supply to agriculture sector at sufficiently low real price, resulting in large-scale substitution for land and labor. With rapid adoption of productive capital inputs, opportunities for growth in output and productivity of resources is large. But if opportunities for adjusting redundant labor resources
out of agriculture are low because of values, social attachments, abilities and other characteristics of farm people, the returns to farm labor may be low indeed. Whether this is the case, depends upon the developing structure and organization of agriculture.

The organization of agriculture is a reflection of parameters in the structure of agriculture. The organization involves the numbers and sizes of farms which make up the industry, the size of the labor force and the amount and composition of capital used etc. To explain why a particular organization might emerge, it is necessary to know the structure of agriculture. It is a systematic framework of institutional, behavioral and technological relationships that go to determine output, efficiency and returns in agriculture.

Understanding of structure in agriculture can be useful for example, in answering a number of fundamental questions which depend heavily on the nature of the resources market in agriculture. Whether a return to an agriculture free of government controls will eventually raise farm income per worker depends on the responsiveness of farm workers to a fall in relative income. The interrelationships of policies affecting national employment and farm labor mobility cannot be accurately judged without gaging the magnitude of parameters in the farm labor function. The demand and supply function for a particular resource obviously is interrelated, through resource prices, technical coefficients and substitution rates, with the demand and supply functions for other resources. Thus the estimation of the basic structure of parameters of demand and supply functions for other resources are also needed.
The close relationship between factor demand and the organization of resources in agriculture along with the importance of factor demand to commodity supply further suggests that the research into agricultural resources is a relevant area for study. However, studies of the basic structure of agriculture and the parameters of supply and demand are limited. Past discussions and econometric studies regarding the resources demand have often been based largely on particular resources. Only Heady and Tweeten's excellent study (50) has investigated quantitatively the interrelationships among the different categories of resources in agriculture. More important, their study has explicitly integrated the products and inputs markets of the agricultural and the non-farm variables. There are several reasons why an integrated study is necessary. Product markets determine gross income, resource markets determine expenses and the two markets determine net income in farming. From a causal and statistical standpoint, many decisions in farming are interdependent. It is almost impossible to determine how much family labor, for example, will remain in agriculture without estimates of farm product prices, national unemployment and factory wages.

There are some difficulties in extending Heady and Tweeten's study (50) much beyond its current contributions. These possibilities, if any, lie in two major aspects of economic structure. The first of these is the intertemporal structure, or, in short, dynamics. The second is the spatial interconnectedness of demand and supply either in resources or products markets. For many agricultural commodities, production decisions
take place many months before supplies reach markets. Given supplies are determined by past production decisions and the intervening hand of weather. The recursive models seem appropriate in describing this kind of nature both as a basis for practical forecasting and as a tool of realistic economic theory. The recursive system is composed of a sequence of causal relationships. It consists of a set of equations each containing a single endogenous variable other than those that have been treated as dependent in prior equations. The endogenous variables enter the system one by one, like links in an infinite chain where each link is explained in terms of earlier links.

For the interregional relationships, the regional commodity demand functions shift over time. But at the time when supplies are forthcoming they are relatively stable. With supplies predetermined, a transportation model, augmented by regional demand functions, might well represent the temporary equilibrium of spatial marketing structure, yielding interregional commodity flows and regional prices received and paid for agricultural commodities (31, 98).

By temporary equilibrium one does not mean static or normative equilibrium. It implies that the economic function of distributing predetermined supplies among various regions is performed in an efficient manner with respect to costs that clears the market. The interregional prices and commodity flows may vary widely from one period of temporary equilibrium to the next, in cyclical, in an explosive or even (because of weather) in an erratic manner.
Synthesizing the recursive production, factor demand and the temporal market equilibrium feature to formulate a dynamic regional interdependence model for the U.S. agriculture would be desirable. By emphasizing the factor market, a better understanding of the structure and organization of agriculture resources for policy purposes will become attainable. Furthermore as an alternative econometric model, it can be subjected to testing and to observing how well it describes the investment behavioral pattern of farmers.

The quantitative results and the structural parameters which will be presented in this study refer to specific types of investment, namely farm machinery and farm buildings. Demand for farm labor will also be estimated. The words "resource, factor, and input" will be used interchangeably in the following chapters.

B. Objectives

The general objective of this study is to describe and analyze the resource structure of American agriculture. A major portion of the study is devoted to developing the econometric models and derivation of quantitative estimates of structural parameters determining farm resources allocation. Specific objectives are (1) to identify the causal and related variables affecting the historic changes in investment demand, (2) to develop a model or models to describe the aggregate demand for farm machinery, farm buildings investment and the farm labor using the causal and related variables, (3) to estimate the parameters of the models developed using the available data for the time period under study, and
(4) to use the models developed and the estimated parameters to simulate and project the national aggregate demand for the above-mentioned factors (based upon certain assumptions to be indicated later).

The organization and contents of this study will be in the following order. After this introductory chapter a broad examination of investment theory and brief review of past econometric studies for durable goods will be presented in Chapter II. The demand theory, supply-demand relationships, spatial and dynamic interrelationships of the agriculture resources will be discussed and developed in Chapter III. Further a review of past studies and hypotheses directly concerned with agriculture resources also will be discussed in this chapter. The econometric models for this study will be the subject of Chapter IV. This chapter will be composed of a proposed model and the final model. The proposed model will be developed on the theoretical basis which will be discussed and developed in Chapter III. It will incorporate the dynamic, spatial relationships of resources demand and further integrating it with the commodity market. The final model will be the workable model based on the proposed model taking care of the foreseeable data limitations. The final model will further be divided into national and regional models. Econometric consideration then will be at the end of this chapter.

After this background material the empirical analysis will be presented in Chapters V and VI. The national recursive model of resources demand bases on time-series estimates along with the sources of data will be presented in Chapter V. Linear regional model estimated with times-series and cross-sectional data (10 farm production regions, see Figure 1),
Figure 1. Farm production regions
using the combination of the analysis of covariance and multiple regression techniques also will be presented in Chapter V.

The national model and the parameters of the model after statistical estimation will be used for simulation and projection Chapter VI. The historical values of investment will be simulated with the model developed and the parameters estimated in order to verify the model. Two different exogenous variables, technology and farm policy also will be simulated with different value and different practice than the prevailing one. Under free market system (free from price support and production control programs) and lower technological advancements (one half of original rates), the national model will be simulated for the resources demand. Further the national model also will be used to project the investment demand for those factors in agriculture up to year 1980. Certain basic assumptions about the general economy and specific assumptions about the individual variables will be made. These assumptions will be stated in Chapter VI on investment projections. The final chapter, i.e., Chapter VII, is devoted to conclusions.
II. ECONOMIC NORMS

At the beginning of this chapter, some theories of investment behavior will be discussed briefly. Then recent innovations in connection with these investment theories will be examined. Following this some economic investigations based on these models will be discussed. The central elements of modern investment theories will provide a basis for specification and integration of individual resource demand functions in the next chapter. Emphasis throughout the remainder of this chapter and the thesis will be on the decision to invest as viewed from the standpoint of the individual entrepreneur. Consequently the discussion revolves around investment theory of the firm.

It will be made clear in the subsequent sections that one has to admit that a simple conceptualization of the investment process is called into question, both by conflicting views among economists themselves and by businessmen's expression of their own ideas of the investment process.

A. Some Theories of Investment Behavior

Investment is the time rate of change in a stock of durable assets. The investment decisions of a firm are likely to involve a number of considerations including expectations about future prices, outputs and reactions of major rivals, current rates of capacity utilization as well as a variety of constraints such as technological conditions and availability of finance.

Investment theories, for purposes of discussion, can be grouped into
four categories:

1. The profit maximization or marginal theories: the profit motive is the fundamental propelling drive in both static marginal theories and the more recent adaptation of marginalism contained in uncertainty, risk and expectation theories;

2. The technically oriented acceleration approach: The technical need for greater capacity to meet an increase in demand for final product are the main motives;

3. Inductive generalizations based upon institutional and empirical studies;

4. The eclectic theories, based on integration of several of the above theories.

1. Marginal investment theory

Marshall has fully developed the theory of marginal analysis including the marginal theory of investment (82, pp. 351-367). Investment will be made by entrepreneurs in such a way that the return from investment in all enterprises will be the same.

There are certain assumptions (86) in the marginal approach: (1) producers are maximizing profit; (2) all future product and factor prices are known; (3) the production function is given; (4) there is no change in technology; and (5) the availability of funds and the rate of interest is known.

Under pure competition, the amount of investment will shift between enterprises until an equilibrium is reached where the value of marginal products of capital for all enterprises are equal. At the same time
the average return to capital will also be equal to the marginal return.

This equilibrium situation has seldom been reached. The reasons are many. First of all, pure competition does not exist in most economies. Varying degrees of monopoly exist in almost all classes of enterprises. Secondly there are continual shifts and disturbances in the economy which occur at intervals shorter than the time lags needed to make the required marginal adjustments. There are other reasons such as most capital stock is constrained to very specific use, the durability of capital, the personal preference and the store of personal experience and individual training which give the variation in return to capital in different enterprises.

In the short-run, capital investment rarely reaches that theoretical equilibrium indicated above. Yet, marginal analysis remains one of the most powerful tools for economic planning and decision-making. The marginal values (shadow prices) which result from programming models, one of the practical uses of marginal analysis, become important decision criteria. The application of marginal theory to investment has revealed many important variables, such as the cost of capital stock and the value of the product by capital stock, which need to be subjected to careful investigation.

The marginal theories, recently, have been subjected to modification. In the real world, those objective conditions that are put ceteris paribus by the marginal theories are really the crucial determinants of investment. It should be recognized that the choice of what properly belong to ceteris paribus is itself an institutional variable and subject to change.
The partial recognition of this institutional change has led to efforts to shift the theory of the firm from a profit maximization orientation to that of utility maximization. Specifically, the use of the utility maximization assumption enables the theoretician to bring the entrepreneurial desire for flexibility into a theoretical model. In other words, if uncertainty about the future exists, a premium is placed on being able to adapt to changing circumstances.

Of course, all investment theories taking uncertainty into account will contain some theory of expectations. These theories usually fall into two distinct categories. For example, in the first category a set of objectives (utility or profit maximization) are characterized as the goals of behavior but in a very broad, general way. In the second category, a subjective desire, say the desire for flexibility, is linked to an objectively measurable variable presumed capable of satisfying the objective desire, for example, a particular type of asset structure.

2. The acceleration approach

The acceleration principle is one of the post-Keynesian approaches to investment theory. The other Keynesian approach is marginal efficiency of capital. Most of their considerations, however, are oriented toward the macro effects. The following is a brief discussion of the marginal efficiency of capital.

"The marginal efficiency of capital is the rate of discount which equates the present worth of the receipt stream to the present worth of the expense stream (67, p. 140)."
The net present worth of an investment is:

\[ V = \int_0^t (R_t - E_t) e^{-J(t)} dt \]

where \( R_t \) is the receipt stream at time \( t \), \( E_t \) is the expense stream, \( j \) is the discount rate, which is treated as variable here and \( J = \int_0^d j(t) \) \( dt \) is a function representing the variation in the discount rate (83, p. 16). \((R-E)_t\) is the net return. The marginal efficiency of capital is equal to the discount rate when the discount rate is such that the present worth of the investment \( V \) is equal to the cost of the investment.

Several decision criteria for selection of an investment using the marginal efficiency of capital have been suggested (102, pp. 18-20). In general, at least theoretically, the interest rate plays an important role in making economic choices in the area of investment just as prices of other commodities affect the choices made by consumers. Through this marginal efficiency of capital theory, the investment decision is also based upon some expected future net incomes and the cost of the capital stock. Thus investment decision theory is quickly linked to the expectation theory.

There are many possible expectation models. One of the most frequently used is the continuity type. The last observed variable is the value predicted for the future. This method is based upon the assumption of continuous development of the variable in question (106, p. 44).

Another type of expectation model is the stationary type. The degree of uncertainty is hypothesized to fluctuate around the average (106, pp. 44-45).
If expectations are going to be included in the theory of investment for better description of the real world, they must be related in some way to past events and/or present datum. Haavelmo made the similar argument that expectations must be a function of some other known relation in developing a workable theory of investment (43, p. 10).

a. The acceleration principle The acceleration principle involves the relationships between the changes in gross output and the induced investment occurring as a result of the changes in gross output. The accelerator for investment is given by Allen (1, p. 62) as:

\[ I_t = k \frac{dy}{dt}, \text{ or for discrete analysis, as } I_t = \Delta K_t = k(Y_t - Y_{t-1}), \]

where \( I_t \) is investment, \((Y_t - Y_{t-1})\) is the change in gross income or output from one period to the next, and \( k \) is the accelerator coefficient relating investment per period with the change in output.

The acceleration principle, in this rigid construction, asserts that the change in the capital stock per unit of time is a linear function of the rate of change in output. Thus the acceleration principle has little or no motivational content.

The most critical and basic accelerator assumption is that firms, prior to an increase in output, must have no excess capacity. Since excess capacity is frequently observed in reality, attempts have been made to adapt the accelerator to these facts. The most common solution has been to view excess capacity primarily as a cyclical phenomenon so that the accelerator works in an upswing but becomes inoperative during a downswing. Others, go further and suggest that secular excess capacity is
often needed for profit maximization in an industry with increasing returns to scale and growing output.

Since the accelerator, technically, deals only with net investment, it might appear unwarranted to suggest that it should also take into account replacement investment. In recognition of this, two schools of thought emerged, the first holding that replacement investment depends on the level of output and the second that it depends on the age distribution of the capital stock.

Still another major difficulty with the simple accelerator is its assumption that firms can obtain funds with little or no difficulty. Since unlimited financial availability does not exist in actuality, profits are generally the major sources of business funds. As a consequence it has been suggested that profits be incorporated into attractive simple acceleration theory.

The original and attractively simple acceleration principle has, in recent years, become complex and rather confused. Emerging from the accelerator discussion are three different theories of investment: the original theory based on change in sales, a capacity oriented theory involving the ratio of absolute sales or output to capacity stock, and a profit model.

b. **Modified acceleration approach** Capacity utilization theories are: (1) The acceleration principle has been fundamentally modified in two related cases. a) The first modification is toward a level of output rather than the rate of change of output. b) The second is the introduction of distributed lags.
The simple capacity model is shown in equation (1).

\[ I_t = a_1 X_t - a_2 K_{t-1} \]  

(1)

Hollis Chenery (10) in a theory very similar to one proposed by Richard M. Goodwin (1, pp. 240-251) suggests how to rationalize the coefficients \(a_1\) and \(a_2\) in terms of pure acceleration reasoning plus a reaction coefficient that indicates how rapidly the capital stock will adjust to a disequilibrium relation between output and capital stock. In Chenery's case, the equation is

\[ I_t = b(BX_t - K_{t-1}) \]  

(2)

where \(I_t\) is investment, \(X_t\) is output, \(K\) is capital stock, \(b\) is the reaction coefficient, \(0 < b \leq 1\) and the \(B\) is \(K^D_t / X^D_t\), the desired capital coefficient, i.e. the desired capital-output relation.

Investment is proportional to the difference between the optimal capital stock \((BX_t)\) and the actual capital stock at the beginning of the period, where the desired capital stock is predicted on the assumption that the current levels of sales will continue into the future. The theory merely stating that investment is proportional to the difference between the actual and desired capital stock. The lagged nature of decision-making in addition to the doubt that 'truly' current sales are expected to continue indefinitely causes the reaction coefficient 'b' to be fractional. Once the identification of current sales with expected sales is made, the theory acquires operational content. Equation (1) can be written as a difference equation (3):

\[ K_t = a_1 X_t + (1 - a_2)K_{t-1} \]  

(3)

with its solution shown in (4)
\[ K_t = (1 - a_2)^t K_0 + \sum_{T=1}^{t} a_1 (1-a_2)^{t-T} X_T \]  

(4)

using notation from Chenery model

\[ K_t = (1-b)^t K_0 + b \sum_{T=1}^{t} (1-b)^{t-T} X_T \]  

(5)

on the assumption that \( b \) in (5) is a positive fraction, the first term in equation (3) will gradually drop out. The dominant part of the expression is contained in the second term. It is the sum of an exponentially declining set of weights applied to previous period outputs. Since \( 0 < b < 1 \), the discrepancy between desired and actual capital stock is never totally eliminated, so that past outputs continually influence current investment.

Koyck provides some worthwhile insights into the explicitly dynamic aspects of investment theory (76). He makes two main theoretical points.

(1) There are distributed lag effects of adjusting the capital stock in response to a change in output.

(2) If one assumes that the distributed lag declines exponentially in time after a certain point, one can then interpret the estimated coefficient in a regression model involving the capital stock, output, and investment as reflecting the parameters of the distributed lag.

A simplified version of Koyck’s model can be represented as

\[ K_t = \sum_{i=0}^{\infty} \lambda^i X_{t-i}, \quad 0 < \lambda < 1 \]  

(1')

Equation (1') represents the capital stock as an exponentially weighted sum of previous outputs. It has been assumed that the exponential declining occurs immediately after the current period. From this relation, Koyck shows that investment defined as the rate of change in capital stock can
be represented as:

$$I_t = \Delta K_t = \alpha D X_{t+1} = -\lambda K_t$$

(2')

This is virtually identical with the capacity model presented in equation (2). In (2') $\lambda$ is a speed of adjustment coefficient. In Chenery's model (2) it is clear $\lambda = 1 - b$. For values of near zero, investment will adjust rapidly to the capital stock so that the capital stock will always be approximately proportional to output according to $\alpha_0$ which can be identified as 'the' capital coefficient. This result corresponds to the instantaneous or strict rate of change accelerator. In the case when $\lambda$ is near unity, the capital stock adjusts very slowly to changes in output.

An example, take the case where the gestation lag occurs after the decision lag. The gestation lag refers to the lags between capital goods production and the time when these new assets are in place and operations can begin. Gestation lags may prove unimportant in some situations, particularly when they are short relative to the period of observation, which ordinarily is a year.

A limitation common to all the linear capacity models is the assumption of exponential weights. A 'more realistic' description of reaction pattern might be a declining rate of reaction for several periods, with no effect of any other periods.

Profit theories: In real world the capital market is imperfect. This is either due to the self-imposed restrictions on the business firm designed to avoid external financing or limited availability of funds. Then the actual investment rate is restricted predominantly to gross profit
levels. There are several divergent views concerning the formulation of this gross profit function.

1. Profit theorists contended that since the entrepreneur should maximize the present value of expected future profits through investment activity, he will invest according to present profits because these closely reflect future profits (64, 71). This is more so if future profits are not expected to diverge greatly from present profits and most revenues from an investment are paid back rapidly.

2. Others look to cost-revenue relations to provide rationale. When total revenue and cost functions are linear, total profits will be a linear function of output (114). According to this view, profit theories are actually a subsidiary hypothesis under the capacity utilization theories.

3. A third view stresses the supply effects, as well as institutional barriers and entrepreneurial caution as the reasons for profits' influence on the rate of investment (71).

3. Institutional and empirical generalizations

Many empirical studies of firm investment behavior have been undertaken with the 'model-free investigations' guided by a priori concepts but in a somewhat more causal, flexible manner. Furthermore, in these studies, direct interview and questionnaire techniques have generally been preferred to strict econometric models.

By far the most outstanding aspect of the direct inquiries is their virtual unanimity in finding that internal liquidity considerations and a strong preference for internal financing are prime factors in determining the volume of investment (2, 55). The main causes are explained as
the disadvantages, risk and higher expense in extending the external debt.

Institutional-empirical approaches have served several functions. For one thing, they have uncovered negative evidence concerning some hypotheses. More positively, they have stressed the importance of the liquidity restraint and trade position. The main shortcomings of this approach have been an absence of a theoretical framework for explaining the investment process.

4. The eclectic approaches

Many theories formulated under this approach have been the consequence of the recognition of the fact that there is a varying amount of empirical truth in each theory mentioned but nothing to justify which is the most superior. Eclectic theories are compounded from many theories. They differ from the institutional and empirical generalization approaches in degree of theoretical rigor. A few micro investment theories can be put into this category. Only two of them will be discussed in this section.

a. Residual-funds theory — Meyer and Kuh (86, pp. 190-205) have formulated the hypotheses of investment decision within the framework of a modern industrial economy typified by oligopolistic markets, large corporations distinctly separated in management and ownership, and highly imperfect equity and monetary markets.

They have recognized that the investment decisions are subjected to highly complex and volatile economic environment. As a consequence, none of the principal existing theories of investment was found to be completely adequate or inadequate. There is a varying amount of empirical truth in
each theory but nothing to justify any claim to absolute superiority for any one theory above all others.

Their proposed theory is thus compounded from many sources. The technological relationships center on the acceleration principle defining the long-run objectives of investment policy. In the short-run, the investment outlay on fixed and working capital are treated as a residual defined to be the difference between the total net flow of funds realized from current operations less the established or conventional dividend payments. Investment will often exceed or fall short of this residual. These excesses and deficiencies should be primarily related to changes in the sales picture since the long-run policy is centered around the acceleration principle. Finally, the profit motive, has been considered to be the main entrepreneurial motive which is closely linked in a world of oligopolistic markets to long-run retention of market share and trade position.

b. **Price-ratio-profit approach** Heady and Tweeten (50) suggested that many of the macro models may not be applicable in agriculture because of the small percentage of the agriculture investment in the total investment. Data limitations are also one of the reasons prohibiting the use of more elaborate investment models used in other economic sectors. The mixture of business decisions with consumption decisions in agriculture and the influence of net farm income on investment in agriculture is such that it is not easy to delineate it there as in other economic sectors. They used net farm income in the investment demand function assuming that in many cases part of farm family consumption is purchase of productive
assets for prestige or other non-monetary utility reasons.

There are some behavior differences expected between farmers and businessmen in regard to investment decisions. Prices and price ratios are seriously considered by farmers attempting to formulate expectations of their ability to pay for a particular factor of production and the relationship of price of the factor to the price of other factor is of interest at the time of purchases. Furthermore, the price ratios, that is the substitution effects, net farm income, equity ratio, stock of productive capital, farm size and interest rate formulate the main explanatory variables of the investment demand functions of agriculture.

The price-ratio-profit model thus also has highly eclectic nature in terms of theory. It even has integrated the marginal theories which have been discussed in the earlier section. The price-ratio model is unique in the studies for agriculture sector. It has appeared in most of agriculture investment studies which have been rewarding (18, 19, 40, 88, 102).

B. Review of Some Econometric Investigations

There are several types of investment models which are based on those investment theories discussed. All econometric models of the investment studied were linear in nature except for the exponential model estimated by Greenberg (39). The following discussions are limited to some of those models which have been thought to have some empirical appeals to this study.

1. The studies

Eisner (28) studied investment demand using the distributed-lag
accelerator. The accelerator in his model differs from the Keynesian accelerator in terms of an accelerator combining the change in gross income with the capacity concept of other writers. He based the use of the accelerator approach on the assumption that business firms try to maximize some monotonically increasing function of profits subject to a production with diminishing marginal returns to factors.

Eisner's main hypotheses are: (1) Increases in investment are generated by the increase in sales over a period of years; (2) the accelerator coefficient is higher the greater the proportion of the change in sales is thought to be permanent; (3) in those firms operating closer to capacity the accelerator coefficients should be higher than otherwise; (4) expectations should influence investment decisions. Since investment is made in response to expectations of the future return on investment, past profits per se should not be relevant to investment except for imperfections in the capital market (28, p. 2). Some other known values, either taken from past experience or from presently known business indicators, should be used as a basis for expectations; (5) the accelerator coefficient should be higher for firms with rising sales. (This is a restatement of (1)).

The empirical results obtained by his study, estimated with two different time periods for the distributed lag, were relatively good. The empirical results showed that the accelerator coefficients tended to get smaller with greater lags.

Diamond reformulated the Eisner models (26). Eisner used the change in sales to a specified high sales ratio as a distributed-lag accelerator
while Diamond used the following accelerator variable:

\[ \left( \frac{S_t}{F_{t-1}}/\frac{S_{t-1}}{F_{t-2}} - 1 \right), \]

where \( S \) refers to sales and \( F \) is fixed assets. The model is

\[ \frac{I_t}{F_{t-1}} = a + \sum_{i=1}^{4} b_i \left[ \frac{S_{t-2+i}}{F_{t-1+i}}/\frac{S_{t-1+i}}{F_{t-2+i}} - 1 \right] + b_5 \left( \frac{F_{t-1}}{F_{t-5}}/\frac{F_{t-3}}{F_{t-2}} \right) + b_6 \left( \frac{P_{t-1}}{F_{t-2}} \right) + b_7 \left( \frac{D_{t-1}}{F_{t-2}} \right) + u_t \]

where \( I \) = gross investment, \( F \) = gross fixed assets, \( S \) = net sales, \( P \) = profit before tax, \( D \) = depreciation change, \( u \) = disturbance term. The equation was estimated by ordinary least squares for a number of industry groups.

The results are consistent with those of Eisner's findings, that is, there is an accelerator relationship with sales, and profits are also significantly affected.

\( R^2 \)'s for various equations range from .19 to .38.

With the main concern of developing the effect of capacity upon investment, Chenery presented a theoretical and empirical study of the effects of the accelerator and plant capacity on the demand for investment (10). He hypothesized that for industries where overcapacity was the general rule, a measure of capacity utilization would have greater causal effect upon investment activity than the accelerator.

Chenery used two models: one model was the usual accelerator, another was a model containing a measure of under- or overcapacity without the inclusion of the accelerator. The estimation procedure used was ordinary least squares. Chenery found that the accelerator gave good results on
industries where, on any industry-wide basis, there was little or no overcapacity.

Greenberg based his study on the hypothesis that the most important variable affecting the demand for investment is the difference between existing and desired plant capacity (39). His model, with the formulation of Bourneuf and Kuh (8, 78), belongs to the capacity adjustment models. The Greenberg model was:

\[ C_{i,t+1} = C_{it} - W_{it} + b \left[ C^{*}_{i,t+1} - (C_{it} - W_{it}) \right] \]

where \( C_{it} \) is the actual stock of plant and equipment, \( W_{it} \) refers to depreciation, \( C^{*}_{i,t+1} \) is desired plant and equipment. Expected sales from Moody's survey data were used as a proxy variable for desired capacity '\( C^{*} \). However, the equations estimated were linear in logarithms and differ from the exponential form in his proposed model.

Greenberg found that (a) profit was not a significant variable; (b) liquidity and a modified accelerator should be considered; and (c) the relationship between desired capital and capital stock was significantly affected.

Bourneuf proposed that plant capacity is one of the most important variables in the determination of investment (8). She estimated two models with the same set of data. Model I (similar to a capacity-adjustment model) is

\[ I_{t} = a(C_{t-1} - Y_{t-1}) + bC_{bt} + c \Delta Y_{t} + K \]

where \( I_{t} \) refers to the investment, \( C \) is the capacity, \( Y \) is the output, \( C_{bt} \) is the capacity at the beginning of year \( t \), and \( C \) refers to the aver-
age capacity for the year $t$.

Model II (capacity equation) is

$$C_{bt} = aI_{t-1} + bC_{bt-1} + K.$$  

Bourneuf claims that model I has better results.

Kuh advocates the capacity utilization theories (78). He argued that the growth rate of a firm will range between a lower and an upper bound. The lower bound is determined by the amount of retained earnings and the upper bound is restricted only by the use and availability of external funds. Heady had essentially the same arguments in his earlier work (47, pp. 550-557).

The capacity-adjustment models developed along this line hypothesized that producers wish to adjust their presently existing capital to some desired amount. The general model is $I_t^T = b(I_t^D - I_{t-1}^T)$, with $I_t$ being net investment in capital for the period $t$, $I_t^D$ the total amount of investment desired for period $t$, $I_{t-1}^T$ the total amount of investment at the end of the previous period $t-1$, and $b$ the coefficient of adjustment or speed of adjustment.

This model is conceptually different from the accelerator model. In using this kind of model, there are some difficulties in finding the appropriate data for the desired capital variable. Some function of gross output could be used as a proxy variable for the desired amount of capital, i.e. assume that the past year's capital-output ratio will be the desired future relationship. Under these circumstances, this model turns out to be a mere modification of accelerator models (102, pp. 66-68).
Kuh's empirical results supported the hypotheses of the effects of desired capital, internal funds, and equity ratio.

Meyer-Kuh's residual fund theory (86) was discussed in the earlier theoretical section under the heading of 'the eclectic approaches'. Meyer-Kuh used the cross-section data for a large number of firms in fifteen different industries instead of the aggregated time series data used by most of the other investment studies. However, a combination of cross-section and time-series data was utilized by employing an interesting technique. They fitted linear functions using the distributed-lag accelerator in some models and a distributed-lag measure of capacity in others. Their findings indicated preference for the capacity utilization variables. They found that liquidity, formulated more like an equity ratio, was one of the statistically significant variables affecting capital investment.

The conclusions from this empirical study are that although short-run behavior might reflect either predominantly profit or capacity influences depending upon the rate of growth and levels of liquidity flows, in the long-run it was a capacity oriented model which most accurately represented entrepreneurial action.

Heady and Tweeten made a most extensive study in the area of demand estimation for capital investment in agriculture (50). The investments included farm machinery, capital stock, equipment and farm buildings. The demand for hired and family labor was also included.

Heady and Tweeten developed some behavioral hypotheses for testing in the agricultural sector. The general hypothesis was discussed in the
earlier theoretical section under the heading of 'the eclectic approach—price-ratio-profit approach'.

A number of models using different combinations of the proposed variables were estimated from available aggregate time-series data (50). The statistical techniques used are the ordinary least squares method and the limited-information-maximum-likelihood method.

The statistical results on the whole were very good. The general hypothesis supported by the empirical results was that the demand for capital investment in agriculture is dependent upon the price of capital, prices received by farmers, prices paid for hired labor, net farm income, the equity ratio, the stock of capital on hand, the size of farm, the rate of interest, government payments, and technology.

Griliches used two price-ratio models in his study of demand for farm tractors (40):

Model I. Total stock of tractors = f( the ratio of price paid for a tractor to the price received by farmers, rate of interest, lagged stock of tractors).

Model II. The annual investment in tractors = f( current tractor prices, the rate of interest, the stock of tractors at the beginning of the year).

Both models were estimated by the least squares method. Each of the variables was reported to be significant at the 5 percent probability level in at least one or more of the equations.

Cromarty published his studies of the demand for farm machinery, farm tractors and farm trucks in 1959 (18, 20). The ordinary least squares and
the limited information maximum-likelihood methods were the estimation procedures for his single equation and simultaneous equation models respectively.

The price-ratio was introduced in his model as the explanatory variable. The statistically significant variables (at or over the 5 percent probability level) in either models were the net farm income and the ratio of the price paid for different capital items to prices received by farmers. Among the variables reported significant in either study, price-ratios excepted, are the asset position of farmers at the beginning of the year and trade-in value of old capital items.

The Cromarty studies were among the first and most extensive work done on the demand for farm equipment. The published equations generally show good results.

The authors DeLeeuw and Klein and co-authors Gehrels and Wiggins used the ordinary linear models, though with different dependent and independent variables, for the study of the demand for investment in several different industrial sectors (25, 71, 36).

The empirical results show various degrees of success. The common explanatory variable, interest rate, was found to be a significant explanatory variable (at the 5 percent probability level) in the DeLeeuw and Gehrels and Wiggins' investment studies while it does not appear significant in the Klein's investment studies. However, in Klein's studies there was significant negative correlation between the interest rate and investment in the railroad and utilities industries. Both of these industries have high capital-output ratios and high capital-labor ratios. The pro-
portion of the total input cost attributable to capital is perhaps larger in railroads and utilities than in any other industry which was studied by Klein. The increasing capital intensity in modern agriculture probably would suggest the inclusion of interest rate as one of the explanatory variables in investment demand.
III. THE ECONOMIC STRUCTURE OF THE DEMAND FOR FACTORS

The formulation of hypotheses concerning the variables affecting the demand for farm inputs relies on underlying economic theory and the economic models used to represent economic relationships. It has been shown that the aggregate supply response of farm products depends fundamentally on the flexibility of resources in agriculture (50). The net farm income in farming is determined both by product markets and by resources markets. Product markets determine gross income, and resources markets determine expenses. Hence, it is logical for this study of resources demand to culminate in an explanation of aggregate farm products market. To a considerable extent, farm input and output prices are determined by non-farm variables such as wage rates, national income and population. Integrated models which include these non-farm variables are necessary for understanding the economic system and hence resource demand relationships in agriculture. In view of the fact that economic processes are enacted over time and among different regions one can expect that the temporal and spatial structure also are crucial in the study of economic structure.

This chapter contains the economic considerations relating to the dynamic interregional supply and demand for farm product, and demand and supply of resources. The procedure is to begin with concepts suggested by static economic theory of the firm and industry. Dynamic conditions and the spatial aspects of the real world then introduce questions concerning the nature of causality, degree of interdependence among variables, regions, time lags, and other fundamental concepts. The theoretical framework for dynamic interregional competitive economic structure of
resources demand will be generated in this chapter. In the last section, some theoretical bases of those significant variables in relating to output and individual input markets will be discussed.

A. The Static Framework of Resources Demand

The static framework is an oversimplification of the economic structure for the agricultural industry. However, the static formulation of the theory of a perfectly competitive firm under perfect knowledge with the goal of profit maximization is a useful starting point for construction of a structural model. Henceforth the structure will refer to the demand, supply and production functions which reflect technology, goals, values, institutions, etc. Certainly, the firm is the logical starting point for analysis of the aggregate product supply and resources demand. Furthermore, under certain assumptions, the agricultural industry is analogous to a farm firm.

The following arguments are developed along the lines of a general Walrasian type model with multiple outputs and generalized production function. Some of the restrictive assumptions made here will be dropped in the next section in order to formulate the more realistic operational theorem for investigating the economic structure of resources demand in agriculture.

Let us assume that firm A has a transformation function which allows it to produce more than one output per activity. For convenience, let us assume also that we have a fully general transformation function which allows all outputs to be produced from all inputs:
\[ F_A(Y_{A_1}, \ldots, Y_{A_m}, X_{A_1}, \ldots, X_{A_n}, \overline{Y}_{A_1}, \ldots, \overline{Y}_{A_n}) = 0 \]

where \( Y_A \)'s are outputs, \( X_A \)'s are inputs and \( \overline{Y}_A \)'s are intermediate outputs. Outputs here are treated as negative inputs.

For simplicity, we shall drop the subscript \( A \) from the function and convert it to an explicit function with an arbitrary good \( \text{(say } Y_1) \) chosen as dependent variable.

\[ Y_1 = f(Y_2, \ldots, Y_n, X_1, \ldots, X_m, \overline{Y}_1, \ldots, \overline{Y}_n) \]

where outputs are considered negative inputs. We further assume that some of the inputs are fixed, such as management ability, which leads to a U-shaped average cost curve and a rising marginal cost curve. The U-shaped cost curve is required in order for a maximum profit equilibrium at zero profits to exist. In reality, the firm's capital capacity may be one of these fixed inputs. Assumed also is the continuous cost function. Also for every set of positive \( P_R \) and \( P_X \), assume that minimum cost of producing every feasible set of outputs is obtained.

The firm will be maximizing profits subject to the production constraint of the above production function:

\[
\prod = \sum_{j=1}^{n} P_R Y_j - \sum_{i=1}^{m} P_X_i X_i - \sum_{j=1}^{n} P_R \overline{Y}_j - \lambda (Y_1 - f(Y_2, \ldots, Y_n, X_1, \ldots, X_m, \overline{Y}_1, \ldots, \overline{Y}_n))
\]

This is maximized when:

1. \[ \frac{\partial \prod}{\partial X_i} = -P_X_i + \lambda f_i = 0, \quad i = 1, \ldots, m \]

2. \[ \frac{\partial \prod}{\partial Y_j} = -P_R_j + \lambda \overline{f}_j = 0, \quad j = 1, \ldots, n \]
3. \( \frac{\partial \Pi}{\partial Y_j} = P_{R_j} + \lambda f_j = 0, \quad j=2,\ldots,n \)

4. \( \frac{\partial \Pi}{\partial Y_1} = P_{R_1} - \lambda = 0, \)

5. \( \frac{\partial \Pi}{\partial \lambda} = -Y_1 + f(Y_2,\ldots,Y_n,X_1,\ldots,X_n,Y_1,\ldots,Y_n) = 0 \)

when an interior maximum is assumed.

Also, the second-order conditions require that

\[ d^2 \Pi = \sum_{i,j} \frac{\partial^2 F}{\partial X_i \partial Y_j} < 0, \quad i=2,\ldots,n, \quad j=1,\ldots,m \]

subject to conditions (1) to (5) i.e., \( d \Pi = 0 \). This condition can be put in bordered Hessian form (77, p. 182). Where single- and double-barred f-terms denoted differentiation with respect to production function once and twice respectively.

Four sets of conditions are set forth here for the multi-output firm which wants to maximize profits:

(a) in equilibrium, the ratio of prices to marginal products for all inputs must be equal;

(b) the ratios of prices to marginal outputs must be equal;

(c) the factor of proportionality in (a) must be equal and opposite in sign to the factor of proportionality in (b); and

(d) the factor of proportionality in (b) must equal the price of \( Y_1 \), i.e. \( P_{R_1} \).

These translate further into the conditions that the marginal cost of any output be equal to a common value whatever input is used to produce the marginal output, and that the marginal output of every good yield a zero
marginal profit in equilibrium.

The firm's demand function for resources can be derived according to the conditions 1, 2, and 3: solving \( f_i \) simultaneously for \( X_i(i=1,\ldots,m) \), where \( f = \frac{\partial f}{\partial X_i} \), the derived demand function for these inputs becomes

\[
X_i = G\left( \frac{P_{X_i}}{P_{R_1}}, \frac{P_{X_i}'}{P_{R_1}}, X_i', Y_j, \bar{Y}_j, \text{Tech.}, j=1,\ldots,m \right), \quad i=1,\ldots,m \text{ except for the } i^{th} \text{ term.}
\]

This can be rewritten as

\[
X_i = G\left( \frac{P_{X_i}, P_{X_i}'}{P_{R_j}}, \frac{SP}{P_{R_j}}, \text{Tech.}, j=1,\ldots,n \text{ except } j^{th} \right),
\]

where the \( u \) is the residual term and \( SP = \sum_{i=1}^{m} X_i' \), \( i'=1,\ldots,m \text{ except the } i^{th} \), is the stock of productive farm assets.

The industrial demands for the \( i^{th} \) input is then the sum of all firm's demands for the \( i^{th} \) input as given in the above equation

\[
X_i = G\left( \frac{P_{X_i}}, \frac{P_{X_i}'}{P_{R_j}}, \frac{SP}{P_{R_j}}, \text{Tech.}, \ldots, U \right).
\]

This resources demand function gives the general hypothesis that the demand for the specific input under study depends upon the price ratios of that input to price received by farmers and prices paid for related inputs to price received by farmers, prices received by farmers, net income, the stock of productive assets and the technology. The functional relationships derived here is nothing new. Heady and Tweeten (50) have derived quite the same hypotheses. And the former is merely a generalization of the latter.
The resources demand functions derived above are the result of the Walrasian general equilibrium system. According to the Walrasian system, prices and quantities of commodities are determined interdependently by a system of demand and supply equations. This is true either for the commodity market or resources market. The complete Walrasian system involves demand and supply functions in the entire economy. By this vein of argument, the interrelated simultaneous equations system will be the appropriate framework for studying the static resources demand and market structure.

Even if the simultaneous system is considered pertinent in the theoretical context, empirical models of particular market necessarily must abstract from the remote markets in the entire economy. The operational theory and manageable models, as in this study for example, must emphasize the market for agricultural inputs and outputs. An investigation taking care of the demands for different types of investment expenditures in agriculture should be made instead of individual demand study. The dependent variables in a simultaneous equation system might be investment in machinery, investment in farm buildings and so on. Such an integrated over-all study, as implied in the above theoretical context, should give greater insight into the economic and other variables affecting the total investment decision in agriculture than individual demand studies. A more complete study should show the underlying structure and combination of variables affecting investment expenditures for all the various types of agricultural investment.

Economic theory of the competitive industry introduces additional
concepts which must be considered in any empirical estimation of the re-
sources structure. For agriculture, the price of several non-farm factors
may be assumed as given or exogenous, i.e., determined by forces outside
the system being examined. That is, the actions of the group of farmers
has little influence on the magnitudes of certain variables determined by
the whole economy or mainly by the non-farm sector.

B. Some Modifications toward the Dynamic and Inter-
regional Competitive System

The type of economic model chosen to represent the market structure
of agriculture depends strongly on the underlying causal framework. A
direct relationship exists between the nature of causality specified in
the economic model and the type of statistical model chosen to estimates
the parameters. So far, the static equilibrium model of Walras stresses
the interdependence of supply and demand in determining equilibrium price
and quantity. This basic premise of simultaneity is doubtful when one
introduces the dynamic economic theory which is thought to be a better
description of the real world. The fact that decisions take time led some
of the economists (the Stockholm school) to conclude that economic de-
cisions are not made simultaneously. Instead, they conceive of the re-
cursive model as the most fundamental at an abstract level of economic
theory. The introduction of the variable uncertainty is one of the reasons
for suggesting a recursive model. The recursive model is composed of a
sequence of causal relationships. The values of economic variables during
a given period are determined by equations in terms of values already cal-
culated, including the initial values of the system.

Much intuitive appeal lies in the disequilibrium nature of the recursive system. For example, in agriculture it seems logical that the current supply quantity often is determined by past price and the current year price is a function of the predetermined current quantity. Inputs are indispensable in any agricultural production. Farmers must make decisions of how much resources to use on the basis of expected rather than actual product prices because of the length of the farm production period. In formulating the output prices considerable uncertainty is involved. The methods of formulation of these expected prices are various, it could be by some weighted averages of the past prices or many others. Simultaneous equations with time subscript and which include price and quantity of the same time period, are dynamic equilibrium models. But they may not be appropriate when production, as in agriculture, is predetermined. The economic structure of the agricultural production and resources demand suggest the possibility of a recursive model. Recursive models seem appropriate in agriculture, both as a basis for practical forecasting and as tools of realistic economic theory (90, 133). For these reasons the use of static resources demand functions as derived above are not justified in all cases in a dynamic economy. It should be modified along the lines of the dynamic conditions of the real world. The first necessary modifications in the formulation of the model have been suggested to be the introduction of recursive economic models.

So far we have based the arguments on the profit-maximization assumptions of the firm and the competitive structure of the markets. This
normative approach bases its inference for a solution solely on a profit-maximizing criterion. The other approach, the behavioral approach, attempts to predict the solutions based on the description of past actual reactions subjected to the same stimuli. In the real world, the firms and industries are acting with some degree of deviation from the normative assumptions. Producers have many different, conflicting goals, and their decisions are influenced by numerous forces. All operate under imperfect knowledge, and each one's knowledge situation differs. Under such conditions, none of the approaches mentioned above will yield completely accurate predictions. Nevertheless, it is argued that the behavioral approach is more useful compared with the normative path when short- or intermediate-run market predictions are desired. It is hypothesized here, without elaboration at this moment, that the degree of deviation from the profit-maximizing position depends upon the size of the producing units, (represented by an index of the value of land and buildings) the farmer's equity, and the lagged unemployment rate etc. The signs and the magnitude of the parameter can be determined by empirical data. The relevance of these variables in products and inputs markets of agriculture are clear, even though it is difficult to say, a priori, whether the relationship is direct or inverse. More discussion of the relevance of these variables, and others, to the product and input markets will be taken care of in the next section.

In addition to the above modification of introducing the intertemporal structure, there is another modification which should be made to the logic behind the theory of the structure of agriculture. That is the regional
uniqueness and the interconnectedness of production, transportation, and demand among regions. As mentioned previously, the production decisions of many agricultural commodities take place many months before supplies reach markets. Hence supplies are determined by past production decisions and some other natural variables. For this reason, regional supplies are independent of temporary market equilibrium. But not the converse. Apparently, the implicit assumption is that the shipping decisions by producers are based on the profit-maximizing goals. Analogous arguments are applied to the resources markets. That is the regional price differentials of outputs and inputs are based on the normative assumption. This is not an unrealistic assumption concerning the shipping pattern. While the absolute price level and producer and consumer reactions are dictated by past reactions to the same stimuli as formulated in the regional demand and supply functions, interregional prices, and commodity and inputs flows may vary widely from one period of temporary equilibrium to the next in a cyclical or in an explosive manner. These temporary equilibrium prices of inputs and outputs at time t will then affect the regional production, consumption and resources demand for the next period. The general idea of moving temporary equilibrium has been proposed by Goodwin (38). As a synthesis of recursive production, inputs demand and temporary equilibrium shipping patterns, the static equilibrium theory of last section has supposedly now been modified toward a better description of the real world.

The production decisions in agriculture are made before products shipments are made, profit expectations cannot be based on the prices that
will result from the forthcoming supply. As the derived demand, the in­
puts demand has the same characteristics. The recursive production and
inputs demand models of the regional farm types at the beginning of a
production period are therefore independent of the marketing process for
that period. Thus on the basis of prices, yields and inputs requirements,
expected profits for the various enterprises in each regional farm type
model can be computed for period $t_0$. Under the given initial stock of
productive farm assets and prevailing government policy, the family of
behavioral (or econometric) equations can then be solved for that time
period. This gives the regional production and investment demand for the
period. Thus regional supplies are a result of adjustments for govern­
ment and farmers' policies of storage and some other natural effects.
By assuming market clearance for each time period, an estimate for total
demand is also available. Now, it follows that given the transportation
costs these regional supplies will form the initial conditions for deter­
mining the interregional commodity flows and prices. The regional demands
can then be determined simultaneously with current regional products prices
under the given exogenous variables such as population, index of per capita
food consumption and personal disposable income. The resulting prices be­
come information for formulating profit expectation in the succeeding year's
production at time $t_0+1$. The whole process can then be repeated an in­
definite number of times.

In the same way, the investments demand which is generated from the
recursive production and investment demand functions in the interregional
system, will determine the interregional flows and prices of inputs under similar given conditions, namely, the given transportation costs and market clearance conditions. All the demand functions are separate from one another but they are similar to the extent that they are all dependent upon the current prices of inputs which are computed at the same time as the quantities demanded. The resulting prices become information for formulating profit expectations for the succeeding year's production and investment demand at time $t_{o+1}$, and the process may be repeated indefinitely.

A schematic diagram of the economic structure of resources and commodity markets is presented in Figure 2. Although it is, of course, a highly simplified representation of the system, it suffices to emphasize that even though production decisions are independent of the current period's market equilibrium they are not independent of past market equilibrium. Also, it shows implicitly how interregional demand does affect interregional shifts in production and investment and how these effects are distributed over time by a dynamic adjustment process.

C. Specification of Output Supply and Input Demand Functions

The main purpose, here, is to conceptualize a simple and, hopefully, workable set of supply and demand functions for domestic farm machinery, farm buildings and farm labor markets in agriculture. While main emphasis is in the factors market, aggregate behavior equations in the commodity market are also discussed as an integrated part of this study.

There are some behavior differences expected between farmers and
Figure 2. Schematic diagram of the economic structure of the resources demand and products supply
businessmen in regard to investment decisions. These differences, apart from those which have been discussed in the last chapter, will be discussed along with the variables hypothesized for the demand functions of factors.

1. Aggregate commodity market

   a. Aggregate production response function The aggregate production response function of farm products depends fundamentally on the resource flexibility in agriculture (50).

   There is a simple and useful approach to estimate the aggregate output and price variables in macroeconomic functions. This approach does provide a basis for inferences about the aggregate production response as compared to a number of studies which dealt exclusively with the supply response of many individual farm commodities (62, 63, 84, 92).

   In here, the aggregate production response function for farm products is specified as:

   \[ Q_t = f\left(\left(\frac{P_R}{P_P}\right)_{t-1}, S_{PLt}, G_t, W_t, T, A(t), C_t\right) \]

   where agricultural output, \(Q_t\), is the production of feed and livestock during the current year, excluding interfarm sales, seed and crops fed to livestock. It represents the current product of agricultural resources available for eventual human consumption. The concept is considered relevant for long-run measure of quantity produced since it is closely tied with the resource structure and is not influenced by fluctuations of non-productive farm inventories.

   The assumptions are that current product(s) produced is predetermined
by past prices ratio \((P_R/P_p)_{t-1}\), stock of productive farm assets at the
beginning of the year, government's programs \(G_t\), weather \(W_t\), level of
technology \(A(t)\), structure dummy variables \(C_t\) and time \(T\).

Given the level of aggregate inputs and technology \(A(t)\), the output
is also known. It follows that the variables \((P_R/P_p)_{t-1}\) and \(G_t\) primarily
are concerned with predicting the aggregate input level in agriculture.
But with the beginning year stock of productive farm assets, \(S^b_{Pt}\), in the
function, only operating inputs, labor and current inputs of durables are
left to be determined by \((P_R/P_p)_{t-1}\) and \(G\).

Since durable assets and labor have little short-run effect on output,
the price variable primarily reflects the short-run influence of operating
inputs. The above equation may be regarded as a dynamic agricultural
production response function with price substituted for the quantity of
operating inputs. This response function is extremely simplified. The
function is specified in a highly simplified form to avoid statistical com­
plications later on. But from knowledge of the input structure (invest­
ment functions) much can be learned about the nature of supply elasticity
in agriculture. Whatever the short-run nature of this response function
long run also can be made by substituting an investment function for \(S^b_{Pt}\)
into this response function.

b. **Stock of productive farm assets** The stock of productive farm
assets, \(S^b_{Pt}\), has been included in the aggregate production response func­
tion as mentioned in the last section. The inclusion of \(S^b_{Pt}\) allows the
changes in scale of the farm plant. In the very short-run, the \(S^b_{Pt}\) is
more or less fixed, but in the longer run, prices influence plant size. The amount of commodities produced, and the last year's stock of productive farm assets, also, come into the picture for determining the necessary adjustment in the total stock of productive farm assets. Hence, in this study, the stock of productive farm assets function has been specified as:

\[ S_{Pt}^b = f (Q_{t-1}^{S1}, S_{Pt-1}^b, T) \]

where the \( S_{Pt}^b \) is the current stock of productive farm assets at the beginning of the year. The \( S_{Pt}^b \) is the amount of stock at the beginning of last year. \( Q_{t-1}^{S1} \) is the quantity of farm products produced in the previous year and \( T \) is the time variable. It is more or less an adjustment model, where the firm views the services which are able to be rendered by a certain level of total productive farm assets as essential in determining the current amount (stock) of productive farm assets.

c. Products supply function The quantity of farm commodities entering the market system in a given year, \( Q_{t}^{S2} \), is useful in explaining current farm prices. It is not an indication of the production potential because inventory changes obscure the true output-input relationships. Since there is no production period for farm inventories, decisions regarding the level of inventories can be based on the current amount of products produced and the demand situations in the farm products market. However, the data for inventory changes in farm products, especially for time series data, are not complete during the period under study. In view of this, it has been hypothesized that the quantity supplied of farm
products depend on the quantity produced and time variables. The latter is a catchall for variables, which include inventory changes, export and some other time effects. The aggregate products supply function is specified as:

\[ S_2 = f(S_1, T) \]

where \( S_2 \) is the amount of commodities supplied, \( S_1 \) is the amount produced and \( T \) is the time variable.

d. Aggregate agriculture price function In this study, the aggregate demand function for agricultural commodities is viewed as depending on the prices of agriculture commodities, prices of consumer goods and services other than foods, disposable personal income per capita, and changes in tastes and preferences. However, tastes and preferences are not readily measureable. An alternative has been to put them in residual term in empirical testing.

As has been explained in previous sections, the agricultural economic system might well be represented by a recursive type of model. And the aggregate commodity production can be described as a cobweb model where price in one period affects production in the next, which in turn affects price, and so on. Accordingly, also under the assumption of consumption equal to amounts supplied, the price function for the aggregate agricultural commodity can be specified as:

\[ P_{R_t} = f(S_2, FC_{N_t}, Y_{D_t}, P_{R_{t-1}}) \]
where \( P_{Rt} \) is the current price of the commodity received by farmers, \( FC_{Nt} \) is the current index of per capita food consumption, \( Y_{Dt} \) is disposable personal income, and \( P_{Rt}' \) is the current price of non-food commodities.

The net farm income (definitional equation) is

\[
Y_{Ft} = f\left( \left( \frac{P_{Rt}}{P_t} \right)_t, S_{Pt}^b, P_{Rt}', Y_{Ft-1}, C_t \right)
\]

where the \( Y_{Ft} \) is the current net farm income. The logic in derivating this equation is as follows. By definition,

\[
Y_{Ft} = Q_t^2 P_{Rt} - Q_{Pt} P_{Pt}
\]

where \( Q_t^2 \) = quantity of farm products sold,

\( P_{Rt} \) = current prices received by farmers,

\( Q_{Pt} \) = total farm inputs,

\( P_{Pt} \) = prices paid for inputs.

It can be visualized from this equation that the current net farm income is a function of the relative price and efficiency. The level of the current net farm income also depends on the amount of the stock of productive farm assets which is a proxy variable for the quantity of inputs available at the beginning of the production period.

Statistics show that although there were changes in net farm income before and after the world war years while there were no erratic year by year changes. As an integrated part of the entire economic situation, net farm income depends on the levels of non-farm products prices \( P_{Rt}' \).

Consequently, the approximated definitional equation for net farm income can be specified as the equation which is stated at the beginning of this
section. Where \( \frac{P_R}{P_p} \) is the ratio of prices received and paid by farmers, \( S_P^{b, t} \) is the stock of productive farm assets at the beginning of the year, \( P_{R, t} \) is the level of non-farm products. \( Y_{P, t-1} \) is the last year's net farm income and \( C_t \) is structure variable.

2. Factor markets

   a. Farm machinery market  

   (1) Machinery supply (or price) function: Machinery supply depends on factories' production and price policies. Production policy, in turn, depends on production planning which is the consequence of long-range market forecasts and the estimated sales for the forthcoming year.

   Production restrictions of particular machines as well as those due to decreased demands are important factors in pricing farm machinery. In addition, material prices, direct labor costs, transportation charges, factory overhead and margins of retailers and manufacturers all contribute to the level of machinery prices.

   Cromarty (18) has pointed out that the pricing policies in the farm machinery industry seldom follow principles outlined in theoretical competitive economics except in a very indirect manner. In general, estimates of price are made on the basis of costs of materials, labor, and past profit. Revisions are made by comparing this price with the price of competitive machines, the level of technological improvements and the level of sales. Still further price revisions may be made on the basis of internal and external economies of scale and on the intentions of some firms to maintain a certain share of the total market.
In this study, it has been postulated that the farm machinery price depends on the last year's price, the current prices of steel and iron, factory wage rates, and on index of the volume of farm machineries which have been shipped to the dealers in the last year. Last year's machinery shipment, supposedly, is used by manufacturers to estimate the current year's machinery demand in determining the farm machinery price. Hence, the farm machinery price function is specified as:

\[ PM_t = f(P_{IST_t}, MSH_{t-1}, P_{NL_t}, P_{Mt-1}, T) \]

where 
\[ P_{IST_t} \] = price for steel and iron, 
\[ MSH_{t-1} \] = index for last year's machinery shipment, 
\[ P_{NL_t} \] = factory wage rate, 
\[ P_{Mt-1} \] = last year's machinery price, 
\[ T \] = time variable.

(2) Demand for farm machinery: Investments in machinery during the current year are likely to be a function of the desired level of machinery inventory since machine services are distributed over several years, not only the year of purchase (40).

The adjustment models recently proposed and estimated by Kuh (78), Bourneuf (8) and Greenberg (39) have high conceptual appeal. A simple capital adjustment model is:

\[ I_t = b \left( S^D_t - S_{t-1} \right) \]

where \[ I_t \] is the amount of investment made in period \( t \), \( S^D_t \) is the total stock of capital desired for period \( t \), and \( S_{t-1} \) is the actual amount of
total capital stock that existed in period t-1. Stocks of productive farm assets on the farm at the beginning of an investment period have an effect on the current year's investment activity. If stocks of assets are high at the end of the preceding investment period, it may signify the presence of excess machine capacity which allows a moderate output expansion without additions to the stock of machinery items.

Few variables are attributed to formulate the desired level of the stock of farm machinery. Prices and price ratios are seriously considered by farmers attempting to formulate expectations of their ability to pay for a particular item of machinery. The price of a particular factor of production is of interest only at the time of purchases. Once the factor has been purchased, the price of that factor and the relationship of the price of the factor to the price of other factors is of no concern. The ability to pay for an input depends upon what happens to wage rates, land price and product prices (50). This justifies the inclusion of prices as variables in the domestic farm machinery investment function. At the time the decision to purchase farm machinery is made not only the level of machine prices, but also the relationships between the machine prices and prices of other factors or prices of products are considered. These latter prices are more likely candidates for expectation variables. Although past efforts to measure the influence of wage rates on farm investment demand have been largely unrewarding (18, 42, 66), the farm wage rate might be singled out as a separable variable in the investment processes because of the large substitution of capital for labor.

Recent investment studies by Meyer and Küh (86) depend heavily upon
net income to explain nonfarm investment patterns. Most agricultural investment demand equations, have also included net farm income as an explanatory variable. This is the important variable from the standpoint of motivation for investment and a variable for expectations. In another study of the demand for agriculture inputs, Griliches (42) could find no good theoretical reason for including income in the demand equations for factors. He says income is usually introduced as a proxy variable for expectations and liquidity in reality, but income has little to do with liquidity (42). Income is a function of prices, quantities marketed etc. Theoretically, each of the determinants of income should be specified independently in the model. Since it is difficult to define all factors determining annual income, the estimates obtained from ordinary least squares procedures break down if the number of explanatory variables becomes very large.

Assets other than investment stock of the particular demand asset are important in the investment function. The demand for a durable asset depends on the form and abundance of farm assets since many assets are technically related.

The ratio of proprietors' fixed assets to total liabilities, the equity ratio, reflects several influences on demand in a dynamic agriculture. It is a measure of the vulnerability of the farm firm to uncertain outcomes. A given loss causes little concern if equity is high, but if equity is low the same loss may increase liabilities above assets, creating an insolvent firm. The equity ratio is a measure of this influence both psychologically for the farmer and actually for outside credit sources.
The equity ratio may be regarded as the culmination of the income generating process. Periods of high income provide an opportunity for farmers to pay debts and build equity. In the long run a large portion of these gains is likely to find its way into additional investment. Hence, the equity ratio is a kind of proxy variable for past income. This is more so because of the probable lagged adjustment of consumption and durable purchases to higher income.

The level of technology represented by the production function also has a bearing on the tendency of farmers to invest. If new technology in the form of machinery items or other durable goods are to be employed farmers need to be able to form expectations as to the increases in production possible from new capital investment.

Interest rates have been regarded as the prime quantifiable motivator of investment in durable goods (18, 24, 36, 40, 67, 86, 136). These results draw exclusively from the reflection of businessmen. Farmers seldom invest to the upper and lower bounds specified by the availability of external and internal capital constraints. Consequently, the interest rates may not be so relevant to farmers as to businessmen.

Other variables such as average farm size, the number of hired agricultural workers, cropland harvested and time, to some extent, all have influences on farm machinery investment. Consequently, the postulated investment function for farm machinery is as follows:

$$Q_{Mt} = f\left( \frac{P_M}{P_R}, ER_t, T \right)$$

where $Q_{Mt}$ is the annual purchases or gross investment in farm machinery,
\((P_M/P_R)_t\) is the ratio of the current machinery price to the price of farm products, \(ER_{t-1}\) is the lagged equity ratio, \(SM_t\) is the stock of farm machinery at the beginning of the year and \(T\) is the time variable.

The demand for motor vehicles and other farm machinery are assumed not to differ much from this specification.

An alternative specification of the demand function for farm machinery could emerge from the following observations. Effective machinery demand in recent years is a function only of replacement requirements and not of a gap between current and desired stocks. Many researchers have obtained certain significant results by including lagged values of machine purchases as independent variables (40, 76, 91). Most of the techniques employed by these authors included a distributed lag scheme to allow the influences of certain variables to be spread out over a period of time.

Consequently, the alternative specification for the machinery demand function may be as:

\[Q_{Mt} = f\left( \frac{P_M}{P_R}, ER_{t-1}, Q_{Mt-1}, T \right)\]

where \(Q_{Mt}\) is the annual gross purchase of farm machinery, \(\frac{P_M}{P_R}\) is the ratio of current machinery price to the price of farm products, \(Q_{Mt-1}\) is lagged purchase of farm machinery and \(T\) is the time variable.

b. Demand for farm building investment

The expected life of farm buildings is much longer than the expected life of other durable goods in agriculture. The adjustment models discussed in the last section for farm machinery still have high conceptual appeal in explaining building investment. An accelerator model would be difficult to estimate, because
a model used to describe farm building investment would need to be an extended-lag accelerator such as:

\[ QBI_t = \sum_{i=1}^{n} b_i (Y_{t-n+i} - Y_{t-1}) \]

where \( n \) may be ten or more years. The explanatory variables of an extended-lag net farm income would probably be so highly intercorrelated that reliable estimation by least squares might prove impossible. In a model with other variables this problem could be solved by arbitrarily weighting the accelerator coefficient in some logical pattern describing a response curve such as those suggested by Koyck (76) and used by DeLeeuw (25). The synthesis might use the weighted (e.g. decreasing geometrical average) net farm income as an explanatory variable in the stock adjustment model.

In a number of previous investment demand studies, price ratios have been used as variables to estimate possible substitution effects between inputs and relative price effects between inputs and outputs (50). From the standpoint of motivation one might expect the price ratio of output and building material to be one of the explanatory variables.

The equity ratio, the ratio of the value of long-term assets (real estate and buildings) to farm mortgage debt outstanding is believed to be quite a relevant variable. In addition to those reasons mentioned with the specification for the machinery demand function, the equity ratio may be even more relevant for farmers than in the nonagricultural sector for the following reasons. The farmer is usually an individual owner and does not have a group of stockholders to share his financial risk. Con-
sequently, many farmers have an aversion to extended use of outside funds. For these reasons, the equity ratio may be one of the more important variables in the determination of investment in farm buildings. This variable should be positively correlated with investment.

One would expect that as farms increase in size the total capital services required from buildings would increase. It is also conceivable that a change in composition of farm products might also have an effect upon farm building investment.

The ratio of the rate of interest also is an important variable. However, many economists today would question the relevance of rates of return in determination of the demand for investment. Because of the greater influence of interest, it may prove to be less significant than expected and less significant than in some of the other highly capitalized industries, due to the fact that most of the capitals in agriculture are internally financed.

Consequently, one may specify the investment demand function for farm buildings as:

\[ Q_{BI_t} = f(YWF_{t-1}, LP_t, P_{Bt}, r, S_{Bt}, G_t) \]

where \( Q_{BI_t} \) = current investment in farm buildings,

\( YWF_{t-1} \) = three-year geometric average of net farm income, \( 3Y_{Ft-1} + 2Y_{Ft-2} + Y_{Ft-3}/6 \), where \( Y_F \) is net farm income,

\( LP_t \) = index of current livestock production,

\( P_{Bt} \) = index of current price for building materials,

\( S_{Bt} \) = stock value of farm buildings at beginning of the year,

\( G_t \) = structure variable for pre- and post-war years.
c. Farm labor market

(1) Demand functions: Demand for labor in agriculture results from the demand for factors in agriculture and indirectly from economic conditions in the non-farm economy. This relationship can be envisioned from the general demand function for factors formulated in the first section of this chapter. The variables which have been hypothesized as affecting demand for labor are: 1) the wage rate in agriculture (as a price of the labor factor), 2) price and quantities of competing resources, 3) price and quantity of agricultural production, 4) technological changes in agriculture, 5) general non-farm economic activity, 6) unemployment rate in the non-farm economy, 7) market structures in the non-farm economy.

In Cromarty's study of the demand for farm machinery, the farm wage rate was a significant variable, however, the sign was negative (18). This shows that under farm wage rate increases, a substitution of machinery for labor did not take place. Heady and Tweeten found that the farm wage rate was not a significant factor in the substitution of machinery for labor in the analysis of the demand for farm machinery and equipment (50).

Bishop regressed migration against the price of farm products and found a positive relationship (6). In relating migration to the farm-nonfarm income ratio, the coefficient was positive and significant. These results led Bishop to suggest that job opportunity was more important than farm or non-farm returns. Where migration was used as a dependent variable against unemployment in the economy, a significantly negative relationship was observed.

Johnson estimated demand and supply functions for hired and family labor (59). The results from this study showed that the demand for hired
labor was a function of farm wage rate with a negative sign and, with
the prices of agricultural products variable indicated a positive sign.
The demand function for hired labor showed a positive sign for the value
of machinery not indicating substitutability. Where machinery prices were
included in the demand for hired labor, the results also did not indicate
substitutability. For family labor the results showed a negative sign
with respect to the farm wage rate but the prices received variable was
inconsistent.

In Schuh's study (100), the demand for hired farm labor was related
to the farm wage rate with a negative sign, positively with farm product
prices, and negatively with technology.

In Heady and Tweeten's analysis of family and hired farm labor a
number of variables were hypothesized as affecting demand for labor (50).
Family labor was hypothesized as a function of 1) ratio of wages of fac­tory workers to income per farm family, 2) ratio of proprietors equity
to liability in agriculture, 3) stock of productive farm machinery, 4)
percentage of farm sales forced through bankruptcy, 5) index of govern­ment policy, 6) an interaction term between unemployment and the ratio
of wages of factory worker to income per farm family, and 7) time. The
sign of the ratio of factory wage to income per farm family variable was
negative. The ratio of proprietor's equity to liabilities in agriculture
was positively related to family labor demand.

In Helmers' study (52), the results of the demand equations estimated
for total farm employment show a number of influences affecting total
farm employees. These are: 1) the positive effect of the farm wage rate on the demand for total farm labor, 2) positive influences of net farm income on total labor in agriculture, 3) the negative operation of non-farm earning opportunities or non-farm employment opportunities on total farm employment, and 4) strong negative technological influences on total farm labor.

Comparing hired and family farm labor demand with respect to the farm wage rate the negative relationship on hired labor demand and the positive effect on family labor is notable. Sign differences also exist for demand elasticities between family and hired farm labor with respect to net farm income and net income per farm.

Technical change has affected the demand for farm labor in two ways. It has increased labor productivity and thus increased the demand for farm labor. But it has increased farm output also, and thus decreased the demand for farm labor through the resulting decline in farm product prices. It is probably that the output increasing effects of technical change have offset the rising productivity of labor resulting in a net decline in the demand for labor in agriculture. Several econometric studies of the farm labor market have supported these observations (59, 100, 101).

In this study, demand for total farm labor is hypothesized as depending on the following specific variables: 1) lagged net farm income, 2) lagged index of mechanical powers on farm, 3) lagged ratio of machinery price to farm wage rates, 4) technological changes index, 5) non-farm factory wage rates, 6) lagged ratio of machinery price to farm wage rates.
Since a large portion of total farm employment is comprised of family labors, the same relationships have been assumed for demand for family farm labor.

Demand for hired labor is hypothesized as depending on: 1) lagged index of cropland per farm, 2) lagged ratio of the index of total farm wage rate to the total value of land and buildings per acre, 3) technological changes, 4) time, and 5) structure dummy variable for post and pre-war periods.

\[ Q_{TLt} = f(\text{IMP}_{t-1}, Y_{Ft-1}, P_{NLt}, A(t), (P_{TL}/T VLBA)_{t-1}, (P_{M}/P_{TL})_{t-1}) \]

\[ Q_{HLt} = f(A_{Ft-1}, (P_{TL}/T VLBA)_{t-1}, P_{Mt}, A(t), C_t, T) \]

where

- \( Q_{TLt} \) = current demand for total farm labor,
- \( Q_{HLt} \) = current demand for hired farm labor,
- \( \text{IMP}_{t-1} \) = lagged index of mechanical powers on farm,
- \( P_{NLt} \) = non-farm factory wage rates,
- \( (P_{TL}/T VLBA)_{t-1} \) = lagged ratio of farm wage rates to total value of land and building per acre,
- \( (P_{M}/P_{TL})_{t-1} \) = lagged ratio of machinery price to farm wage rate,
- \( A(t) \) = technological changes index,
- \( A_{Ft-1} \) = lagged index of cropland per farm,
- \( C_t \) = structure dummy variable for pre- and post-war periods,
- \( T \) = time.
(1) Labor supply: Although primary emphasis in this study lies on demand, supply plays a related role in the determination of labor use. Labor in contrast to other agricultural input, such as machinery, is not the output of another firm. Rather, it is a primary input. Economic theory suggests that an individual supply function for labor is derived from the utility function of the individual (53, pp. 23, 137, 129-131). Current economic thinking postulates that the supply of farm labor is a function of the price of farm labor and alternative non-farm job opportunities. Alternative non-farm job opportunities are a function of non-farm wage rates and various impediments to the farm-nonfarm labor flow. Various variables have been suggested as impediments to farm-nonfarm mobility. Among those cited are unemployment conditions in the non-farm economy, transportation costs, non-farm job rationing, asset fixities of farm operators, imperfect knowledge, and the preference for farm and rural life on the part of farm people.

With the exception of the evidence on unemployment conditions, evidence with respect to the other hypothesized impediments seems to be tenuous, conflicting or absent. Bishop (6) refers to the magnitude of recent migration rates to refute the imperfect knowledge hypothesis, whereas Johnson (58) has doubted that unions have distorted the wage structure sufficiently to act as an effective impediment.

Quite comprehensive evidence on farm-nonfarm mobility, however, has been presented by Perkins in his study of farm-nonfarm job mobility for the 1955-1959 period (94). His study shows that unemployment in the non-farm sector, age, and lack of nonfarm job experience are the important impediments to farm-nonfarm job migration. Clearly, the agricultural
labor force has become a shock absorber for the non-farm labor market. The burdens of deficient demand conditions in the non-farm economy and structural change in the non-farm labor market in part have been placed on members of the farm labor force.

In this study, the total farm wage rate has been hypothesized as positively depending on number of labor demands, non-farm factory wage rate, lagged unemployment rate, technology, farm machinery price, structure dummy variable and time. The hired labor wage rate has been hypothesized as solely a function of total farm wage rate.

\[ P_{TLt} = f(Q_{TLt}^D, P_{NLt}, U_{t-1}, A(t), P_{Mt}, G_t, T) \]

where

- \( P_{TLt} \) = current total farm wage rate,
- \( Q_{TLt}^D \) = current amount of labor demanded
- \( P_{NLt} \) = non-farm factory wage rate,
- \( U_{t-1} \) = lagged unemployment rate,
- \( A(t) \) = technology,
- \( P_{Mt} \) = farm machinery price,
- \( G_t \) = structure dummy variable for post- and pre-war years,
- \( T \) = time.
IV. THE RECURSIVE MODELS AND ECONOMETRIC CONSIDERATIONS

A. The Proposed Models

The ultimate goal of agricultural economic research should be a definite, integrated model of the product and resource structure of agriculture. There are several reasons why an integrated model is necessary. Product markets determine gross income, resource markets determine expenses and the two markets determine net income in farming. From a causal and statistical standpoint, many decisions in farming are interdependent. It is almost impossible to determine how many hired workers, for example, will remain in agriculture without estimates of farm product prices, national unemployment and factory wages. To a considerable extent, farm input and output prices are determined by non-farm variables such as wage rates, national income and population. The mobility of farm labor is conditioned by the rate of national unemployment. Integrated models which include these nonfarm variables are necessary for predicting farm income, output and efficiency.

The studies of Brandow (9), Cromarty (17) and Fox (31) have emphasized the totality and interdependence of farm product markets. While there are few notable quantitative studies of the resources markets, such as Griliches (40, 41), Johnson (59), Heady and Yeh (51), Cromarty (3), Heady and Tweeten (50), Maudon (84), Schuh (100), Scott (102), Helmers (52), Minden (88) and Reynolds (96), only Heady and Tweeten’s study has supplemented and integrated with commodity studies to provide adequate know-
ledge of prices, quantities and efficiency in agriculture.

The regional interdependence is one of the other factors which is crucial in the study of economic structure. There has been progress in the application of interregional models to policy analysis. In agricultural economics, one must cite among other pioneers the works of Mighell and Black (87). Fox (31), Heady and Egbert (49), and Judge (61, 62). While their studies are exclusively in the product markets and are static analysis. In the studies of resources markets, either due to the data limitations or technical difficulties, the studies of Scott (102), Minden (88), Helmers (52), Heady and Tweeten (50) and Reynolds (96) studies are in terms of separated regional analyses.

There are difficulties for any future work to extend these basic studies much beyond their current contributions. These possibilities are in the two major aspects of economic structure. The first of these is the intertemporal structure or, in short, dynamics. The second is the interconnectedness of production, transportation, and demand.

Economic theories may be categorized as static or dynamic. Most work in economic structure has been static in nature. However, as economic processes are enacted over time, we should expect that temporal structure is crucial in economic understanding. Only in special cases should we find that static tools are sufficient to gain an adequate understanding of economic events. For many agricultural commodities, production decisions take place many months before supplies reach markets. Given supplies are determined by past production decisions and the intervening hand of weather. For this reason, regional supplies are independent of
temporary market equilibrium. But not the converse. The market distributes the predetermined supplies of commodities over space, determines prices and interregional price differentials. The transportation model is not, by itself, adequate to describe the substance of interregional marketing structure. Its assumption of fixed demands is surely erroneous. That is, during a given period regional supplies are predetermined, but regional demands depend upon prices and so do interregional commodity flows.

Regional demand functions shift over times. But at the time when supplies are forthcoming they are relatively stable. With supplies predetermined, a transportation model, augmented by regional demand functions, can represent the temporary equilibrium of spatial marketing structure, yielding interregional commodity flows and regional prices received and paid for agricultural commodities. This construction is already the foundation of several interregional studies (31, 99).

By temporary equilibrium one does not mean static or normative equilibrium. It implies that the economic function of distributing predetermined supplies among various regions is performed in an efficient manner with respect to costs that clears the market. The interregional prices and commodity flows may vary widely from one period of temporary equilibrium to the next, in cyclical, in an explosive or even (because of weather) in an erratic manner.

Day (22, 23) has suggested a dynamic interregional competition model based on a synthesis of recursive programming models of production and temporary equilibrium models of shipping patterns. The general method
proposed follows the so called 'dynamic coupling' of Goodwin (38). The production decisions are interdependent on past market equilibriums, because market prices do enter production decisions through expectations, with a lag. Interregional demand does affect interregional shifts in production, investment and land utilization, but these effects are distributed over time by a dynamic adjustment process.

D. Lee Bawden (4) has recently completed a regional interdependence study for the turkey industry in the United States based on the same feature of 'dynamic coupling'. However, it differs from Day's proposed model with respect to supply. His model exploits dynamic behavioral supply equations rather than a recursive programming formulation. The quantitative forecasts indicate that his model is well suited for short-run predictions.

The synthesis of recursive production hence recursive resources demand (as the derived demand) and temporary market equilibrium models to formulate a general dynamic regional interdependence model for the U.S. agriculture would be desirable. A dynamic interregional model, based on the theoretical formulation developed in Chapter III and aimed at accurate prediction in the immediate future will be developed. The model will be descriptive (behavioral) in nature with emphasis on adjustment in resources demand—both in quantity and location—through time. However, it can be readily conceived that many of the regional data are either not available or limited in time-series. Due to these reasons, the following proposed models will be separated into the tentative and the final model. The final model, which has dropped the aspects of the integration of the inter-
regional relationships developed in the tentative model, will then be subjected to empirical testing for describing the resources demand structures in United States agriculture.

1. A tentative model

In formulating an econometric model, the nature of the economic system to be analyzed should determine the type of equations to be used and the method used in fitting them.

In this tentative model, as is true also in the final model, the commodities supplied are assumed to be given by past production decisions and the intervening hand of weather.

Wold (137, 138) believes that many economic systems are of the recursive type, whereas certain other econometricians believe that systems of simultaneous relations are typical. The recursive system is composed of a sequence of causal relationships. It consists of a set of equations each containing a single endogenous variable other than those that have been treated as dependent in prior equations (45). The endogenous variables enter the system one by one, like links in an infinite chain, where each link is explained in terms of earlier links.

Recursive models seem appropriate in agriculture, both as a basis for practical forecasting and as tools of realistic economic theory (29, 133, p. 734). It seems logical that the current prices are a function of the predetermined quantity. As an extremely simplified example, agricultural production can be described as a cobweb model, which in turn is considered to fall into a recursive pattern, where price in one period affects pro-
duction in the next, which in turn affects price, and so on. Of course, a more complete model would include more variables and more relationships represented in equational forms. The recursive model also seems appropriate for the resources demand market.

For these reasons, regional supplies are independent of temporary market equilibrium. The market distributes the predetermined supplies of commodities over space, determines prices and interregional price differentials. A transportation model augmented by regional demand functions, as proposed in this tentative model, can adequately describe the substance of interregional marketing structure. The essence is that the regional demand functions are not assumed fixed; rather they are assumed to shift over time.

This tentative model differs from Day's recursive programming models (23) with respect to supply. The dynamic behavioral supply equations are employed here rather than a recursive programming formulation.

This model consists of the separate regional aggregate commodity supply and demand functions, separate regional supply and demand for factors' functions and the transportation submodels for commodity and factor. The logic and specification for the commodity demand, supply functions and the factor demand, supply functions has been fully treated in section 3 of the last chapter (Chapter III). The theoretical framework for this has also been developed in Chapter II. Consequently, to avoid repetition, only a brief description of those behavioral equations are given in this section. The logic, specifications and formulation of the interregional relationships and modified transportation model, will be discussed more
fully in this section. These interregional aspects, incidentally, have been dropped in the final model for lack of data.

As stated, the given supplies of farm commodities are determined by past production decisions and the intervening hand of weather. For this reason, regional supplies are independent of temporary market equilibrium. But not the converse. The market distributes the predetermined supplies of commodities over space, determines prices over regions. The regional aggregate production and supply function for farm products are specified as:

\[ Q_{ti}^S_1 = f\left( \frac{P_R}{P_P}(t-1), S_{Pt,i}^b, G_t, W_t, T, A(t), G_t \right), \]

\[ Q_{ti}^S_2 = f\left( Q_{ti}^S_1, T \right), \]

where we have: \( Q_{ti}^S_1 \) = quantity of commodities produced; \( \frac{P_R}{P_P}(t-1) \) = lagged ratio of price received and paid by farmers; \( S_{Pt}^b \) = stock of productive assets at the beginning of the year; \( G_t \) = government's price policy; \( W_t \) = current weather index, \( T \) = time; \( A(t) \) = technological index; \( G_t \) = dummy variable, refers to the structure change pre- and post-war; \( Q_{ti}^S_2 \) = amount of farm commodity supplied. Subscript \( i \) refers to regional numbers.

The regional demand functions for agriculture commodities are specified as:

\[ Q_{tj}^D = f\left( P_R, P_{R'}, F_{CN}, Y_{Dt} \right), \]

where \( Q_{tj}^D \) = quantity demanded; \( P_R \) = current price of agriculture commodity; \( P_{R'} \) = current price of commodities excluding agriculture commodities; \( F_{CN} \) = index of per capita food consumption; \( Y_{Dt} \) = personal disposable income; \( j \) = consuming regions.
Regional demand functions shift over time. But at the time when supplies are forthcoming they are relatively stable. With supplies predetermined, a transportation model, augmented by these regional demand functions might represent the temporary equilibrium of spatial marketing structure, yielding interregional commodity flows and regional prices received and paid for agricultural commodities. The temporary equilibrium here, refers to the economic function of distributing predetermined supplies among various regions in an efficient manner with respect to cost that clears the market. The implicit assumption is that the shipping decisions by producers are based on the profit-maximizing goal and, hence, regional price differentials are based on normative assumptions. The absolute price level and producer and consumer reactions are dictated by past reactions to the same stimuli (as discussed and specified in the recursive nature of the supply and demand of agriculture commodities). These behavioral equations are estimated by regression analysis. The formulation attempts to predict on the basis of a description of past actual market behavior. Although Day (22) has favored the normative path, the present approach is argued to be the more useful approach when short- or intermediate-run market predictions are desired.

In an attempt to reduce this sub-model concerning the interregional shipping pattern and price differentials to a simplified version of reality, the following restrictive assumptions are also made. Thus perfect competition assumptions dictate the requirements for the regional pattern of prices and flows of the commodity. Therefore, each firm is assumed to have the objective of maximizing profits. The supply source and market
for each region is assumed to be represented by a fixed point. All regions are connected by transportation costs and flows of agricultural commodities among regions are assumed unhampered by governmental or other interference. It is further assumed that consumers are indifferent as to source of supply and that the product is homogeneous. Also, it is assumed that for any time period, t, that total production and total consumption of farm products are equal.

There are some other obvious assumptions. The production and consumption of farm products can take place in all regions and farm products consumed out of local production does not require transporting since each region is represented by a point. There are no negative shipments and no cross-hauling.

The normative assumption for shipping decisions by producers appears reasonable and probably approximates actual conditions, but the assumption of perfect knowledge by the shipper is clearly fallacious. On this account, the model is expected to yield perhaps useful forecasts of area prices, and probably unreliable prognostications of the shipping pattern.

The sub-model which embraces the above arguments is developed below:

The primal solution can be formulated as follows:

Let: subscript i indicate the producing region \((i=1,\ldots,n)\), subscript j indicates the consuming region \((j=1,\ldots,m)\). In this submodel, it is assumed that \(n = m = 10\) since each region can be both a producing and a consuming region. Each region can be categorized as a surplus (origin) or a deficit (destination) region by comparing their \(Q^S\) and \(Q^D\) at each time t.
Subscript $t$ indicates time in years

$X_{ij}$ = quantity shipped from region $i$ to region $j$

$TC_{ij}$ = transfer cost from region $i$ to region $j$

$TC_{ij} = 0$, when $i = j$

$P_{Ri}$ = agriculture commodity price in producing region $i$ at the producer level

$P_{Rj}$ = agriculture commodity price in consuming region $j$.

The other variables are defined previously.

Given:

$Q_{t_i}^{S_1} = f((PR/Pp)_{t-1,i}, S_{Pb}, G_t, W_i, T, A(t)_i, C_t)$

$Q_{t_i}^{S_2} = f(Q_{t_i}^{S_1}, T)$

$Q_{t_j}^{D} = f(P_{Rt_{t_j}}, PG_{Nt_{j}}, Y_{Dt_{j}}, P_{R} t_{j})$

$P_{R(t-1)j}$

$P_{Rt_{t_j}}$

$TC_{ij}$

$P_{Rt_{t_j}}$ is an unknown and is determined by the complete solution, but it is considered exogenous to the primal solution. As a practical procedure one might choose $P_{R(t-1)j}$ to substitute with $P_{Rt_{t_j}}$

and to start the computation.

The problem then is:

Find $X_{(t)ij}$ for all $i$ and $j$ (shipping pattern);

Which minimizes: $\sum_{i=1}^{n} \sum_{j=1}^{m} X_{(t)ij} \cdot TC_{ij}$
Subject to:  \[ X(t)_{ij} \geq 0 \]  \hspace{1cm} (a)

\[ Q_{S_i}^S = \sum_{j=1}^{m} X(t)_{ij} \]  \hspace{1cm} (b)

\[ Q_{D_j}^D = \sum_{i=1}^{n} X(t)_{ij} \]  \hspace{1cm} (c)

\[ \sum_{i=1}^{n} Q_{S_i}^S = \sum_{j=1}^{m} Q_{D_j}^D \]  \hspace{1cm} (d)

for all \( i, j \).

There are many solutions to (b) and (c) subject to (a) and (d), and given any feasible solution of \( n+m-1 \) shipments, the simplex method provides a means of converging the above problem to the optimum program (21) in terms of satisfying the objective function. The equilibrium prices are tied together by a specific set of transportation costs used, and the relevant transport costs used in obtaining the optimum set of flows, are less than for every possible alternative delivery which is not made. Thus the solution obtained will be unique except for the case when two or more sources find two or more markets equally profitable.

The regional (equilibrium) prices, \( P_{R(t)_{ij}} \), are still unknown at this stage. In the real world, the regional prices constitute one of the unknowns necessary for solution, since it is conditioned by the demand function specified previously. In practical problems, however, with a finite number of regions an initial approximate set of regional prices can be obtained. With given \( Q_{S_i}^S \) and known transportation costs \( TC_{ij} \) and by utilizing the information (just information) about \( Q_{D_j}^D \) given by the consumption functions, one can derive a unique set of regional prices with
the aid of the duality theorem of linear programming. This set of shadow prices will correspond to the equilibrium set of flows and which may be used as the approximation value to check and facilitate the procedures to reach the equilibrium solution.

The dual solution of this problem is:

Maximizing \[ W = \sum_{j=1}^{m} Q_{tj}^D DR(t)_j - \sum_{i=1}^{n} Q_{ti}^S DP(t)_i \]

Subject to \[ DR(t)_j - DP(t)_i \leq TC_{ij} \]

\[ DR(t)_j > 0 \]

Find: \( DR(t)_j \) for all \( j \) (shadow prices)

\( DP(t)_i \) for all \( i \) (shadow prices).

Where the \( DR(t)_j \) and \( DP(t)_i \) are dummy variables at this moment and will be given the interpretation below.

This dual problem has been constructed from the primal solution of minimizing the total transportation costs. The objective then can be thought of as that of finding the \( DR(t)_j \) and \( DP(t)_i \) that will maximize the total gain in value of amounts shipped subject to nonpositive profits on each shipment. By this formulation, it is possible to interpret the \( DR(t)_j \) and \( DR(t)_i \) that will maximize the total gain in value of amounts shipped subject to nonpositive profits on each shipment. By this formulation, it is possible to interpret the \( DR(t)_j \) and \( DR(t)_i \) as the value of the product at supply origin \( i \) and as the value of the product delivered at destination \( j \). The first equation for the restriction on the above
can be written as

\[ \text{DR}(t)_j \leq \text{DP}(t)_i + \text{TC}_{ij}. \]

This is implying that for routes in the basis, destination value equals supply point value plus transportation costs. For those routes not in the basis, destination value is equal to or less than the supply point value plus transport costs.

With the DR\((t)_j\) and DP\((t)_i\) found from the dual solution, one can proceed to solve the regional prices P(t)_i and P(t)_j. Here, the Q^{S2}_{(t)_i} is known. The formulation is

\[
\begin{align*}
\text{Minimize} & \quad \sum_{j} P_R(t)_j - \sum_{i} \sum_{j} TC_{ij} - \sum_{i} P_R(t)_i \\
\text{Subject to:} & \quad \sum_{j} Q^{D}_{(t)_j} = f(P_R(t)_j, P_R(t)_j, FCN(t)_j, YD(t)_j) & \quad \text{Regional demand function.} \\
& \quad \sum_{i=1}^{n} Q^{S}_{(t)_i} = \sum_{j=1}^{m} Q^{D}_{(t)_j} \\
& \quad P_R(t)_a - P_R(t)_b = DR(t)_a - DR(t)_b & (j=a,b) \\
& \quad P_R(t)_c - P_R(t)_d = DP(t)_c - DP(t)_d & (i=c,d) \\
& \quad P_R(t)_j - P_R(t)_i = DR(t)_j - DP(t)_i.
\end{align*}
\]

This is a corollary solution. These restrictions are set up so that regional demand function and the total consumption are equal to the total production. Other restrictions are trying to keep the regional prices and their corresponding shadow prices consistent among the regions.
Complete solution of the problem encompasses all three phases: primal, dual, and corollary. The procedure includes the sequential solution:

I. Time (t)
   
   A. Stage I: Use the known value of $P_R(t)i$, solve the regional supply equations for $Q_{t1}$.
   
   B. Stage 2:
   
   (1). Trial 1
      
      (a) Arbitrarily start with $Q^{D}_{(t-1)j}$ and through the primal, dual and corollary solutions find $X_{tij}$, $DP(t)i$, $DR(t)j$.
      
      (b) Solve for $P_R(t)j$, $P_R(t)i$.

   (2). Trial 2:
      
      (a) Use the $P_R(t)j$ found above to solve $Q^D(t)j$ through demand equations.
      
      (b) Solve for the $X_{ij}$, $DP(t)i$ and $DR(t)j$ through the primal and dual solutions.
      
      (c) Compare these new shadow prices with those in the previous trial. If they are identical, a final solution for year $t$ has been reached. Solve for regional (equilibrium) prices $P_R(t)j$ and $P_R(t)i$ through corollary solution and proceed for the solution of year $t+1$ with the same procedure as for year $t$.
      
      (d) If they differ, a final solution has not been reached;
repeat the same procedures as in trial 2, and continue new trials until an equilibrium solution for year \( t \) has been reached.

This procedure may be repeated until answers to the desired number of time periods are obtained. This procedure has been called reactive programming (62, 113). For ordinary cases, the final solution can be obtained at the trial 2. While with careful selection of initial \( P_{R(t)} \), say if it is equilibrium value, then trial I is enough to yield the satisfactory solutions for year \( t \) and the subsequent years.

Conceptually analogous procedures can be developed for regional farm input prices. Regional demand for different individual farm inputs depend, as discussed in Chapter III, on the nature of the supply and demand functions of farm products. While supply functions for farm inputs especially for durable goods, depends more on the non-farm variables—for example, demand for farm machinery depends most probably on past machinery prices, farm commodity prices and farmer's equity position—the other influencing variables may be the levels of production technology and the stock of farm machinery at the beginning of the year. The regional demand function for total farm machinery can be specified as:

\[
D_{M(t)} = f\left(\frac{PM}{PR(t-1)}_i, A(t)_i, ER(t-1)_i, T, S(t)_i\right), \text{the demand region } i=1, \ldots, 10.
\]

The regional machinery supply functions can be specified as

\[
S_{M(t)_j} = f(PM(t)_j, T, IS(t)_j, MSH(t-1)_j, ENLt, T), \text{ the number of } j \text{ unde-}
\]
terminated, depends on the location of machinery manufacturing plants. Where, $Q_{M(t)}^S$ is the regional farm machinery supply; $P_{M(t)}$ is the regional farm machinery price; $P_{IS(t)}$ is the regional wholesale price for iron and steel; $MSH_{t-1}$ is the index of farm machinery shipment in the previous year; $P_{NLt}$ is the factory wage rate; $T$ is time.

It can be visualized that $Q_{M(t)}^D$ is predetermined at the beginning of the year. It is mainly determined by last year's regional farm product prices and farm machinery prices. Given $Q_{M(t)}^D$ and $TC_{ij}$ (transportation costs) for farm machinery, the $Q_{M(t)}^S$ ($=Q_{M(t)}^D$) and the $P_{M(t)}$ can be solved analogously, and the farm commodity prices, by the primal, dual and corollary programs as are formulated at the beginning of this section.

Without going into the logic about specifications of other behavioral equations, the whole (tentative) model is presented in the following. The model is immediately followed by brief description of the variables. The logic behind the specifications of behavioral equations has been treated in section 3 of the last chapter (Chapter III).

The Model:

Regional stock of productive farm assets including money capital

$$S_{Pt}^b = f(Q_{(t-1)i}^S, S_{P(t-1)i}^b, T)$$

Regional aggregate production response function

$$Q_{ti}^S = f((PR/Pp)_{t-1}, i, S_{Pt,i}^b, G_t, W_t, T, A(t)i, C_t)$$

Regional aggregate commodity supply function
Regional aggregate products demand function

\[ Q_{tj}^D = f(P_{Rt,j}, P_{R't,j}, FG_{Nt,j}, Y_{Dt,j}) \]

reactive programming (transportation) submodel:

\[ P_{R(t),i,j} \text{ are solved via a revised reactive programming (transportation) submodel} \]

Definitional equations:

Net farm income = \( Y_{Ft} = f(Y_{Ft-1}, S_{Ft}^b, P_{Rt}, X_{Rt}, \left( \frac{P_{R}}{P_{P}} \right)_t) \)

Weighted net farm income = \( Y_{WFt} = \frac{3Y_{Ft-1} + 2Y_{Ft-2} + Y_{Ft-3}}{6} \)

Farm machinery market:

Regional demand for all farm machinery

\[ Q_{M(t)i}^D = f(\left( \frac{PM}{PR} \right)_{(t-1)i}, A(t)_i, ER(t-1)_i, S_{M(t)i}, T) \]

Regional demand for farm motor vehicles

\[ Q_{MV(t)i}^D = f(\left( \frac{PM_{MV}}{PR} \right)_{(t-1)i}, A(t)_i, ER(t-1)_i, A_{F(t-1)_i}, S_{MV(t)i}, T) \]

Regional demand for other farm machinery and equipment

\[ Q_{ME(t)i}^D = Q_{MT(t)i}^D - Q_{MV(t)i}^D \]

Regional machinery supply functions

\[ Q_{M(t)j}^S = f(PM(t)j, P_{IS(t)}, MSH(t-1)_j, P_{NLt,j}, T) \]
\[ Q_{MV(t)} = f(P_{MV(t)}, j, P_{LS(t)}, j, MSH(t-1), j, P_{NL(t)}(j, T)) \]

\[ Q_{ME(t)} = f(P_{ME(t)}(j, P_{LS(t)}(j, MSH(t-1), j, P_{NL(t)}(j, T)) \]

Reactive programming (transportation) submodel

Regional demand for farm building investment

\[ Q_{FB(t)} = f(Y_{FB(t-1)}, i, LP_t, i, ER(t-1)i, A(t)_{i, P_{Bti}}, C_{ti}) \]

Farm labor market:

Regional demand for total farm employees

\[ Q_{TL(t)} = f(Y_{F(t-1)i, IMP(t-1)i, A(t)i, P_{NL(t)i}, (PTL/TVLBA)_{t-1}, i(P_{M(t)}_{PTL})_{t-1, i}) \]

Regional supply of total farm labor

\[ P_{TL(t)} = f(Q_{TL(t)}, i, P_{NL(t), i, P_{M(t-1)}i, U_{t-1}, C_{t}, T}) \]

Regional demand for hired farm employees

\[ Q_{HL(t)} = f(P_{TL/TVLBA}t, i, A_F(t-1), i, A(t), C_{t}, T) \]

Regional demand for family farm employees

\[ Q_{FL(t)} = Q_{TL(t)} - Q_{HL(t)} \]

Regional hire farm wage rate

\[ P_{HL(t)} = f(P_{TL(t)}i) \]
The Variables:

Endogenous variables:

- \( Q^t_s \) = Quantity of farm products produced
- \( Q^t_s2 \) = Quantity of farm products supplied
- \( S^b_{P_t} \) = Stock of productive farm assets at beginning of year
- \( Q^D_t \) = Quantity of farm products demanded
- \( Y^F_{t} \) = Net farm income
- \( Y^W_{WFT} \) = Weighted net farm income for last three years
- \( Q^D_{Mt} \) = Quantity of total farm machinery demanded
- \( Q^D_{MVT} \) = Quantity of farm motor vehicles demanded
- \( Q^D_{MEt} \) = Quantity of other farm machinery and equipment demanded
- \( Q^S_{Mt} \) = Quantity of total farm machinery supplied
- \( Q^S_{MVT} \) = Quantity of farm motor vehicles supplied
- \( Q^S_{MEt} \) = Quantity of other farm machinery and equipment demanded
- \( Q^B1_{1t} \) = Value of investment for service buildings on farm
- \( Q^D_{TTLt} \) = Quantity of total labor demanded
- \( P_{TLt} \) = The farm wage rate
- \( Q^D_{HLT} \) = Quantity of hired labor demanded
- \( Q^D_{FLLt} \) = Quantity of family labor demanded
- \( P_{HLLt} \) = Farm wage rate for hired labor
Other endogenous variables:

\[ P_{R(t)ij} \] = Prices for farm products at producing and consuming regions

\[ P_{M(t)i,j} \] = Prices for total farm machinery at machinery demand and supply regions

\[ P_{MV(t)i,j} \] = Prices for farm motor vehicles at machinery demand and supply regions

\[ P_{ME(t)i,j} \] = Prices for other farm machinery and equipment at machinery demand and supply regions.

These are solved by revised (transportation) programming submodels.

Exogenous variables:

\[ S_{P(t-1)}^{b} \] = Stock of productive farm assets at the beginning of last year

\[ Q_{(t-1)} \] = Amount of farm products produced in last year

\( T \) = Time

\( (P_{R}/P_{P})_{t-1} \) = last year's ratio of prices received and paid by farms

\( C_{t} \) = Current government's policy index

\( W_{t} \) = Current weather index

\( A_{(t)} \) = Current technological index

\( C_{t} \) = Dummy variables refer to structure changes pre- and post-world war II

\( P_{R'} \) = Wholesale price index excluded food and farm products

\( FC_{NT} \) = Per capita food consumption index
$Y_{Dt}$ = Personal disposable income

$T'$ = Index for production efficiency, i.e., total output divided by total input

$Y_{Ft-1}$ = Net farm income for last year

$Y_{Ft-2}$ = Net farm income for the year before last

$Y_{Ft-3}$ = Net farm income for three years ago

$(P_M/P_R)_{t-1}$ = Last year's ratio of farm machinery prices to prices received by farmers

$E_{Rt-1}$ = Last year's farmers' equity ratio

$S_{M(t)}$ = Stock of total farm machinery at beginning of year

$(P_MV/P_R)_{t-1}$ = Last year's ratio of farm motor vehicles prices to prices received by farmers

$A_{Pt-1}$ = Last year's cropland index

$S_{MVt}$ = Stock of farm motor vehicles at beginning of year

$P_{IS}$ = Current price index for iron and steel

$MSH_{t-1}$ = Index for the amount of machinery shipped, lagged one year

$PNLt$ = Factory wage rate

$L_{Pt}$ = Current index for livestock production

$P_{Bt}$ = Current price for farm building

$P_{Pt}$ = Price paid by farmers for aggregate inputs

$IMP_{t-1}$ = Last year's index of mechanical powe on farm

$U_{t-1}$ = Last year's national unemployment rate

$P_{M_{t-1}}$ = Last year's price for total farm machinery

$TV_{LBA}$ = Index of the total value of farm land and buildings per acre
2. The final model

In the last section, an interregional factor demand model in agriculture has been proposed which integrates factors and products markets. However for some of the important variables, the data needed in the empirical analysis are either very difficult to find or not available. For example, a complete set of data for the transportation costs among ten production regions for a period 1924 to 1965 are very difficult to obtain. In order to operationalize the model under the constraints of these data limitations, the proposed model has been separated into the national and regional models.

In the final national model all of the features which were incorporated in the proposed model, except the modified transportation submodel, are maintained. In the regional models the multiple covariance analysis models, instead of the simple equation for each region, are employed. These models are essentially the results of combining the techniques of covariance analysis and multiple regression with certain algebraic re-combinations of intercept and dummy variable.

a. The national model

On the basis of economic theory and logic developed for the proposed model in the last section, the final model has the same set of functional relationships and similar specifications of the variables as in the proposed model except for the modified transportation submodel which has been dropped. Without loss of precision, the model is presented here in functional form. All variables have been defined in the last sections. The model is:
Stock of productive farm assets including money capital

\[ S_{Pt}^b = f(Q_{t}^{S1}, S_{Pt-1}^b, T) \]

Aggregate production response function

\[ Q_{t}^{S1} = f((P_{R}/P_{P})_{t-1}, S_{Pt-1}^b, G_t, W_t, A(t), T, C) \]

Aggregate commodity supply function

\[ Q_{t}^S = f(Q_{t}^{S1}, T) \]

Aggregate products demand function

\[ P_{Rt} = f(FC_{Nt}, Y_{Dt}, Q_{t}^S, G_t, P_{Rt}) \]

Definitional equations:

Net farm income

\[ Y_{Pt} = f(P_{Rt}, T', (P_{R}/P_{P})_t, S_{Pt}^b, (P_{R}/P_{P})_t, Y_{Pt}) \]

Weighted net farm income

\[ Y_{WFr} = (3Y_{Pt} + 2Y_{Pt-1} + Y_{Pt-2}) / 6 \]

Farm machinery market

Demand for all farm machinery

\[ Q_{Mt}^D = f(P_{M/Pr}, t-1, A(t), ER_{t-1}, S_{Mt}, T) \]

Demand for farm motor vehicles

\[ Q_{MVt}^D = f(ER_{t-1}, AF_{t-1}, A(t), S_{MVt}, T) \]

Demand for other farm machinery and equipment

\[ Q_{MBt}^D = Q_{Mt}^D - Q_{MVt}^D \]

Total machinery supply functions

\[ P_{MT} = f(P_{IST}, MSH_{t-1}, P_{NLt}, P_{Mt-1}, T) \]

Demand for farm building investment

\[ Q_{BIT} = f(ER_{t-1}, L_{Pt}, P_{Bt}, S_{Bt}, Y_{WFr-1}, C_t) \]
Farm labor market

Demand for total farm employees

\[ Q_{TL}^D = f(IM_{t-1}, Y_{Pt-1}, P_{NLt}, A(t), (P_{TL}/TVBLA)_{t-1}, (P_{LT}/P_{TL})_{t-1}) \]

Supply of total farm labor

\[ P_{TL} = f(P_{Mt}, A(t), P_{NLt}, U_{t-1}, Q_{TLt}, T, C_t) \]

Demand for hired farm employees

\[ Q_{HLT}^D = f(A(t), A_{Ft-1}, P_{Mt}, (P_{TL}/TVBLA)_{t-1}, T, C_t) \]

Demand for family farm employees

\[ Q_{FLT}^D = Q_{TLt}^D - Q_{HLT}^D \]

b. Regional models

Even less census data is available for regional analysis than for national analysis. For a number of important variables, data on a regional basis are available annually only since World War II. When a proposed economic behavioral model suggests lagging certain variables for one year or more, the length of the time series for analysis and consequently the statistical degrees of freedom are further reduced. On the basis of economic theory for the national model approximately the same variables are included in the regional model.

The usual method for regression analysis of regional data is to estimate separate regression equations from each area. With this procedure the length of the series available for this study would limit the total degrees of freedom (with reduction due to lags) to approximately 16. Assuming that four to six independent variables would be needed to explain a substantial proportion of the variance of the dependent variable, the residual sum of squares from regression would be associated with ap-
approximately 10 degrees of freedom. This would be insufficient to get good statistical results where a separate equation is used for each region.

The final regional models used in this study include all regions simultaneously in one equation (for each factor, each region and year providing an observation). The models are essentially the combination of the analysis of covariance (93, pp. 437-465) with multiple regression (14). With further incorporation of the algebraic recombination of certain intercept and dummy variables, the models become multiple covariance analysis with additional regression variables. Slopes and differences of slopes as well as intercept differences are obtained for testing. This kind of model has several advantages over the usual simple equation model. First, it provides an immediate statistical test for differences found between regions: Comparison by general inspection of separate equations is more fallible and less precise, while statistical comparison of separate regression equations is more difficult and time consuming.

The second advantage is that inclusion of all regions in one equation gives a much higher number of observations. Although the number of independent variables are also increased because of the addition of dummy variables, not all differences for all variables and all regions are expected to be significant and there would be a greater relative increase in the degrees of freedom associated with the residual sum of squares rather than the increase in the number of explanatory variables. An underlying statistical assumption in following this procedure requires that observations from all regions are drawn from a common population. This, however, is an assumption which must be made if separate equations
are estimated in the usual way and statistical tests performed between regressions. If there is no significant increase in the variance of variables, the relative increase in degrees of freedom for the residual sum of squares should increase the probability of obtaining good statistical results. More precise statistical results lend greater credence to subsequent economic analysis and interpretation.

Regional demand for total farm machinery: The following model is used to obtain regression equations for the ten production regions;

\[ Q_{Mt} = b_0 + \sum_{i=1}^{m-1} b_i + c Q_{Mt-1} + \sum_{i=1}^{m-1} d_i Q_{Mt-1,i} + e E_{Rt-1} + f_i E_{Rt-1,i} + g (P_M/P_R)_t + hT + U_t \]

where \( b_0 \) is the overall intercept; \( b_i \) is the difference in intercept between the \( i^{th} \) region and \( b_0 \) (\( i=1,2,\ldots,m-1 \)), and \( m \) is the number of regions (10 in this study). \( Q_{Mt} \) is the current investment in total farm machinery deflated by the wholesale price index; \( Q_{Mt-1} \) is one year lagged investment in total farm machinery deflated by the wholesale price index; \( d_i \) is the slope difference for \( Q_{Mt-1} \) between the \( i^{th} \) region and the \( m^{th} \) region given by \( c \); \( f_i \) is the slope difference for \( ER_{t-1} \) between the \( i^{th} \) region and the \( m^{th} \) region given by \( e \); \( (P_M/P_R)_t \) is the index of the ratio of the farm machinery price to the price received by farmers for farm products (1957-'59 = 100). \( T \) is the time trend, and is represented by the last two digits of the year. \( U_t \) is the error term.

The alternative stock adjustment model for the total machinery demand
is as follows:

$$Q_{Mt} = b_0 + \sum_{i=1}^{m-1} b_i A_t + \sum_{i=1}^{m-1} d_i A_t + c Q_{Mt-1} + e E_{t-1} + \sum_{i=1}^{m-1} f_i E_{t-1} + i + g S_{Mt}$$

$$+ \sum_{i=1}^{m-1} h_i S_{Mt} + j (P_{Mt}/P_{R})_{t-1} + h T + U_t$$

where $A_t$ is the technological index; $S_{Mt}$ is the stock value of the total farm machinery at the beginning of the year; the ratio $(P_{Mt}/P_{R})_{t-1}$ is a one year lagged index of the ratio of farm machinery price paid to the prices received by farmers for farm products (1957-59 = 100); and the remaining variables and coefficients as defined in the preceding equation.

Regional demand for motor vehicles: The expectation and stock adjustment models for the demand of motor vehicles are presented separately below.

The expectation model:

$$Q_{MVT} = b_0 + \sum_{i=1}^{m-1} b_i + c Q_{MVT-1} + \sum_{i=1}^{m-1} d_i Q_{MVT-1} + e E_{t-1} + \sum_{i=1}^{m-1} f_i E_{t-1} + i + g (P_{MV}/P_{R})_t$$

$$+ h T + U_t$$

The stock adjustment model:

$$Q_{MVT} = b_0 + \sum_{i=1}^{m-1} b_i + c A_t + \sum_{i=1}^{m-1} d_i A_t + e E_{t-1} + \sum_{i=1}^{m-1} f_i E_{t-1} + i + g S_{MVT}$$

$$+ \sum_{i=1}^{m-1} h_i S_{MVT} + j (P_{MV}/P_{R})_{t-1} + h T + U_t.$$
Regional demand for total farm labors: The regional model for the demand of total farm labors is as follows:

\[ Q_{TLt} = b_0 + \sum_{i=1}^{m-1} b_i + c(IMP)_{t-1} + dY_{Ft-1} + \sum_{i=1}^{m} e_i Y_{Ft-1,i} + fP_{NLt} + gA_t \]

\[ + \sum_{i=1}^{m} h_i A_{t-1} + j(P_{TL/TVBLA})_{t-1} + \sum_{i=1}^{m} k_i (P_{TL/TVBLA})_{t-1,i} + l(P_{F/TL})_{t-1} + U_t. \]

\( b_0 \) is the overall intercept, \( b_i \) is the difference between the \( i^{\text{th}} \) region and \( b_0 \) (where \( i=1,2,\ldots,m-1 \)), and \( m \) is the number of regions (10 in this study). \( Q_{TLt} \) is the quantity of the total farm labor demanded; \( IMP_{t-1} \) is a one year lagged index of the mechanical power on farms; \( Y_{Ft-1} \) is net farm income lagged one year; \( e_i \) is the slope difference for \( Y_{Ft-1} \) between the \( i^{\text{th}} \) region and the \( m^{\text{th}} \) region given by \( d \). \( P_{NLt} \) is the index of the factory wage rate (1957-’59=100); \( A_t \) is the technological change index (1957-’59=100); \( h_i \) is the slope difference for \( A_t \) between the \( i^{\text{th}} \) region and the \( m^{\text{th}} \) region given by \( g \); \( (P_{TL/TVBLA})_{t-1} \) is the index of the ratio of farm wage rate to total value of buildings and land per acre, lagged one year (1957-’59=100); \( k_i \) is the slope difference for \( (P_{TL/TVBLA})_{t-1} \) between the \( i^{\text{th}} \) region and the \( m^{\text{th}} \) region given by \( j \); \( (P_{TL/TVBLA})_{t-1} \) is the index of the ratio of farm machinery to farm wage rate (1957-’59=100), lagged one year; and \( U_t \) is the error term.

The demand for hired farm labor:

\[ Q_{HLt} = b_0 + \sum_{i=1}^{m-1} b_i + cP_{Mt} + dA_t + e_A_{t,i} + fA_{Ft-1} + \sum_{i=1}^{m} g_i A_{Ft-1,i} \]

\[ + h(P_{TL/TVBLA})_{t-1} + \sum_{i=1}^{m} j(P_{TL/TVBLA})_{t-1,i} + kF_t + U_t. \]
where $Q_{D_{HL}}^t$ is the quantity of hired labor demanded; $A_{t-1}$ is the index of cropland per farm in acres, lagged one year; with other variables and the relationships between the coefficients defined as in the demand for total labor.

Regional demand for farm building investment:

$$Q_{D_{BIt}}^t = b_0 + \sum_{i=1}^{m-1} b_i + cP_{Bt} + dS_{Bt} + e Y_{WFT-l}^t + \sum_{i=1}^{m-1} f_i Y_{WFT-l,1}^t + g E_{Rt-l}^t + \sum_{i=1}^{m-1} h_i E_{Rt-l,1}^t + J T + U_t,$$

where $Q_{D_{BIt}}^t$ is the annual gross investment in productive farm buildings; $P_{Bt}$ is the index of the price of farm building materials (1957-1959=100); $S_{Bt}$ is the stock value of productive farm buildings at the beginning of the year; $T$ is time trend; and $U$ is the error term. $Y_{WFT-l}^t$ is the lagged geometric average of the net farm income; $f_i$ is the slope difference for $Y_{WFT-l}^t$ between the $i^{th}$ region and the $m^{th}$ region given by $e$; $E_{Rt-l}^t$ is the one year lagged equity ratio; $h_i$ is the slope difference for $E_{Rt-l}^t$ between the $i^{th}$ region and the $m^{th}$ region given by $g$. All variables are deflated by the wholesale price index.

B. The Econometric Considerations

Economic variables are frequently interdependent. The existence of a system of equations including both the equations upon which main interest centers (say the production response function) and equations which generate its determining variables (say the price generating equations) may lead to a biased single equation estimate of the former relationship.
Marshak and Andrews (81) and Hoch (54) show, however, that no such biases will occur if the price generating functions are separable from the production response function (i.e., if prices are in no way dependent on the disturbance term of the production response function). A time lag between the decision period and time of final output suggests that this may be an appropriate assumption for agriculture, though it may not be appropriate for certain non-agricultural industries where there is mutual interdependence between the current price and output variables. Supply in the latter situation should theoretically be estimated using simultaneous equation methods, though in practice much will depend upon the period over which prices and output are aggregated. This has important implications for what will be appropriate estimation procedures for alternative formulations of the system of equations. The time period chosen and the production processes involved determine whether the model is recursive, simultaneous or both (recursive with simultaneous subsets).

1. **Recursive versus simultaneous systems**

Suppose one has the system of equations

\[ B y_t + C z_t = u_t \]

The above system is a recursive system if the following properties hold:

1. **Recursive versus simultaneous systems**

Suppose one has the system of equations

\[ B y_t + C z_t = u_t \]

The above system is a recursive system if the following properties hold:

- **B** is lower triangular
- \( E(u_{it}; y_{jt}) = 0 \) for \( i < j \) for all \( t \)

This implies that the stochastic disturbances in the equations are distributed independently. Assumptions 2 and 3 permit one to estimate \( y_{it} \)

\[ y_{it} = -\sum_{i+1} G b_{jt} y_{jt} + \sum_{j=1} C z_{jt} + u_{it} \]
from the conditional likelihood function derivable from equation 4. In that estimation procedure the problem of identification does not arise as it would if one estimated the reduced form without the assumptions 2 and 3 from equation

\[ y_t + B^{-1} C z_t = B^{-1} u_t \]

Recursive systems are frequently given a causal interpretation. There continues to be an intensive discussion on the concept of causality in econometric investigations (5, 104, 107, 137). Causality in recursive systems is understood to imply an asymmetric relationship. Controlling an endogenous variable \( y_j \) implies that one exerts at least stochastic control on a variable \( y_i \), if \( i < j \). The converse does not hold. In pure simultaneous relationships it is generally held that this division cannot be imposed. A recursive system, as defined above, always possesses the property of causality as defined. Recursive systems can be subdivided into pure causal chains and conditional chains. Pure causal chains, after appropriate substitution, transform the matrix \( B \) into a diagonal matrix. The cobweb theorem, as applied to the supply and demand for hogs, is an example at the micro level. Conditional causal chains are formally similar to interdependent systems (simultaneous equation systems), with the important difference being that the behavioral relations of the equation systems are specified in terms of conditional expectations. Following this line of argument, Strotz and Wold (107) have argued that a simultaneous equation can be seen as the limiting form of a recursive system, where the adaptation process of the economy is instantaneous. The question
then remains whether causality exists in a non-recursive system. Wold (137) argues that a causal-chain model, where some types of simultaneous systems could be used to construct a model on the basis of behavioral relations, might synthesize the recursive and interdependent systems. This model would accept other relations and approximations that might break the pattern of the triangular coefficient matrix and yet maintain the stimulus-response interpretation.

It can be easily visualized that the proposed final model in this study is a recursive model. This model has been constructed on the lag-causal ordering of the commodity markets and the causal structure of the demand for factors markets which are discussed in detail in the previous sections.

2. **Use of least-squares techniques**

Wold and Jureen have shown that least-squares regression will yield unbiased estimates of the parameters in a system of linear equations if the system is recursive and if all the residuals are uncorrelated (140, p. 51).

In the recursive system specified by the triangular coefficient matrix of the endogenous variables, the covariance matrix of the residuals is also assumed to be a diagonal matrix. Wold and Jureen (140, p. 203) assert that intercorrelation of these off-diagonal residuals can be reduced to negligible proportions if the relationships are arranged as a series of lag relationships.

Other arguments have been advanced for use of least-squares techniques, even if the assumption of a diagonal covariance matrix is invalid. Klein
(70, p. 866) endorsed least squares for cobweb models and also concurred with Fox's argument for least squares estimation of market demand relations of farm products where supply varies much more than demand (31). Waugh (135, p. 386) reviewed the use of least squares and simultaneous systems in operational uses of the past decade and concluded that least squares, as often as not, give superior estimates. On the other hand, Chirst (11) noted that specification errors, other than simultaneity, often invalidated interdependent estimates.

Least-squares regression techniques were used to estimate the parameters of the recursive model developed in this study. Possible difficulties in the assumption of uncorrelated error terms of the recursive model was taken into account in making this decision.

a. Least-squares The least-squares regression model is of the following form:

\[ Y_i = \beta_1 + \beta_2 X_{2i} + \ldots + \beta_K X_{Ki} + U_i \]

where \( Y_i \) is the dependent variable, the \( X \)'s are the independent (explanatory) variables, the \( \beta \)'s are the coefficients of the model and \( U \) is the error term. This model can be stated more compactly in matrix notation:

\[ Y = X B + U \quad (A) \]

where \( Y \) is a vector of \( n \) observations on the dependent variable, \( X \) is an \((n \times k)\) matrix of \( n \) observations on \( K \) independent variables, \( B \) is a vector of unknown coefficients and \( U \) is a vector of errors.

To estimate the vector of coefficients by least-squares, the following assumptions are made (60, p. 107):
(a) $E(u) = 0$, i.e., the $U_i$ are random variables with zero expectation;
(b) $E(u'u') = \sigma^2 I_n$, i.e., the $U_i$ have constant variance $\sigma^2$ (homoscedasticity) and $E(U_iU_t\delta) = 0$ for $\delta \neq 0$ (independent errors); 
(c) $X$ is a nonsingular matrix;
(d) $X$ is a fixed set of numbers; and
(e) the number of observations exceeds the number of parameters to be estimated.

We are interested in estimating the parameters of Equation (A). Let $\hat{B}$ denote a vector of estimates of $B$. Now we may rewrite Equation (A) as

$$Y = X\hat{B} + e$$

where $e$ denotes the vector of $n$ residuals ($Y - X\hat{B}$).

The principle of least squares is that the value of $B$ should be chosen so as to minimize the sum of squared residuals, $e'e$.

$$e'e = (Y-X\hat{B})'(Y-X\hat{B})$$

By differentiating $e'e$ with respect to $\hat{B}$ and equating the result to zero, we obtain:

$$X'X\hat{B} = X'Y$$

By premultiplying both sides by $(X'X)^{-1}$, we obtain:

$$\hat{B} = (X'X)^{-1}X'Y$$

where $(X'X)^{-1}$ is the inverse of $(X'X)$. The variance of $\hat{B}$ can be shown to be:

$$\text{Var} (\hat{B}) = \sigma^2 (X'X)^{-1}$$

and the variance of any coefficient $B_i$ may be obtained by taking the $i$th term from the principal diagonal of $(X'X)^{-1}$ and multiplying by $\sigma^2$, the variance of $U_i$ (60, p. 110). $S^2$, the least-squares estimate of $\sigma^2$,
be shown to be:

\[ s^2 = \frac{e'e}{(n-K)} = \frac{(Y'Y - B'X'Y)}{n-K}. \]

It can be shown that least-squares estimators are linear, unbiased and that they possess a smaller variance than any other linear unbiased estimator (60, p. 110). Therefore, the best, linear, unbiased estimator of \( B \) is the least-squares estimate \( \hat{B} \) given in

\[ \hat{B} = (X'X)^{-1}X'Y. \]

In addition to our earlier set of assumptions, it must be assumed that the \( U_1 \) are normally distributed if we are going to use the F- or t-tests of significance (60, p. 115). The t-test is the ratio of the estimated regression coefficient to its standard error. This t-test is used to test whether the regression coefficient is significantly different from zero. The F-test is the ratio of the regression mean square to the residual mean square. The F-test is used to test the significance of the overall regression. That is, the F-test is used to test the hypothesis that the explanatory variables do not influence the dependent variable. \( R^2 \) values are used to indicate the percent of variation in the dependent variable that is explained by the explanatory variables. \( R^2 \) is called the coefficient of determination.

**Multicollinearity**

Multicollinearity is the high correlation between two (or more) explanatory variables. Multicollinearity makes it difficult to disentangle the separate influences of the explanatory variables and obtain a reasonably precise estimate of their separate effects (60, p. 201). Subsequently, the assumption (C) for using the least squares technique is not met. Multicollinearity is often a problem in economic
time-series, especially whenever a larger number of explanatory variables are used. The problem becomes greater when lagged variables are used and the coefficient of the lagged variables are estimated by least squares along with the coefficients of the other explanatory variables. It is possible to have a relationship that fits very well (a high $R^2$) while no coefficient tests to be significantly different from zero (37, p. 193). In some cases, as Haavelmo (43) argues, the estimate of $S^2$ (sum of squares of error) will be impaired by highly correlated independent variables. The inflated standard errors of the regression coefficients will, hence, present difficulties in rejecting very diverse hypotheses about the regression coefficients.

In using the ordinary least-squares estimation method, there are certain ways to alleviate the problem. Where two explanatory variables (other than lagged variables) are highly correlated, a common practice is to remove one of the variables from the equation. Experience indicates that the multicollinearity problem is not severe if the correlation between any two explanatory variables is less than .8. Lagged variables are usually significantly correlated with one another and with the associated current variable. In that case, the general method is to enter a function of the lagged variables as a single variable in the regression equation. A number of possible functions of the lagged variables can be devised. The declining geometric weighted average of lagged variables will be used in this study whenever weighting of lagged variables will be required.

Recently, another weighting function which may be used to replace
intercorrelated variables in cases of either with or without lagged ex-
planatory variables has been suggested. It is a linear combination of the
intercorrelated variables based on the first principal component (55, 57,
72, 134). This method, quite appropriate when no a priori knowledge about
a weighting scheme is available, is quite useful in some cases.

b. Autocorrelation of errors  Autocorrelated error terms exist when
the error term of one period is not independent of the error of previous
periods. When autocorrelated errors are present, assumption (b) for es-
timation by least-squares regression is not met. The least-squares esti-
mators remain unbiased and consistent but they are inefficient when auto-
correlation exists (115).

Time-series regression equations quite often have positive autocor-
related error terms. Klein (68) has shown that the problem of autocor-
relation increases with shorter time periods. Autocorrelation may be
causd by 1) omission of important variables either due to incorrect
specification or deliberate omission of some variables due to limited
length of time series data, 2) incorrect specification of the form of
the relationship between economic variables and 3) errors of measurement
in the explanatory variables. There is a strong likelihood that an error
of observation committed in one time period is likely to be repeated in
the next time period and hence give rise to autocorrelated errors.

Two generally accepted tests for autocorrelation are the Von-Neuman
ratio (132) and the Durbin-Watson test (27).

The Durbin-Watson test is:
\[ d = \sum_{t=2}^{N} (u_t - u_{t-1})^2 / \sum_{t=1}^{N} u_t^2 \]

where \( u_t(t=1,\ldots,n) \) are the residuals from a fitted least-squares regression. Tables of significance have been worked out by Durbin-Watson for up to five independent variables and 100 observations (27). Exact significance levels are not available but upper (\( d_u \)) and lower (\( d_L \)) bounds to test for positive autocorrelation are calculated. The tables are symmetric for negative autocorrelation in the range of 2 to 4.

If the computed \( d \) value is less than table value of \( d_L \), the hypothesis of random disturbance is rejected in favor of positive autocorrelation. If the computed \( d \) value is greater than \( d_u \), the hypothesis of random disturbances is not rejected. If the computed \( d \) value falls between \( d_L \) and \( d_u \) the test for positive autocorrelation is inconclusive (60, p. 192).

Theil and Nagar (111) have obtained a more accurate approximation for the distribution of the Durbin-Watson statistic. This criterion defines as significant those values of \( d \) which are significant or inconclusive in the Durbin-Watson test.

Both the Von-Neuman ratio and the Durbin-Watson tests are considered questionable for errors from equations containing lagged endogenous variables. The presence of lagged endogenous variables violates the assumption of the fixed regressors in using the ordinary least square estimation method. Consequently, the coefficients of the lagged variables carry away part of the autocorrelation in the residuals with biased coefficients, invalidating the use of the test criteria which are based on residuals.

When lagged endogenous variables are included as explanatory variables,
one should proceed to estimate the structural coefficients as if autocorrelation was present. Koyck proposes a technique to obtain consistent estimators which depend on the assumption that the error term, \( u_t \), is generated by an autoregressive scheme,

\[
u_t = \rho u_{t-1} + e_t.
\]

The assumptions are that \( u_t \) has a zero mean and a constant variance, \( e_t \) is not correlated with \( u_{t-1} \) and there is no autocorrelation among the \( e \)'s (76, p. 34). Further, he assumes specific values of \( \rho \). Estimation by this technique is referred to as autoregressive least squares.

In an equation such as the following, (assuming that a first-order autoregressive scheme applies) the cases in which an estimated coefficient \( (b') \) is a consistent estimator of the real regression coefficient \( (b) \), has been outlined by Fuller (33). He shows that, given Koyck's basic equation, \( y_t = ax_t + by_{t-1} + u_t \) combines with the first-order autoregressive scheme of \( u_t = \rho u_{t-1} + e_t \) leads to:

\[
u_t = \rho (y_{t-1} - a x_{t-1} - b y_{t-2}) + e_t.
\]

By substituting this equation into \( y_t = ax_t + by_{t-1} + u_t \), he shows that the probability limit of \( b' \) is given by

\[
\text{plim } b' = b + \frac{\rho}{1+\rho_b} \left\{ \frac{(1-\rho^2)\bar{xy}}{1-\rho^2} - b^2 \right\}.
\]

Under these assumptions, \( b' \) is a consistent estimator of \( b \) only when \( \rho = 0 \). These results indicate that a more accurate estimate of \( b \) can be obtained if the value of \( \rho \) is known.

Methods for estimating \( \rho \) have been presented by Klein (68) and Cochrane and Orcutt (13). A simplified method for estimating \( \rho \) and the regression coefficients by an iterative process has been developed by
Fuller and Martin (34, 35).

The essences of the Fuller-Martin method is as follows: Assume a basic equation of the following from \( y_t = ax_t + by_{t-1} + u_t \), and combining with the assumed first-order autoregressive scheme of \( u_t = \rho u_{t-1} + \epsilon_t \) leads to:

\[
\begin{align*}
\hat{u}_t &= \rho (y_{t-1} - ax_{t-1} - by_{t-2}) + \epsilon_t .
\end{align*}
\]

By substituting the last equation into the first equation, the next equation will yield the result:

\[
y_t = ax_t + (b + \rho) y_{t-1} - a \rho x_{t-1} - b \rho y_{t-2} + \epsilon_t .
\]

A regression on those variables provides initial values of estimation of \( a, b, \) and \( \rho \). By a method of non-linear regression (79), a function of the estimates of the coefficients is expanded in a first-order Taylor expansion about the point defined by the initial values above. The sums of squares and cross products for Taylor expansion become linear combinations of the parameters in the above equation. The results of the Taylor expansion yield:

\[
y_t = y_o + z_1 \hat{a} + z_2 \hat{b} + z_3 \hat{\rho} ,
\]

where \( y_0 = y_t - \hat{y}_t \), the residuals in the equation

\[
y_t = ax_t + (b + \rho) y_{t-1} - a \rho x_{t-1} - b \rho y_{t-2} + \epsilon_t ,
\]

\[
\begin{align*}
z_1 &= x_{t-1} - \rho x_{t-1} ,
Z_2 &= y_{t-1} - \rho y_{t-2} ,
Z_3 &= y_{t-1} - \hat{a} x_{t-1} - \hat{b} y_{t-2} ,
\end{align*}
\]

where \( \hat{a}, \hat{b}, \hat{\rho} \) are the initial estimates of the coefficients, and the \( \Delta a, \Delta b, \) and \( \Delta \rho \) represent changes in the estimates for each iteration. The least-squares method applied to \( y_t = y_0 + z_1 \Delta a + z_2 \Delta b + z_3 \Delta \rho \) produces
further changes in the estimates, and the iterative procedure continues until the change becomes sufficiently small. The final values are consistent estimates of the coefficient.

This technique has advantages, however, it only guarantees a local minimum of the residual sum of squares.

Another method which is among the easiest has been suggested by Theil and Nagar (111) and is used in estimating most of the equations in this study. The calculated d-statistic can be used to give a simple estimate of $\rho$ by the simple formula $\hat{\rho} = 1 - \frac{1}{n} d$. The first-order autoregressive scheme: $u_t = \rho u_{t-1} + w_t$, $-1 \leq \rho \leq 1$, with the estimated $\hat{\rho}$ then, could be used to transform the original data and the transformed data are re-estimated by ordinary least squares. If the original equation is $y_t = b x_t + u_t$, the re-estimated equation after transformation is $(y_t - \hat{\rho} y_{t-1}) = b (x_t - \hat{\rho} x_{t-1}) + e_t$. It is a time consuming method because with most existing computer programs it is necessary to go on and off the machine and transform the data between each trial. However it is far cheaper in terms of computer time.

a. **Dummy variables**  Phase plane shifts or substantial changes in all economic parameters do occur in economies at certain times. Changes may occur between wartime and peacetime, or between economic booms and depressions. Usually these kinds of discrete changes can be accounted for by using appropriate dummy variables.

Dummy variables are used to permit changes in the intercept, changes in the slope coefficient or both (108). The use of dummy variables in a single equation usually has the advantage of a larger number of degrees
of freedom. If dummy variables are used for estimating both the intercept and the slope coefficients, there is no "degrees of freedom" advantage.

If one wants to differentiate a change in the intercept between the pre-war (e.g., explanatory variable A) and post-war, one could construct the simplest dummy variable in the following manner.

\[ X_1 = \begin{cases} 0 & \text{in each pre-war (including war) year} \\ 1 & \text{in all post-war years.} \end{cases} \]

If one wants to estimate the change in the slope of pre-war (including war years) and post-war for an explanatory variable (e.g., explanatory variable A), one could follow the following procedure:

\[ X_2 = \text{explanatory variable A in each year,} \]
\[ X_3 = \begin{cases} 0 & \text{in all years except post-war year} \\ \text{explanatory variable A in post-war year.} \end{cases} \]

The estimated coefficient of the explanatory variable A would be \( \beta_2 + \beta_3 \) for post-war year and \( \beta_2 \) for other years.

Dummy variables will also be used in the cross-sectional analysis of this study to represent regional variation.

b. Trend The question of time trend which has often arisen when handling time-series data. The suggested methods for removing time trend include the use of orthogonal polynomials (112, p. 189) and inclusion of a function of time in the regression equation with the remaining explanatory variables (48). The second method may not be as adequate as the use of the first method when time seems to have a complex trend. The second method has been adopted in this study.
V. EMPIRICAL ESTIMATION OF THE FUNCTIONAL RELATIONS

A. Variable and Data Sources

Limitations in the research resources and time have been main reasons for estimating the economic relationships which are based mainly on the theory of the firm using the aggregate data. The other reason could be the attempt to condense the multifarious and random appearing behavior of individuals into a few meaningful, consistent relationships useful for predictive purposes.

Serious discrepancies can arise in predicting the micro relationships, for example the effect of a rise in farm income on farm machinery purchases, from aggregate income and sales data. The problems of achieving consistent estimation of micro relationships with aggregate approach, thus become the central issue.

Klein and Theil (69, 109) have suggested to estimate the macro parameter from macro variables formed from micro variables weighed to insure consistency. Whereas May (85) has suggested analyzing the type of underlying economic relationships which must necessarily hold to allow consistent statistical estimation and prediction from simple available aggregates. 'Simple aggregates' may be arithmetic sums of homogeneous inputs or weighted sums of less than homogeneous data.

Theil's proposed criteria for economic aggregation and the so-called 'perfect aggregation procedure' (109) have been extended by Allen (1) and Foote (30, pp. 84-87). However, it is conceivable that the criteria for economic aggregation, since it might involve the aggregation over non-homogeneous commodities, largely are superimposed on the index number
criteria. Theil's 'perfect aggregation' is not feasible since in most instances the micro parameters are unknown and considerable costs are involved in their estimation. For the most part, it is necessary to rely on simple aggregate of prices, quantities and income based on index number procedures when the variables are non-homogeneous.

The grouping already used by USDA conform reasonably with the above mentioned aggregation criteria. Reasonably consistent results are obtainable by simple aggregation if inputs are relatively homogeneous with respect to the variables which influence the economic relationship. Data limitations require use of some input groups which are aggregated over types of farms and regions in violation of the aggregation criteria.

Throughout this study, main sources of data come from the publications of the United States Department of Agriculture supplemented by the published data from the Department of Commerce. The description of data and their sources are as follows. Unless otherwise stated, the data are available both for nation and 10 production regions.

\[ D_{FLt} \]
Total farm employment (hired plus family) measured in million persons.
Sources:  
   a. Historical statistics of the United States (130).

\[ D_{HLt} \]
Demand for hired farm employees measured in million persons.
Sources: Same as the total farm employment.

\[ D_{FLt} \]
Demand for family farm employees, measured in million persons.
Sources: Same as the total farm employment.
Quantity of all farm machinery purchased (gross investment) by farmers in the current year, deflated, in millions of dollars. Regional data will be explained later.


Amount of motor vehicles purchased during the current year. The variable includes tractors, trucks and the productive portion of automobile purchases (40 percent) (deflated value in millions of dollars) Regional data will be explained later.

Sources: Same as the total farm machinery.

Amount of farm machinery and equipment purchases during the current year for productive purposes. The variable includes planting, harvesting and tillage machines, farm wagons, sprayers, gas and electric engines, and dairying and haying equipment. Motor vehicles are excluded (deflated value in millions of dollars). Regional data will be explained later.

Sources: Same as the total farm machinery.

Annual investment expenditures (gross investment) on new and remodeled farm buildings, in millions of dollars deflated by the wholesale price index.


Beginning year stock of productive farm assets including farm real estate, less value of operator's dwellings; livestock; machinery; motor vehicles less 60 percent of the value of auto-
mobiles; stocks of feed crops held for subsequent use on farms and working capital, in index form and deflated by the wholesale price index (1957-59=100).

Sources: a. Historical statistics of the United States (130).

$Q_{t1}^{S1}$ Index of the farm output (1957-'59=100).
Source: U.S.D.A. Changes in Farm Production and Efficiency.

$Q_{t2}^{S2}$ Index of the volume of farm products marketed, for consumption, non-farm and government storage, and export.

$P_{rt}$ Index of the prices received by farmers for crops and livestock, deflated. Regional analysis used the national data.
Sources: a. U.S.D.A. Agriculture Prices (118).
b. U.S.D.A. Agriculture Statistics (119).

$Y_{rt}$ Total net farm income, deflated, including cash form receipts, nonfarm income, and government payments minus production expenses, in millions of dollars.

$Y_{WFr}$ Declining geometric average of the net farm income (deflated).
$Y_{WFr} = 3Y_{rt} + 2Y_{rt-1} + Y_{rt-2}/6.$
\( P_{TLt} \) Composite farm wage rate, in index form deflated by the wholesale price index (1957-'59=100).


\( P_{HLt} \) Wage rate of hired farm employees, in index form deflated by the wholesale price index (1957-'59=100).

Source: U.S.D.A. Farm Labor (117).

\( P_{Mt} \) Index of the current price of all farm machinery. Regional analysis used the national data.

Sources: Same as the prices received by farmers.

\( (P_{TL}/TVLBA)_t \): Index of the ratio of the composite farm wage rate to the total value of land and building per acre, 1957-'59=100.

Sources: a. Same as (a) and (b) in \( P_{TL} \).
b. U.S.D.A. Current Developments in the Farm Real Estate Market (121).

\( (P_{M}/P_{TL})_t \) Index of the ratio of the farm machinery price to the composite farm wage rate. (1957-'59=100).

Sources: Same as \( P_{Mt} \) and \( P_{TLt} \).

\( MSH_{t-1} \) Value of farm machines and equipment sold last year for domestic uses (deflated value in index form (1957-'59=100)). Regional analysis also used the national data.

b. Agriculture Statistics (119).
\[ \text{IMP}_{t-1} \quad \text{Index of the stock of mechanical power and machines (1957-}'59=100), \text{ lagged one year. Regional analysis also used the national data.} \\
\text{Source: U.S.D.A. Changes in Farm Production and Efficiency (120).} \]

\[ \text{P}_{Wt} \quad \text{Wholesale price index. Regional analysis also used the national data.} \\
\text{Source: Statistical Abstract of the United States (116).} \]

\[ \text{P}_{Pt} \quad \text{Index of the prices paid by the farmers for items used in production, including interest, taxes and wage rates with current value deflated by the wholesale price index. Regional analysis also used the national data.} \\
\text{Source: U.S.D.A. Agriculture Prices (118).} \]

\[ \text{P}_{Bt} \quad \text{Index of the price paid for farm building materials (1957-}'59=100) \text{ (deflated by the wholesale price index). Regional analysis also used national data.} \\
\text{Source: U.S.D.A. Agri. Prices (118).} \]

\[ \text{G}_{t} \quad \text{Index of the government agriculture policy. During those years when acreage allotment or production controls are in force, with flexible price supports, the value of -1 is given. If price supports are fixed, with rigid support of 85% or over, the value of +1 is given. For those years when soil bank and subsequent agriculture adjustment act provisions are in force, an additional -1 is given. The values are summed to form index G}_{t}. \]
Source: Constructed by this writer based on the article which is written by Wayne D. Rasmussen and Gladys L. Baker, titled "A Short History of Price Support and Adjustment Legislation and Programs for Agriculture, 1933-'65" (95).

\[(PR/PP)_{t-1}\] Previous year’s index of the ratio of prices received by farmers for crops and livestock to prices paid by farmers for items used in production, including interest, taxes and wage rates. Regional analysis also used the national data.

Sources: Same as the prices received by farmers.

\[Y_{WFT-1}\] Geometric average of the net farm income for the preceding three years, deflated and in millions of dollars.

Sources: Same as the \[Y_{WFT}\].

\[W_t\] Stallings' index of the influence of weather on farm output.

Sources: a. Stallings, James L. Weather indexes (105).

b. The data for years 1958-'65 have been indexed by this writer using Stallings' formulation.

\[T\] Time, an index composed of the last two digits of the respective years.

\[T'\] Index of productivity, the ratio of farm output to all farm inputs in the respective years.

Source: U.S.D.A. Changes in Farm Production and Efficiency (120).

\[F_{Rt}\] Wholesale price index other than food.

Source: Statistical Abstract of the United States (116).
\( FC_t \)  
Index of per capita food consumption, 1957-'59=100.  
Source: U.S.D.A. National Food Situation (125).

\( Y_{Dt} \)  
Disposable personal income, deflated, for the U.S. in respective years.  

\( A_{F_{t-1}} \)  
Index of cropland per farm, in acres, lagged one year. 1957-'59=100.  
   b. U.S.D.A. Number of Farms and Land in Farms (129).

\( (P_{TL}/TVLBA)_{t-1} \)  
Index of the ratio of composite farm wage rate to total value of land and building per acre, 1957-'59=100, lagged one year.  
Sources: a. Same as (a) and (b) in \( P_{TL} \).  
   b. U.S. Dept. of Agriculture Current Developments in the Farm Real Estate Market (121).

\( U_{t-1} \)  
Preceding year's national rate of unemployment, in percent.  
Source: Statistical Abstract of the United States (116).

\( P_{NL_t} \)  
Index of the deflated non-farm wage rate (1957-'59=100).  

\( e_t \)  
Variable reflecting the once-for-all shift in structure. During the World War II period and pre-war years the variable is zero, while during the post-war period the variable is 1.
ER_{t-1}  Farmers' equity ratio, lagged one year. Computed from the total value of land and building divided by outstanding mortgage debt.

b. Agriculture Statistics (119).

P_{tSt}  Wholesale price index of iron and steel. Deflated by wholesale price index (1957-'59=100).


Y_{t-1}  Rate of interest on new farm mortgage, in percent, lagged one year. Regional analysis also used the national data.


L_{t}  Index of the gross production of livestock and livestock products (1957-'59=100).

Source:  U.S.D.A. Changes in Farm Production and Efficiency (120).

S_{tBt}  Stock value of farm buildings at the beginning of year, excluding operators' dwellings. Deflated by wholesale price index (1957-'59=100). Regional analysis also used the national data.

Sources:  a. Agriculture Statistics (119).
b. U.S.D.A. Current Developments in the Farm Real Estate Market (121).
c. William G. Murray. Farm Appraisal and Valuation (89).
$S_M^t$  
Stock value of total farm machinery at the beginning of year. Deflated by wholesale price index (1957-'59=100).

Source: U.S. Dept. of Agriculture. Farm Income Section (126).

$S_{MV}^t$  
Stock value of productive motor vehicles on farms (estimated as 40 percent of the total value) at the beginning of year. Deflated by wholesale price index (1957-'59=100).

Source: U.S.D.A. Farm Income Section (126).

$(P_M/P_{TL})_{t-1}$  
Ratio of the farm machinery price to the composite farm wage rate in index form lagged one year (1957-'59=100).

Sources: Same as $(P_M/P_{TL})_t$.

$A(t)$  
Technological change index (1957-'59=100).

Sources: a. Hiromitsu Kaneda. Regional Patterns of Technical Change in U.S. Agriculture. 1950-1963 (65). The basic model used in his study is as follows:

$$(V/L)_t = AW_t^b G(t),$$

where $V/L$ is value added per unit of labor input (in man-hours) and $W$ is the real wage rate. This model recognizes explicitly the relationships between labor input and labor cost, and underlies the constant elasticities of substitution in the above function. The equation incorporates a variable $G(t)$ (accounting for the influence of time, including weather conditions and the level of technology), which is not necessarily a simple (regular) function of time.
The $G(t)$, technological change index, was estimated by pooling the time-series and the cross-section data.

b. The national time-series data and regional data other than 1950-'63 were computed by this writer following the procedures suggested by Kaneda. National annual average rate of technological change was computed as 0.03 percent.

\[ Q_{Mt} \]

Annual regional purchases (gross investment) of the total farm machines deflated by wholesale price index. These figures were derived by dividing the stock value of total farm machines in a given region (126) by the U.S. total stock values (126). This percentage was then multiplied by the total U.S. purchases to give a regional purchase figure.

\[ Q_{Mt} = Q_{Mt} \cdot \frac{S_{Mt}}{S_{Mt}} \]

where $S_{Mt}$ refers to stock value of total farm machines in the $i$th region; $S_{Mt}$ is the national stock values of total farm machines.

\[ Q_{MVti} \]

Annual regional purchases (gross investment) of the motor vehicles deflated by wholesale price index. These figures were derived in the same fashion as the $Q_{Mt}$. The $S_{MVti}$ and $S_{MVti}$ data were from the same sources as the $S_{Mt}$ and $S_{Mt}$.

\[ Q_{METi} \]

Annual regional purchases (gross investment) of other farm machines deflated by wholesale price index.

\[ Q_{METi} = Q_{Mt} - Q_{MVti} \]
Annual regional gross investment in farm buildings. Deflated by wholesale price index. Derived in the same fashion as the national stock value of farm real estate (121) and national stock value of farm real estate (121).

Annual regional gross investment for total farm machines, lagged one year. Data sources are the same as \( Q_{Mt} \).

Annual regional gross investment for farm motor vehicles, lagged one year. Data sources are the same as \( Q_{MVT} \).

Annual regional gross investment for other farm machines, lagged one year.

\[
Q_{MEi(t-1)} = Q_{Mi(t-1)} - Q_{MVi(t-1)}.
\]

B. Results of National Model 1924-1965

1. Aggregate commodity market

The production (response) function: The production response function estimated with 1924 to 1965 annual data is as follows:

\[
Q_{S1} = -43.52882 + 0.123264 \left( \frac{PR}{Pp} \right) t - 0.21986 \cdot SPt + 0.776164 \cdot Gt + 0.248210 \cdot Wt + 1.137410 \cdot T + 0.119460 \cdot A(t) - 2.534415 \cdot Gt.
\]

\[
R^2 = 0.9873
\]

\[
d = 1.92998^*
\]

The variable \( Q_{S1} \) is the index of the commodity produced. The equation is linear in original values of variables defined in the first section of this chapter. The coefficient of each variable is highly significant and displays
the anticipated sign in the equation. The student t-values are presented in the parenthesis below each coefficient. The hypothesis that the residuals are not autocorrelated is accepted at the one percent probability level. In the remainder of this study one asterisk on Durbin-Watson d-statistic will indicate the insignificant autocorrelation.

The elasticity of output $Q^b_t$ with respect to $(P_R/P_P)_{t-1}$ computed at the 1924 to 1965 mean is 0.17. This is essentially a production response elasticity with respect to one year lag index of the parity ratio. The elasticity with respect to $S_{Pt}$ is 0.33 and 0.15 with respect to $A(t)$.

The variables in the equation provide the basis for ascertaining two general sources of the increased output: (a) changes in the input levels indicated by the variable $(P_R/P_P)_{t-1}$ and $S_{Pt}$; (b) changes in the output due to technological improvements. The technological index indicates the changes in output due to management and efficiency. If $A(t)$ is at the 1965 value and other variables are at the 1924 value, the elasticity indicates output would have been 3.7 percent greater than the predicted 1924 output. This computed contribution of the technological improvements to the agriculture production would have been greater if one uses the output-input or productivity index (of U.S.D.A.) as the technological variable. The productivity index puts all of the effects of weather, management and efficiency together. The separate effect of the technological improvements is hard to assess by employing such kind of variable.

The above equation further indicates that output was increased 27 percent from 1924 to 1965 due to increased investment in agriculture ($S_{Pt}$).

To summarize, the major portion of the increase in output from 1924
to 1965 is associated with investment and technological improvements. Short run price influence had lesser effect on the secular increase in output.

Aggregate commodity supply function: The estimated commodity supply function using the time series from 1924 to 1965 is as follows:

\[ Q_t^{S2} = -12.19 + 0.61 T + 0.78 Q_t^{S1} \]

\[ R^2 = 0.98 \]
\[ d = 1.73^* \]

The variable \( Q_t^{S2} \) is the predicted supply quantity, including changes in inventories. The student t-values are presented in the parenthesis. The coefficients of the variables explain a high proportion of the annual variation in \( Q_t^{S2} \). The hypothesis that the residuals are not autocorrelated is accepted at the one percent probability level.

The time variable, \( T \), which includes the inventory changes, have been significant in explaining the annual variation of aggregate quantity supplied. The supply elasticity with respect to time variable computed at the mean is 0.35. This magnitude is less than one-half of the supply elasticity with respect to the index of the commodity produced (0.81).

Aggregate commodity price function: The estimated aggregate commodity price function using the annual data from 1924 to 1965 is as follows:

\[ P_t = 220.9714 + 2.137803 FCN_t + 0.117606Y_t - 1.101805 Q_t^{S2} \]
\[ + 2.449223 G_t - 2.5506 P_{t-1} \]

\[ R^2 = 0.93 \]
\[ d = 1.39^* \]
The variable \( P_R \) is the index of commodity price received by farmers; FCN is the index of per capita food consumption; \( Y_D \) is the disposable personal income for the U.S.; \( Q^{S2} \) is the index of agriculture commodity supplied; \( G \) is an index of government agriculture policy; and \( P_R' \) is the wholesale price index other than food. All variables except \( G \) and FCN are deflated by wholesale price index. The figures in parentheses are student t-values of the coefficients above them.

All variables are significant at the one percent probability level and have the expected sign. The hypothesis of non-autocorrelated error term is also accepted. All independent variables together explained 93 percent of the annual variation in commodity prices.

The variable, \( Q^{S2} \) is among the significant explanatory variables in explaining the annual variation of commodity prices. The price flexibility of \( P_R \) with respect to \( Q^{S2} \) computed at the mean is \(-0.78\). A one percent increase in the index of commodity supplied, the index of price received by farmers decreases more than 0.78 percent on the long run. The price flexibility with respect to FCN computed also at the mean is 1.86. Hence, the estimated demand elasticity is 0.51. It has to be noted that the coefficient of the quantity variable in the price equation is the constant price flexibility. It is not strictly correct to assume that the inverse is the price elasticity of demand. That is, the price flexibility generally is defined as the coefficient of quantity when price is the dependent variable. Price elasticity of demand generally is defined as the coefficient of price when quantity is the dependent variable. The two concepts are equivalent only if there is no error in the model or the equation is independent of the direction of normalization. This price equation is not
qualified for the latter point. Consequently there is no great confidence in this estimated demand elasticity.

The increasing level of personal disposable income, $Y_D$, and the price supporting policy have been helping, at least, to maintain the level of agricultural commodity prices over time. The price flexibilities with respect to $Y_D$ and $G$ computed at the means are respectively 0.25 and 0.006, whereas the level of the wholesale price index of commodities other than food has been running against the level of prices received by farmers. This has appeared in the negative coefficient of $P_R$. The fact that the index of prices received by farmers had been deflated by wholesale price index which is composed mainly of non-food commodities, might be the reason for the negative coefficient. The computed price flexibility with respect to this variable, at the mean, is -2.34.

The Net farm income function: The estimated definitional net farm income equation is as follows:

$$ Y_{Ft} = -38327.38 - 2768.483 C_t + 214.3666 P_{Rt} + 100.641 X_{Rt} + 33.05465 S_{Pt}^b $$

$$ + 101.0416 (P_R/P_P)_t + 0.567146 Y_{Ft-1} $$

$$ (3.75) \quad (2.36) \quad (4.4) \quad (2.28) \quad (2.89) \quad (7.95) \quad (2.89) \quad (7.95) $$

$$ R^2 = 0.96 \quad d = 1.82^* $$

This definitional equation was estimated from annual data from 1924 to 1965. The student t-values for each coefficient are indicated in the parentheses. The price variable $P_R/P_P$ is included in several forms. One in the original form of $P_R/P_P$ and other in the form of $[T'(P_R/P_P)]$, where $T'$ is the productivity index which is the ratio of total output to total input. The product of $T'$ and $(P_R/P_P)$ has been referred to as $X_R$ in the
above equation. The results indicate that a one percent increase in $\frac{P_R}{P_P}$ increases 1.49 percent $Y_P$ in the 1924 to 1965 period. With a one percent increase in the interaction term of $T'$ and $\frac{P_R}{P_P}$, $Y_P$ increases 0.68 percent.

The results indicate also that increasing $S_P^b$ contributes to the increment of $Y_P$, whereas the structure variable indicates that $Y_P$ declines more in real value over the post-war years than pre-war years.

2. Factor markets

The demand for total farm machinery: The estimated demand function for total farm machinery is as follows:

$$Q_{Mt}^D = -3910.750 - 1.1915328 (\frac{P_M}{P_R})_{t-1} + 33.321269 A(t) + 29.38883 T + 132.5875 ER_{t-1} + 0.0321888 S_{Mt}^*$$

$$R^2 = 0.898$$

The variable $Q_{Mt}^D$ is the demand for total farm machinery in dollars term; $(\frac{P_M}{P_R})_{t-1}$ is the one year lagged index of the ratio of farm machinery to price received by farmers. $ER_{t-1}$ is the one year lagged equity ratio; $S_{Mt}$ is the stock value of total farm machinery at the beginning of the year and $T$ is time variable. All variables except $A(t)$ and $T$ are deflated by the wholesale price index. All variables have the expected sign. The $t$-value for the coefficients are indicated in parenthesis below each coefficient. Except for $(\frac{P_M}{P_R})_{t-1}$ and $S_{Mt}$, all variables are significant at the one percent probability level, though $S_{Mt}$ is significant at five percent probability level.
Level of technology $A(t)$, and lagged (one year) equity ratio are the most significant variables in influencing the demand for total farm machinery. It is quite conceivable that the technological change has lead to the utilization of more machinery than labor. Certainly, the substitution of machinery for labor has been taking place over time. One percent improvement in technology led the demand for total farm machinery to increase 1.6 percent.

Lagged equity ratio is also an influential variable in determining the demand for total farm machinery. The $t$-value for the coefficient of equity ratio is significant at one percent probability level.

By this equation, which is based on the stock adjustment model as discussed in Chapter III, the regression coefficient of $S_{MT}$ is the difference between depreciation rate and the adjustment coefficient (50). The average depreciation rate of the total farm machinery had been computed from the separate set of data as 0.138 (18). Consequently the adjustment coefficient of the total farm machinery was computed as 0.106. This implies that the average increment of the total farm machinery investment has been approximately 11 percent per year of the stock value of farm machinery at the beginning of each year.

The elasticities of demand for annual investment of total farm machinery, $D_{MT}$, with respect to prices ratio $(P_M/P_R)_{t-1}$ is approximately $-0.05$ measured at the mean.

Supply of all farm machinery: The estimated supply functions of all farm machinery is as follows:
\[ P_{Mt} = 11.95938 + 0.39262 \ P_{IS} + 0.735667T + 0.003607\ MSH_{t-1} + 0.32623\ P_{NLt} \]
\[ (3.46) \quad (-2.23) \quad (1.29) \quad (1.94) \]
\[ r^2 = 0.883 \quad d = 1.586^* \]

The variable \( P_M \) is the price index of farm machinery; \( P_{IS} \) is the wholesale price of iron and steel; \( MSH_{t-1} \) is the index of machinery shipment; \( P_{NL} \) is price index of non-farm wage rate and \( T \) is time variable. All variables except \( T \) and \( MSH_{t-1} \) are deflated by wholesale price index, and are expressed as a percentage of the 1957 to 1959 average. The annual data extend from 1924 to 1965.

All variables except \( MSH_{t-1} \) are significant at one percent probability level. \( MSH_{t-1} \) is significant at the five percent probability level. All variables have the expected sign.

The price flexibility of machinery shipment (supply) computed from the equation is 0.02. Since it is near zero, the supply elasticity (1/price flexibility) is very large.

The result was consistent with the hypothesis that machinery supply is highly elastic. Although this equation indicates supply is less than perfectly elastic, it does indicate that price is relatively unresponsive to quantity changes in the short-run.

That farmers are price takers (quantity a function of price) and manufacturers are price setters (price a function of quantity) should be inferred from this supply equation.

A variable significantly explaining machinery prices is \( P_{IS} \). A one percent increase in iron and steel price raises machinery price 0.34 percent according to this equation. The result is not surprising, since
steel and iron are the important raw materials in farm machinery. Non-farm wage rates affect the cost of machinery production and the empirical result in this study shows that it has a very significant effect on machinery price.

The short-run year to year variation in total farm machinery price is very small. The coefficient for one year lagged farm machinery price is 0.58, and is a significant variable by the t-test (at the one percent probability level).

Demand for motor vehicles estimated by least squares; Variables considered to be important influences on demand quantities of motor vehicles are the level of technology, lagged one year equity ratio, time variable, lagged index of cropland and the stock of motor vehicles on farm at the beginning of the year. The logic of the specification and the nature of expectations and adjustments are discussed previously in Chapter III.

Coefficients, student t-values and related statistics for motor vehicle demand equation are as follows:

\[
Q_{MVt} = -2138.35 + 17.76596A(t) + 83.28165ER_{t-1} + 8.386136T + 3.918741AF_{t-1} \\
+ 0.012950S_{MVt} \quad R^2 = 0.8384 \quad \text{d} = 1.22
\]

(2.41) (5.01) (0.73) (0.36) (0.35)

Student t-value for the coefficient of each variable is presented in the parentheses. All variables have the expected signs. The Durbin-Watson d-statistic falls in the inconclusive range.

Lagged (one year) equity ratio and the level of technology are again highly significant (at the one percent probability level) in explaining
the demand for motor vehicles as in the demand for total farm machinery equation.

The stock of motor vehicles is not significant in this demand equation as compared to the significant influence of the stock value for the demand of total farm machinery. The average depreciation rate of the motor vehicles was computed as 0.132 from the separate set of data. Though it is doubtful to infer with the insignificant coefficient, the adjustment coefficient for motor vehicles was computed as 0.10 in this empirical result. This adjustment coefficient is as high as in the demand for total farm machinery.

Demand for other farm machinery and equipment: The definitional equation of the demand for other machinery and equipment is as follows:

\[ D_{ME_t} = D_{MT_t} - D_{MV_t}. \]

The demand for other farm machinery and equipment are treated as the residual in terms of subtracting the demand for motor vehicles from the demand for total farm machinery. No estimation of the parameters was made since it is a definitional equation.

Shifts in machinery demand: Total machinery demand equation indicates that total farm machinery purchases would have been 67 percent greater in 1924 if farmers would have experienced the financial or equity position present in 1965, ceteris paribus. More efficient methods of production, substitution of cheap operating inputs for farm labor and horsepower, improved management and inflation permitted a slight increase in net farm income and a considerable improvement in the equity of farmers from 1924 to 1965 despite the rise in the ratio of \((P_M/P_R)\). An 'acceleration'
influence may be evident; since adoption of machinery in early years partially was responsible for the increased efficiency and improved financial position of farmers, this permitted greater machinery purchases in later years. Table 1 indicates that the major sources of the increased machinery demand have been due to the equity positions of farmers, the level of technology and the structural changes represented by the time variable. Effects of the technological level are more than offset by the effects of price on the demand for total farm machinery, consequently leaving the equity and 'structure' to explain almost the entire shift in machinery demand since 1924. The situation is quite similar in the demand for motor vehicles. The most notable structural changes embodied in the time variable are the continuous improvement in the quality and adaptability of machinery.

Table 1. Estimate percentage changes in annual gross investment in farm machinery from 1924 to 1965 attributed to prices, technology, demand structure and equity

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Variables</th>
<th>((P_M/P_R)_{t-1})</th>
<th>(A(t))</th>
<th>(T)</th>
<th>(ER_{t-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand for total farm machinery</td>
<td>-0.049</td>
<td>1.58</td>
<td>0.62</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>Demand for motor vehicles</td>
<td>-</td>
<td>1.59</td>
<td>0.33</td>
<td>0.61</td>
<td></td>
</tr>
</tbody>
</table>

Concurrent with these improvements is the increased awareness by farmers of the returns and convenience from using improved machinery. Of course, it is well to remember that the structural and financial categories are not entirely independent.

Perhaps the most basic indirect source of the structural increase in
demand for machinery is the growth of the American education. Without the large investment in education, it is unlikely that engineering and other talents of human resources would have been able to develop rapidly the steel, coal and automobile industries so vital to the growth of the farm machinery industry.

The non-farm sector has performed an important role in farm mechanization. If the supply of farm machinery were not highly elastic and if small increase in farm demand would have brought sharp machinery price increases, farm mechanization undoubtedly, would have progressed less rapidly. The fact that manufacturers have made farm machines available in quantities and of the quality desired by farmers, has been an important element explaining the rapid growth of farm machinery investment. In turn, using the stock of farm machinery and substitution of machinery for farm produced power has been a significant element in the rising farm labor efficiency.

Thus, the development of America's agriculture is an interdependent accomplishment. The basic ingredients are the natural resources, educational attainment and technological know-how for building farm machines and the desire and ability to use them profitably on farms. On this foundation, the total economy grows as the machines have been made available to farmers. This allows financial surpluses for farmers to purchase more machines. Simultaneously, workers who are freed from farming, provide the basis for further expansion of industry and improved standards of living for both the farm and non-farm sectors. Although the growth of America's agricultural plant principally was financed internally from
net farm income, a strong non-farm sector, undoubtedly, can be an important source of credit in times of rapid expansion of farm investment.

Demand for farm building investment: The deflated total value of real estate increased by 288 percent during 1924-1965 period (121). The increase is largely due to annual investment in building improvements, including fences, windmills, and wells. In this study, the quantity demanded (annual gross investment of building materials) is specified as a function of prices, index of livestock production, interest rate, stock of productive farm building assets, three years' weighted average of the net farm income, the structure variable for pre- and post world war years.

All indexes are expressed as a percentage of the 1957 to 1959 average. All variables are annual data for the U.S. from 1924 to 1965.

The six independent variables in the following equation, explain 87 percent of the annual variation about the mean of \( Q_{\text{BIt}} \). Coefficients of all variables except the index of livestock production are highly significant (at the one percent probability level). The signs of all the variables are consistent as expected.

\[
Q_{\text{BIt}} = 817.9438 + 375.2627C_t + 34.1892ER_{t-1} + 2.049107LP_{t-1} - 9.858559P_{Bt} - 0.004864S_{Bt} + Y_{WFT-1} - 9.858559P_{Bt} \\
(6.20) \quad (4.56) \quad (1.75) \quad (4.07) \quad (1.82) \quad (3.70)
\]

\[ R^2 = 0.98 \]
\[ d = 1.27^* \]

The weighted three years' average of the net farm income is the most significant variable. The price for building materials and stock of farm building also are highly significant. As mentioned in the demand for total farm machinery the regression coefficient of the stock value of farm building \( S_{\text{BIt}} \) is the depreciation rate \( h \) minus the adjustment coefficient
g (50). Hence, the negative coefficients of $S_{Bt}$ indicate that $g$ exceeds $h$ by 0.005. The exact depreciation rate is unknown (data not available), but probably is considerably below the machinery depreciation rate. If the depreciation rate is 0.10, the adjustment rate is $0.10 + 0.005 = 0.1005$. The level of adjustment coefficients are quite compatible with the demand for farm machinery.

According to this equation, the price elasticity of $Q_{Bt}$ estimated at the mean is $-1.0$. Income elasticity of $Q_{Bt}$ with respect to lagged three years' weighted average of the net farm income $Y_{W,t-1}$, is $0.19$.

Shifts in building investment demand: In 1965, annual gross investment in building improvements was 97 percent above the 1924 level. Three hypothetical sources of the investment increases are: (a) equity ratio, (b) livestock production index, and (c) structure $C_t$. If 1965 values are given these variables, the farm building demand equation indicates that demand would have been 166 percent greater than in 1924. If price $P_B$ had been at the 1965 level in 1924, other things equal, the demand quantity would have been 70 percent less than the actual demand in 1924 according to the equation. The large building investment needed to store and house the increased inventories of livestock and feed also need large building investment to store and house them. The index of livestock production might be the proxy variable for these changes. The $t$-value of this proxy variable appeared to be significant at the one percent probability level. If livestock production had been at the 1965 value in 1924, demand would have been 34 percent above the 1924 level, other things equal.
The agriculture production efficiency has been increased over time, with relatively stable inputs prices farmers apparently improved their financial status sufficiently to increase purchases of building improvements by a sizeable amount. But the influence of both building material prices and equity would reduce demand by a net of about 25 percent.

The structural changes only explain about 120 percent increase in building investment during 1924-1965. Structural changes are a broad range of physical and technological influences. Technological influence may not be as dramatic as for farm machinery; nevertheless, changes in methods of storing feeds, handling dairy cattle, etc. have influenced demand for buildings. Influences tending to reduce farm numbers and replace labor with other resources also have created an impact on the investment in real estate. Some of these influences reduce demand, others increase demand, but the net influence according to above equation is to shift demand to the right for post-war years.

The empirical analysis for the demand for farm machinery and farm building indicates that increasing annual investment in machinery and buildings may be explained substantially by (a) level of technology, (b) financial structure, and (c) slowly changing influences reflected by a time variable. For machinery input, the influence shifting demand to the right at the most rapid rate was (a), the improvement in financial status due to greater efficiency, lower prices of operating inputs and inflation, tended to increase annual investment for durable inputs. Structure and time variables include improvements in quality, adaptability and convenience of durables. Other components of the time variable are the gradual awareness by farmers of better management practices and of
the profitability and convenience of investment in durable resources. The structure and time variables are also influential in the demand for all other durable inputs in this study.

The supply of farm machinery is analyzed as part of an recursive model. The long run price flexibility is approximately 0.02. Thus, supply prices are quite unresponsive to changes in quantity. In this elastic supply function, the most influential variable appears to be the price of iron and steel. A one percent increase in the price of iron and steel tends to increase the supply price about 3.5 percent. It should be noted that the price of non-farm labor is also highly significant.

Demand for total farm employees: The time-series data of the total farm employment is that of the sum of hired and family employment data. It might be expected that the demand for total farm employment would be an average or aggregate of the demands for hired and family labor. The total farm employment data represent the total number of persons employed in agriculture.

The estimated demand equation for total farm employment is as follows:

\[
Q_{TLt}^D = 17640.22 - 17.87216 IMP_{t-1} + 0.075626Y_{Ft-1} - 63.44567PNLt - 11.42658A(t) - 17.56882(P_{TL/TVLBA})_{t-1} + 3.304025(P_M/P_{TL})_{t-1} - 17.56882(P_{TL/TVLBA})_{t-1} + 3.304025(P_M/P_{TL})_{t-1}.
\]

\[R^2 = 0.97\]
\[d = 1.62*\]

The lagged index of the price ratio of farm machinery to farm wage rate is a significant explanatory variable (at the five percent probability level). The positive coefficient suggests that total demand for farm labor declines on farms in response to a fall in the relative price of
farm machinery. This is consistent with the hypothesis that machinery substitutes for labor with a relative decline in the machinery price. However, the long-run elasticity measured at the mean for the total labor demanded with respect to this price ratio is lower than expected. The computed elasticity was 0.004.

The demand for total farm labor showed, in this equation, a negative relationship with the lagged index of the mechanical power on farms. A one percent increase in the index of the mechanical power on farms in the previous year reduced the current year's total labor demand by more than 1.11 percent. This empirical result provides the evidence that modern mechanization on farms gives an increasing impact on the declining demand for total farm labor.

The lagged net farm income, $Y_{t-1}$, exhibits the expected positive relationships with total farm employment. In aggregate, therefore, it appears that total employment in agriculture tends to increase in response to increase in previous year's net farm income. This increase in total farm labor would be expected to be manifested through an increase in the family farm labor force rather than the hired labor force.

The effects of technological improvements have a significant (at the five percent probability level) negative effect on the demand for family farm labor and consequently reduce the demand for total farm labor. The technological improvements lead to the substitution of farm machinery for labor. From this empirical analysis, a one percent increase in technological index will reduce the demand for farm labor (in terms of the number of persons) over 1.12 percent.
The negative coefficient for index of the one year lagged ratio of the farm wage rate to the price of land and buildings per acre suggests that as the price of labor rises relative to the price of land and buildings per acre, total labor declines on farms. With a one percent increase in the ratio of the price of labor to the price of land, and buildings, in a given year, total farm labor will decline roughly 1.5 percent in the next year.

The result also indicates that the wage rate for factory workers is a significant explanatory variable in total farm labor demand. A sustained one percent increase in \( P_{NL} \) tends to reduce the total farm labor demand by approximately 4.8 percent. This apparently is exerted through the farm migration process. With job opportunities growing in the non-farm economy farm laborers tend to migrate from agriculture.

The supply function of total labor: The supply function of total labor estimated with annual time series from 1924 to 1965 is as follows:

\[
P_{TTL_t} = 3.869360 - 0.618736 P_{Mt} - 0.045359 A(t) + 1.371446 P_{NL_t} - 1.211193 U_{t-1} + 0.003175 Q_{TLt} + 0.199450 T - 1.372308 C_t.
\]

\[
(4.64) \quad (0.41) \quad (4.39)
\]

\[
(6.24) \quad (1.66) \quad (0.31) \quad (0.27)
\]

\[d = 1.53^* \]

\[\rho = 0.33\]

The variable \( C_t \) is a structure variable with values of zero from 1924 to 1946, and values of 1 from 1947 to 1965. \( P_M \) is the index of farm machinery price, \( A(t) \) is technological index, \( P_{NL} \) is the wage rate of factory workers and \( U \) is the proportion of the national labor force unemployed. \( Q_{TL} \) is the amount of total farm labor demanded and \( T \) is time.
variable. All price indexes were deflated by wholesale price index (1957-1959=100). $p$ is the autoregressive coefficient. Student t-values are indicated in parentheses below the coefficients. All coefficients display the expected signs.

The long run price flexibility with respect to labor demand computed at the mean is 0.42. With this low price flexibility, the labor demand and/or supply did not exert a significant effect on the farm wage rate. The insignificant effects of labor demand and/or supply of farm labor on farm wage rates, probably is one of the main causes for excessive labor supply, excessive products supply and hence the result is low farm income in the agriculture sector. This is due to the failures of farm wage rates to reflect the market conditions.

The result with a negative coefficient for $P_M$ also indicates that there are more competitive relationships between labor and machinery than complementary. $P_{NL}$ and $U_{t-1}$ are both significant explanatory variables for farm wage rate. A sustained one percent rise in $P_{NL}$ tends to increase $P_{TL}$ more than one percent when $U_{t-1}$ is at the 1924-1965 average level.

As indicated by the positive coefficient of the time variable $T$, time trend for real farm wage rate displayed a slight annual increase over time. The structure variable, $C_t$, appeared insignificant in this function. It is very possible that the effects of structure changes on farm wage rate have been taken care of by the time variable $T$.

The technological index, $A(t)$, has the expected negative sign. The elasticity of farm wage rate with respect to technological index computed at the mean is -0.06. The substitutional effects of machinery on farm
labor are again supported by this empirical result.

The demand for hired farm labor: The estimated demand equations for hired farm employees is as follows:

\[ Q_{HLI_t} = 3583.077 + 9.282995 A(t) + 5.407297A_{Ft-1} + 0.804702 P_{Mt} \]

\[ - 3.659986\left(\frac{P_{VA/LBA}}{P_{T/L}}\right)_{t-1} - 51.41593T + 188.4969 C_t \]

\[ R^2 = 0.968 \]

\[ d = 1.64978* \]

\[ \rho = 0.23 \]

A number of independent variables reflecting price of agricultural resources were significantly influential on the demand for hired farm employees. These included both resource prices independently and in ratio form.

Index of the price of farm machinery also is a significant explanatory variable. The positive coefficient suggests that hired labor declines on farms in response to a fall in the price of farm machinery. This is consistent with the hypothesis that machinery substitutes for labor with a decline in machinery price. The estimated elasticity computed at the mean is 0.03.

The negative coefficient for the lagged index of the ratio of the farm wage rate to the price of land and buildings per acre suggests that as the price of labor rises relative to the price of land, hired labor declines on farms.

The lagged index of cropland per farm \( A_{Ft-1} \), are significantly positive in the demand for hired farm labor equation. The elasticity of hired labor demand with respect to this variable computed at the mean is 0.18.
The level of technology, $A(t)$, is also an influential variable. However, it has a quite small positive coefficient as compared to the coefficient of the demand for total farm machinery and motor vehicle functions. The technological improvements in agriculture have been in favor of mechanization. The effects of technological improvements have a significant negative effect on the demand for family farm labor and consequently the demand for total farm labor. Its effect on hired farm labor is not clear. Improvements in technology will increase the labor efficiency which induces higher demand for labor. On the other hand, the technological improvements lead to the substitution of farm machinery for labor. In the demand for hired farm labor, the latter effects might have been offset by the former.

Time is a significant explanatory variable. The elasticity of the demand for hired farm labor with respect to time variable, $T$, is roughly -0.9. Despite the relative decline in the annual demand for the hired labor over time, the absolute amount of the demand for hired labor has increased in post-war years. This can be identified from the significant positive coefficient for the structure variable, $G_t$.

The demand for family farm labor: The demand for family farm labor is defined as follows:

$$Q_{Ft}^D = Q_{TLt}^D - Q_{HLt}^D.$$  

The variable $Q_{Ft}^D$ is the quantity demanded (in terms of persons employed) of the family farm labor; $Q_{TLt}^D$ is demand for total farm labor; and $Q_{HLt}^D$ is the demand for hired farm labor. More than 75 percent out of the total farm labor (in terms of persons employed) demanded in the period under
study belongs to family farm labor. The quantity demanded (in terms of persons employed) for family labor is treated as the residual of the demand for total labor after subtracting the hired labor. Thus, the parameters for the demand function of family farm labor is not estimated since it is a definitional equation.

G. Results of Regional Models 1946-1965

Demand for total farm machinery: The regression results reported in Table 2 included all variables of the demand for total farm machinery function which were found to be statistically significant (see the footnotes for table 2). The Durbin-Watson statistic also indicated that the errors were not autocorrelated in the equation.

The stock adjustment model was tried for regional machinery demand. However, the high multicollinearity among the stock value of farm machinery, time trend and technological index led to the nonsignificance of the coefficients of many variables. Consequently the regression reported in Table 2 was the expectation model.

The overall coefficient for the time trend is significant. The overall coefficient for the ratio of farm machinery prices to prices received by farmers also is significant and with the expected negative sign.

The overall coefficient for one-year-lagged farm machinery investment is significant. For the coefficient of the same variable, only the Delta States region coefficient was significantly different from the overall coefficient.

The overall coefficient for the lagged equity ratio is a significant
Table 2. Regression equation and related statistics for regional total farm machinery demand

<table>
<thead>
<tr>
<th>Names of variables and statistics</th>
<th>Notation</th>
<th>Statistics and regression coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall regression 'F' ratio</td>
<td>F</td>
<td>379.886</td>
</tr>
<tr>
<td>Coefficient of determination</td>
<td>R^2</td>
<td>0.986</td>
</tr>
<tr>
<td>Durbin-Watson statistics</td>
<td>d</td>
<td>1.648**</td>
</tr>
<tr>
<td>Overall intercept</td>
<td>b_0</td>
<td>-745.54 (-4.40)***</td>
</tr>
<tr>
<td>Diff. in the intercept for Lake States Reg.</td>
<td>b_3</td>
<td>164.67 (1.30)*</td>
</tr>
<tr>
<td>Diff. in the intercept for Corn Belt Reg.</td>
<td>b_4</td>
<td>321.94 (2.65)***</td>
</tr>
<tr>
<td>Diff. in the intercept for Northern Plains Reg.</td>
<td>b_5</td>
<td>283.55 (2.47)**</td>
</tr>
<tr>
<td>Diff. in the intercept for Appalachian Reg.</td>
<td>b_6</td>
<td>166.24 (1.38)*</td>
</tr>
<tr>
<td>Overall time trend</td>
<td>T</td>
<td>14.72 (4.59)***</td>
</tr>
<tr>
<td>Overall coeff. Q_{Mt-1}</td>
<td>Q_{Mt-1}</td>
<td>0.867 (-3.34)***</td>
</tr>
<tr>
<td>Diff. in the coeff. of Q_{Mt-1} for Delta States Reg.</td>
<td>Q_{Mt-1,7}</td>
<td>-0.690 (-1.34)*</td>
</tr>
<tr>
<td>Overall coeff. of ER_{t-1}</td>
<td>ER_{t-1}</td>
<td>15.87 (2.88)***</td>
</tr>
<tr>
<td>Diff. in the coeff. of ER_{t-1} for North-east Reg.</td>
<td>ER_{t-1,2}</td>
<td>24.04 (2.01)**</td>
</tr>
<tr>
<td>Diff. in the coeff. of ER_{t-1} for Northern Plains Reg.</td>
<td>ER_{t-1,5}</td>
<td>-9.67 (-1.60)*</td>
</tr>
<tr>
<td>Diff. in the coeff. for Appalachian Reg.</td>
<td>ER_{t-1,6}</td>
<td>-9.44 (-1.56)*</td>
</tr>
<tr>
<td>Overall coeff. for P_{M}/P_{R}</td>
<td>P_{M}/P_{R}</td>
<td>-2.56 (-3.29)***</td>
</tr>
</tbody>
</table>

*** Indicates coefficients significant at probability level 0<P<0.01.

** Indicates coefficients significant at probability level 0.01<P<0.05.

* Indicates coefficients significant at probability level 0.05<P<0.20.
explanatory variable in the farm machinery demand with the positive relationships. The significant regional differences from the overall coefficient are found for the Northeast, Northern plains and Appalachian regions. It has to be noted that the regional regression coefficients are the difference between overall coefficient and the regional differences.

To illustrate the broader aspects of regression results from the model, the coefficients and variables for 10 farm production regions in the United States are presented in Table 3. It provides estimates for total farm machinery demand functions in each of the ten farm production regions in the United States. Thus one aggregate regression was used to derive 10 different and complete equations, one for each region.

Elasticities for variables in those equations were calculated at the respective means and are reported in Table 4.

General results obtained in this regional estimation are consistent with the national function. The regional results further indicate that the Appalachian and Northern Plains regions have a lesser response in farm machinery investment with respect to lagged equity ratio. The Appalachian region is generally considered as having a depressed agricultural sector. Areas or sectors suffering from chronic income depression are often characterized by large personal debts. As a consequence, the low equity ratio generally leads to the lower elasticity of farm machinery investment with respect to equity ratio.

Demand for farm motor vehicles: The same types of analyses were performed for the regional demand for farm motor vehicles. The stock adjustment model also was tried unsuccessfully for the regional farm motor
Table 3. Regression coefficients for the regional total farm machinery demand

<table>
<thead>
<tr>
<th>Region</th>
<th>Constant</th>
<th>T</th>
<th>QMt-1</th>
<th>ERt-1</th>
<th>PM/PR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Region</td>
<td>-745.54</td>
<td>14.72</td>
<td>0.867</td>
<td>15.87</td>
<td>-2.56</td>
</tr>
<tr>
<td>North-east Region</td>
<td>-745.54</td>
<td>14.72</td>
<td>0.867</td>
<td>39.91</td>
<td>-2.56</td>
</tr>
<tr>
<td>Lake States Region</td>
<td>-580.87</td>
<td>14.72</td>
<td>0.867</td>
<td>15.87</td>
<td>-2.56</td>
</tr>
<tr>
<td>Corn Belt Region</td>
<td>-423.60</td>
<td>14.72</td>
<td>0.867</td>
<td>15.87</td>
<td>-2.56</td>
</tr>
<tr>
<td>Northern Plains Region</td>
<td>-462.99</td>
<td>14.72</td>
<td>0.867</td>
<td>6.20</td>
<td>-2.56</td>
</tr>
<tr>
<td>Appalachian Region</td>
<td>-579.30</td>
<td>14.72</td>
<td>0.867</td>
<td>6.43</td>
<td>-2.56</td>
</tr>
<tr>
<td>South-east Region</td>
<td>-745.54</td>
<td>14.72</td>
<td>0.867</td>
<td>15.87</td>
<td>-2.56</td>
</tr>
<tr>
<td>Delta States Region</td>
<td>-745.54</td>
<td>14.72</td>
<td>0.177</td>
<td>15.87</td>
<td>-2.56</td>
</tr>
<tr>
<td>So. Plains Region</td>
<td>-745.54</td>
<td>14.72</td>
<td>0.867</td>
<td>15.87</td>
<td>-2.56</td>
</tr>
<tr>
<td>Mountain States Region</td>
<td>-745.54</td>
<td>14.72</td>
<td>0.867</td>
<td>15.87</td>
<td>-2.56</td>
</tr>
</tbody>
</table>

Table 4. Elasticities computed at the means of the variables for total farm machinery demand

<table>
<thead>
<tr>
<th>Names of variables</th>
<th>Notation</th>
<th>Elasticities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time trend</td>
<td>T</td>
<td>2.610</td>
</tr>
<tr>
<td>QMt-1 for Pacific Reg.</td>
<td>QMt-1</td>
<td>0.021</td>
</tr>
<tr>
<td>QMt-1,7 for Delta States Reg.</td>
<td>QMt-1,7</td>
<td>0.006</td>
</tr>
<tr>
<td>ERt-1 for Pacific Reg.</td>
<td>ERt-1</td>
<td>0.015</td>
</tr>
<tr>
<td>ERt-1,2 for N.E. Reg.</td>
<td>ERt-1,2</td>
<td>0.023</td>
</tr>
<tr>
<td>ERt-1,5 for N.P. Reg.</td>
<td>ERt-1,5</td>
<td>0.003</td>
</tr>
<tr>
<td>ERt-1,6 for Appalachian Reg.</td>
<td>ERt-1,6</td>
<td>0.005</td>
</tr>
<tr>
<td>PM/PR for Pacific</td>
<td>PM/PR</td>
<td>-0.727</td>
</tr>
</tbody>
</table>
vehicles demand. High multicollinearity among stock values of motor vehicles, technological index and the time trend were evidenced. Hence, only the results for the expectation model were reported.

All variables of the demand for motor vehicles functions which were found to be statistically significant (see the footnotes for Table 5) were reported in Table 5. The Durbin-Watson statistic indicated that the errors were unautocorrelated in the equation.

The overall coefficients for the one-year-lagged investment, the lagged equity ratio and the lagged ratio of motor vehicles prices to price received by farmers are statistically significant and all have expected signs. For the lagged equity ratio, the regression results indicated that there were significant differences in the coefficients for the Northeast, Corn Belt and Appalachian regions. Regional regression coefficients are the difference between overall coefficients and the regional differences.

To illustrate the broader aspects of regression results from the model, the coefficients and variables for 10 farm production regions in the United States also are presented in Table 6. It provides estimates for farm motor vehicles demand functions in each of the ten farm production regions. Thus, one aggregated regression was used to derive 10 different and complete equations, one for each region.

Elasticities for variables in those equations were calculated at the respective means and are reported in Table 7.

The results obtained in the regional analysis are generally consistent with the national analysis and the general hypotheses except there is an inconsistent sign for the coefficient of lagged equity ratio in the.
Table 5. Regression equation and related statistics for regional farm motor vehicles demand

<table>
<thead>
<tr>
<th>Names of variable and statistics</th>
<th>Notation</th>
<th>Statistics and regression coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall regression 'F' ratio</td>
<td>( F )</td>
<td>238.10</td>
</tr>
<tr>
<td>Coeff. of determination</td>
<td>( R^2 )</td>
<td>0.978</td>
</tr>
<tr>
<td>Durbin-Watson statistics</td>
<td>( d )</td>
<td>2.130**</td>
</tr>
<tr>
<td>Overall intercept</td>
<td>( b_0 )</td>
<td>-140.8</td>
</tr>
<tr>
<td>Diff. in the intercept for Corn Belt</td>
<td>( b_4 )</td>
<td>186.16**</td>
</tr>
<tr>
<td>Overall coeff. for ( OMV_{t-1} )</td>
<td>( OMV_{t-1} )</td>
<td>65.01**</td>
</tr>
<tr>
<td>Overall coeff. for ( ER_{t-1} )</td>
<td>( ER_{t-1} )</td>
<td>5.05*</td>
</tr>
<tr>
<td>Diff. in the coeff. of ( ER_{t-1} ) for North-east Reg.</td>
<td>( ER_{t-1,2} )</td>
<td>14.13*</td>
</tr>
<tr>
<td>Diff. in the coeff. of ( ER_{t-1} ) for Corn Belt Reg.</td>
<td>( ER_{t-1,4} )</td>
<td>-6.24*</td>
</tr>
<tr>
<td>Diff. in the coeff. of ( ER_{t-1} ) for Appalachian Reg.</td>
<td>( ER_{t-1,6} )</td>
<td>-4.82*</td>
</tr>
<tr>
<td>Overall coeff. for ( PMV/PR )</td>
<td>( PMV/PR )</td>
<td>=0.55**</td>
</tr>
</tbody>
</table>

\*\*\* Indicates coefficients significant at probability level \( 0 < p \leq 0.01 \).

\*\* Indicates coefficients significant at probability level \( 0 < p \leq 0.05 \).

\* Indicates coefficients significant at probability level \( 0.05 < p \leq 0.20 \).
Table 6. Regression coefficient for the regional farm motor vehicles demand

<table>
<thead>
<tr>
<th>Region</th>
<th>Constant</th>
<th>$Q_{MV,t-1}$</th>
<th>$E_{R,t-1}$</th>
<th>$P_{MV/P_R}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Region</td>
<td>-140.8</td>
<td>65.01</td>
<td>5.05</td>
<td>-0.55</td>
</tr>
<tr>
<td>North-east Region</td>
<td>-140.8</td>
<td>65.01</td>
<td>19.18</td>
<td>-0.55</td>
</tr>
<tr>
<td>Lake States Region</td>
<td>-140.8</td>
<td>65.01</td>
<td>5.05</td>
<td>-0.55</td>
</tr>
<tr>
<td>Corn Belt Region</td>
<td>45.36</td>
<td>65.01</td>
<td>-1.19</td>
<td>-0.55</td>
</tr>
<tr>
<td>Northern Plains Region</td>
<td>-140.8</td>
<td>65.01</td>
<td>5.05</td>
<td>-0.55</td>
</tr>
<tr>
<td>Appalachian Region</td>
<td>-140.8</td>
<td>65.01</td>
<td>0.23</td>
<td>-0.55</td>
</tr>
<tr>
<td>South-east Region</td>
<td>-140.8</td>
<td>65.01</td>
<td>5.05</td>
<td>-0.55</td>
</tr>
<tr>
<td>Delta States Region</td>
<td>-140.8</td>
<td>65.01</td>
<td>5.05</td>
<td>-0.55</td>
</tr>
<tr>
<td>Southern Plains Region</td>
<td>-140.8</td>
<td>65.01</td>
<td>5.05</td>
<td>-0.55</td>
</tr>
<tr>
<td>Mountain States Region</td>
<td>-140.8</td>
<td>65.01</td>
<td>5.05</td>
<td>-0.55</td>
</tr>
</tbody>
</table>

Table 7. Elasticities computed at the means of the variables for farm motor vehicles demand

<table>
<thead>
<tr>
<th>Names of variables</th>
<th>Notation</th>
<th>Elasticities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of machine prices to prices received by farmers</td>
<td>$P_{MV/P_R}$</td>
<td>-0.294</td>
</tr>
<tr>
<td>Lagged equity ratio for Pacific Reg.</td>
<td>$E_{R,t-1}$</td>
<td>0.055</td>
</tr>
<tr>
<td>Lagged equity ratio for North-east Reg.</td>
<td>$E_{R,t-1,2}$</td>
<td>0.110</td>
</tr>
<tr>
<td>Lagged equity ratio for Corn Belt Reg.</td>
<td>$E_{R,t-1,4}$</td>
<td>-0.003</td>
</tr>
<tr>
<td>Lagged equity ratio for Appalachian Reg.</td>
<td>$E_{R,t-1,6}$</td>
<td>0.002</td>
</tr>
<tr>
<td>Lagged investment</td>
<td>$Q_{MV,t-1}$</td>
<td>6.220</td>
</tr>
</tbody>
</table>
Corn Belt. The high coefficient value for the lagged farm machinery investment suggests that if there were no high multicollinearity among stock value of motor vehicles, technological index and the time trend, the stock variable instead of the lagged investment variable would yield statistically and economically more meaningful results in the analysis.

Regional farm buildings investment: The regression results reported in Table 8 included all variables of the demand for farm building function which proved statistically significant (see the footnotes for Table 8). The Durbin-Watson statistic also indicated that the errors were not autocorrelated in the equation.

The overall coefficient for weighted net farm income (one year lagged) is positive and is significant at the 1 percent probability level. The regional coefficients of income variable in other regions (except the Mountain region) indicate slightly different responses from the overall income effect.

The overall coefficient for the equity ratio (one year lagged) is not significant. All regions, except the Pacific region, have significant positive coefficients for the lagged equity ratio. These results are evidence that the equity ratio as a basis for making long-term investment does have a strong effect on building demand.

The effects of a higher equity ratio on farm building investments will likely enable farmers to couple with the other forces of change; for example the increase in gross physical production, than as the direct motivating force.
Table 8. Regression equation and related statistics for regional farm buildings demand

<table>
<thead>
<tr>
<th>Names of variables and statistics</th>
<th>Notation</th>
<th>Statistics and regression coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall regression ( F ) ratio</td>
<td>( F )</td>
<td>601.51 ( )</td>
</tr>
<tr>
<td>Coefficient of determination</td>
<td>( R^2 )</td>
<td>0.992 ( )</td>
</tr>
<tr>
<td>Durbin-Watson statistic</td>
<td>( d )</td>
<td>1.870**</td>
</tr>
<tr>
<td>Overall intercept</td>
<td>( b )</td>
<td>463.91 (9.22)**</td>
</tr>
<tr>
<td>Diff. in the intercept for Corn State Reg.</td>
<td>( b_3 )</td>
<td>-42.12 (-1.59)*</td>
</tr>
<tr>
<td>Diff. in the intercept for Appalachian Reg.</td>
<td>( b_5 )</td>
<td>-70.65 (-3.29)**</td>
</tr>
<tr>
<td>Overall time trend</td>
<td>( T )</td>
<td>-4.09 (-4.58)**</td>
</tr>
<tr>
<td>Price of farm building materials</td>
<td>( P_B )</td>
<td>-1.49 (-2.38)**</td>
</tr>
<tr>
<td>Stock value of farm buildings</td>
<td>( S_B )</td>
<td>0.00128 (2.09)**</td>
</tr>
<tr>
<td>Overall coeff. for ( Y_{WFt-1} )</td>
<td>( Y_{WFt-1} )</td>
<td>0.105 (4.82)**</td>
</tr>
<tr>
<td>Diff. in the coeff. of ( Y_{WFt-1} ) for North-east Reg.</td>
<td>( Y_{WFt-1,2} )</td>
<td>-0.100 (-3.24)**</td>
</tr>
<tr>
<td>Diff. in the coeff. of ( Y_{WFt-1} ) for Lake States Reg.</td>
<td>( Y_{WFt-1,3} )</td>
<td>-0.089 (-3.92)**</td>
</tr>
<tr>
<td>Diff. in the coeff. of ( Y_{WFt-1} ) for Corn Belt Reg.</td>
<td>( Y_{WFt-1,4} )</td>
<td>-0.040 (-1.85)*</td>
</tr>
<tr>
<td>Diff. in the coeff. of ( Y_{WFt-1} ) for Northern Plains Reg.</td>
<td>( Y_{WFt-1,5} )</td>
<td>-0.074 (-3.98)**</td>
</tr>
<tr>
<td>Diff. in the coeff. of ( Y_{WFt-1} ) for Appalachian Reg.</td>
<td>( Y_{WFt-1,6} )</td>
<td>-0.074 (-3.92)**</td>
</tr>
<tr>
<td>Diff. in the coeff. of ( Y_{WFt-1} ) for South-east Reg.</td>
<td>( Y_{WFt-1,7} )</td>
<td>-0.103 (-3.92)**</td>
</tr>
<tr>
<td>Diff. in the coeff. of ( Y_{WFt-1} ) for Delta State Reg.</td>
<td>( Y_{WFt-1,8} )</td>
<td>-0.142 (-4.57)**</td>
</tr>
<tr>
<td>Diff. in the coeff. of ( Y_{WFt-1} ) for Southern Plains Reg.</td>
<td>( Y_{WFt-1,9} )</td>
<td>-0.0680 (-2.74)**</td>
</tr>
<tr>
<td>Coeff. of ( ER_{t-1} ) for North-east Reg.</td>
<td>( ER_{t-1,2} )</td>
<td>11.31 (1.61)*</td>
</tr>
<tr>
<td>Coeff. of ( ER_{t-1} ) for Lake States Reg.</td>
<td>( ER_{t-1,3} )</td>
<td>7.56 (1.90)*</td>
</tr>
<tr>
<td>Coeff. of ( ER_{t-1} ) for Corn Belt Reg.</td>
<td>( ER_{t-1,4} )</td>
<td>9.53 (2.84)**</td>
</tr>
<tr>
<td>Coeff. of ( ER_{t-1} ) for Northern Plains Reg.</td>
<td>( ER_{t-1,5} )</td>
<td>12.05 (3.77)**</td>
</tr>
<tr>
<td>Coeff. of ( ER_{t-1} ) for Appalachian Reg.</td>
<td>( ER_{t-1,6} )</td>
<td>11.43 (3.55)**</td>
</tr>
</tbody>
</table>

*a*Please see footnotes under Table 5 for explanation of asterisks.
Table 8. (Continued)

<table>
<thead>
<tr>
<th>Names of variables and statistics</th>
<th>Notation</th>
<th>Statistics and regression coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coeff. of ER&lt;sub&gt;t-1&lt;/sub&gt; for Southeast Reg.</td>
<td>ER&lt;sub&gt;t-1,7&lt;/sub&gt;</td>
<td>6.72 (2.05)**</td>
</tr>
<tr>
<td>Coeff. of ER&lt;sub&gt;t-1&lt;/sub&gt; for Delta State Reg.</td>
<td>ER&lt;sub&gt;t-1,8&lt;/sub&gt;</td>
<td>7.61 (2.31)**</td>
</tr>
<tr>
<td>Coeff. of ER&lt;sub&gt;t-1&lt;/sub&gt; for Southern Plains Reg.</td>
<td>ER&lt;sub&gt;t-1,9&lt;/sub&gt;</td>
<td>8.88 (2.61)**</td>
</tr>
<tr>
<td>Coeff. of ER&lt;sub&gt;t-1&lt;/sub&gt; for Mountain Reg.</td>
<td>ER&lt;sub&gt;t-1,10&lt;/sub&gt;</td>
<td>5.53 (1.19)*</td>
</tr>
</tbody>
</table>

The time trend and price of farm building materials proved to be significant and negative in the equation. The stock value of farm buildings also was significant in explaining the annual gross investment of farm buildings. The magnitudes of adjustment coefficients could not be computed because the regional depreciation rates of farm buildings were not available.

To illustrate the broader aspects of regression results from the model, the coefficients and variables for 10 farm production regions in the United States are presented in Table 9. It provides estimates for farm building demand functions in each of the ten farm production regions. Thus, one aggregate regression equation was used to derive 10 different and complete equations, one for each region.

Elasticities for variables in those equations were calculated at the respective means and are reported in Table 10.

In the farm buildings investment demand functions, the most significant
Table 9. Regression coefficients for the regional buildings investment

<table>
<thead>
<tr>
<th>Region</th>
<th>Constant</th>
<th>$Y_{WFr-t-1}$</th>
<th>$P_B$</th>
<th>$T$</th>
<th>$S_B$</th>
<th>$ER_{t-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Reg.</td>
<td>463.91</td>
<td>0.105</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>--</td>
</tr>
<tr>
<td>North-east Reg.</td>
<td>463.91</td>
<td>0.005</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>11.31</td>
</tr>
<tr>
<td>Lake States Reg.</td>
<td>463.91</td>
<td>0.016</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>7.56</td>
</tr>
<tr>
<td>Corn Belt Reg.</td>
<td>421.79</td>
<td>0.065</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>9.53</td>
</tr>
<tr>
<td>Northern Plains Reg.</td>
<td>463.91</td>
<td>0.016</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>12.05</td>
</tr>
<tr>
<td>Appalachian Reg.</td>
<td>383.26</td>
<td>0.031</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>11.43</td>
</tr>
<tr>
<td>Southeast Reg.</td>
<td>463.91</td>
<td>0.002</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>6.72</td>
</tr>
<tr>
<td>Delta States Reg.</td>
<td>463.91</td>
<td>-0.037</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>7.61</td>
</tr>
<tr>
<td>Southern Plains</td>
<td>463.91</td>
<td>0.037</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>8.88</td>
</tr>
<tr>
<td>Mountain States Reg.</td>
<td>463.91</td>
<td>0.105</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>5.53</td>
</tr>
</tbody>
</table>
Table 10. Elasticities computed at the means of the variables for farm buildings investment

<table>
<thead>
<tr>
<th>Names of variables</th>
<th>Notation</th>
<th>Elasticities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price of farm building materials</td>
<td>$P_B$</td>
<td>1.37</td>
</tr>
<tr>
<td>Stock values of farm building</td>
<td>$S_B$</td>
<td>0.32</td>
</tr>
<tr>
<td>Lagged weighted income</td>
<td>$Y_{WFt-1}$</td>
<td>0.146</td>
</tr>
<tr>
<td>$Y_{WFt-1}$ for North-east Reg.</td>
<td>$Y_{WFt-1,2}$</td>
<td>0.00485</td>
</tr>
<tr>
<td>$Y_{WFt-1}$ for Lake States Reg.</td>
<td>$Y_{WFt-1,3}$</td>
<td>0.0244</td>
</tr>
<tr>
<td>$Y_{WFt-1}$ for Corn Belt Reg.</td>
<td>$Y_{WFt-1,4}$</td>
<td>0.0837</td>
</tr>
<tr>
<td>$Y_{WFt-1}$ for Northern Plains Reg.</td>
<td>$Y_{WFt-1,5}$</td>
<td>0.01996</td>
</tr>
<tr>
<td>$Y_{WFt-1}$ for Appalachian Reg.</td>
<td>$Y_{WFt-1,6}$</td>
<td>0.058</td>
</tr>
<tr>
<td>$Y_{WFt-1}$ for South-east Reg.</td>
<td>$Y_{WFt-1,7}$</td>
<td>0.0034</td>
</tr>
<tr>
<td>$Y_{WFt-1}$ for Delta States Reg.</td>
<td>$Y_{WFt-1,8}$</td>
<td>0.074</td>
</tr>
<tr>
<td>$Y_{WFt-1}$ for Southern Plains Reg.</td>
<td>$Y_{WFt-1,9}$</td>
<td>0.046</td>
</tr>
<tr>
<td>$Y_{WFt-1}$ for Mountain States Reg.</td>
<td>$Y_{WFt-1,10}$</td>
<td>0.114</td>
</tr>
<tr>
<td>Time trend</td>
<td>$T$</td>
<td>2.16</td>
</tr>
<tr>
<td>Lagged equity ratio for North-east</td>
<td>$ER_{t-1,2}$</td>
<td>0.097</td>
</tr>
<tr>
<td>Lagged equity ratio for Lake States</td>
<td>$ER_{t-1,3}$</td>
<td>0.071</td>
</tr>
<tr>
<td>Lagged equity ratio for Corn Belt</td>
<td>$ER_{t-1,4}$</td>
<td>0.048</td>
</tr>
<tr>
<td>Lagged equity ratio for Northern Plains</td>
<td>$ER_{t-1,5}$</td>
<td>0.159</td>
</tr>
<tr>
<td>Lagged equity ratio for Appalachian</td>
<td>$ER_{t-1,6}$</td>
<td>0.184</td>
</tr>
<tr>
<td>Lagged equity ratio for South-east</td>
<td>$ER_{t-1,7}$</td>
<td>0.1398</td>
</tr>
<tr>
<td>Lagged equity ratio for Delta States</td>
<td>$ER_{t-1,8}$</td>
<td>0.187</td>
</tr>
<tr>
<td>Lagged equity ratio for Southern Plains</td>
<td>$ER_{t-1,9}$</td>
<td>0.111</td>
</tr>
<tr>
<td>Lagged equity ratio for Mountain States</td>
<td>$ER_{t-1,10}$</td>
<td>0.080</td>
</tr>
</tbody>
</table>
variables included the weighted net farm income, equity ratio, time trend, price for building materials and stock value of farm buildings. As expected, regional differences in the farmers' responses with respect to the same set of variables for the farm buildings investment were not significant.

Regional demand for total farm labor: The regression results reported in Table 11 included all variables of the demand for total farm labor function which were found to be statistically significant (see the footnotes for Table 11). The Durbin-Watson statistic indicated that the errors were not autocorrelated in the equation.

The overall coefficient for the technological change index was negative and was significant at 1 percent probability level. The regional differences of the same variable also were significant but with a positive sign. However, the regional regression coefficients, which were the differences between overall and the regional difference, had consistent negative signs.

The weighted net farm income, lagged one year, was tried as an explanatory variable but proved to be nonsignificant. The lagged ratio of composite farm wage rate to total value of building and land per acre were negative and significant for the Northern Plains and Appalachian regions. An inconsistent sign for the Mountain region was found. The positive relations for the lagged ratio of machinery prices to farm labor wages were found for the Northeast and Lake States regions in contrast with the inconsistent sign found for the Southeast region.
Table 11. Regression equation and related statistics for regional total farm labor demand^a

<table>
<thead>
<tr>
<th>Names of variables and statistics</th>
<th>Notation</th>
<th>Statistics and regression coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall regression 'F' ratio</td>
<td>F</td>
<td>1602.06</td>
</tr>
<tr>
<td>Coefficient of determination</td>
<td>R²</td>
<td>0.998</td>
</tr>
<tr>
<td>Durbin-Watson statistics</td>
<td>d</td>
<td>1.58**</td>
</tr>
<tr>
<td>Overall intercept</td>
<td>b₀</td>
<td>3371.98</td>
</tr>
<tr>
<td>Diff. in the intercept for North-east Reg.</td>
<td>b₂</td>
<td>-2186.79***</td>
</tr>
<tr>
<td>Diff. in the intercept for Lake States Reg.</td>
<td>b₃</td>
<td>-1764.42**</td>
</tr>
<tr>
<td>Diff. in the intercept for Corn Belt Reg.</td>
<td>b₄</td>
<td>-1091.34*</td>
</tr>
<tr>
<td>Diff. in the intercept for Northern Plains Reg.</td>
<td>b₅</td>
<td>-1590.38*</td>
</tr>
<tr>
<td>Diff. in the intercept for Appalachian Reg.</td>
<td>b₆</td>
<td>-899.48*</td>
</tr>
<tr>
<td>Diff. in the intercept for South-east Reg.</td>
<td>b₇</td>
<td>-949.52*</td>
</tr>
<tr>
<td>Diff. in the intercept for Delta States Reg.</td>
<td>b₈</td>
<td>-2119.45***</td>
</tr>
<tr>
<td>Diff. in the intercept for Southern Plains Reg.</td>
<td>b₉</td>
<td>-1699.32**</td>
</tr>
<tr>
<td>Diff. in the intercept for Mountain Reg.</td>
<td>b₁₀</td>
<td>-941.08*</td>
</tr>
<tr>
<td>Overall coeff. of A(t)</td>
<td>A(t)₂</td>
<td>15.75</td>
</tr>
<tr>
<td>Diff. in the coeff. of A(t) for Northeast Reg.</td>
<td>A(t)₃</td>
<td>15.40</td>
</tr>
<tr>
<td>Diff. in the coeff. of A(t) for Lake States Reg.</td>
<td>A(t)₄</td>
<td>13.00</td>
</tr>
<tr>
<td>Diff. in the coeff. of A(t) for Corn Belt Reg.</td>
<td>A(t)₅</td>
<td>16.45</td>
</tr>
<tr>
<td>Diff. in the coeff. of A(t) for Northern Plains Reg.</td>
<td>A(t)₆</td>
<td>12.96</td>
</tr>
<tr>
<td>Diff. in the coeff. of A(t) for Appalachian Reg.</td>
<td>A(t)₇</td>
<td>5.00</td>
</tr>
<tr>
<td>Diff. in the coeff. of A(t) for South-east Reg.</td>
<td>A(t)₈</td>
<td>15.70</td>
</tr>
<tr>
<td>Diff. in the coeff. of A(t) for Delta States Reg.</td>
<td></td>
<td>(2.66)***</td>
</tr>
</tbody>
</table>

^aPlease see footnote under Table 5 for explanations of asterisks.
Table 11. (Continued)

<table>
<thead>
<tr>
<th>Names of variables and statistics</th>
<th>Notation</th>
<th>Statistics and regression coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diff. in the coeff. of A(t) for Southern Plains Reg.</td>
<td>A(t)9</td>
<td>15.71 (2.66)***</td>
</tr>
<tr>
<td>Diff. in the coeff. of A(t) for Mountain Reg.</td>
<td>A(t)10</td>
<td>1.56 (2.62)***</td>
</tr>
<tr>
<td>Coeff. of (P TL/TVBLA) for Northern Plains Reg.</td>
<td>(P TL/TVBLA)</td>
<td>-4.01 (-1.53)*</td>
</tr>
<tr>
<td>Coeff. of (P TL/TVBLA) for Appalachian Reg.</td>
<td>(P TL/TVBLA)</td>
<td>3.25 (1.29)*</td>
</tr>
<tr>
<td>Coeff. of (P TL/TVBLA) for Mountain Reg.</td>
<td>(P TL/TVBLA)</td>
<td>-5.30 (-2.27)**</td>
</tr>
<tr>
<td>Overall coeff. for P NLt</td>
<td>P NL</td>
<td>-9.22 (-3.67)***</td>
</tr>
<tr>
<td>Overall coeff. for IMP t-1</td>
<td>IMP t-1</td>
<td>-1.85 (-2.96)***</td>
</tr>
<tr>
<td>Coeff. of (P M/P TL) for Northeast Reg.</td>
<td>(P M/P TL)t-1,2</td>
<td>5.26 (1.49)*</td>
</tr>
<tr>
<td>Coeff. of (P M/P TL) for Lake States Reg.</td>
<td>(P M/P TL)t-1,3</td>
<td>6.03 (1.69)*</td>
</tr>
<tr>
<td>Coeff. of (P M/P TL) for Southeast Reg.</td>
<td>(P M/P TL)t-1,7</td>
<td>-4.43 (-1.43)*</td>
</tr>
</tbody>
</table>

The overall coefficients for non-farm wage rates and lagged index of mechanical power were found to be significant and with consistent negative signs in explaining the demand for total farm labor.

To illustrate the broader aspects of regression results from the model, the coefficients and variables for 10 farm production regions in the United States are presented in Table 12. It provides estimates for total farm labor demand functions in each of the 10 farm production regions. Thus, one aggregate equation was used to derive 10 different and complete equations, one for each region.

Elasticities for variables in those equations were calculated at the respective means and are reported in Table 13.
Table 12. Regression coefficients for the regional total farm labor demand

<table>
<thead>
<tr>
<th>Region</th>
<th>Constant</th>
<th>$A(t)$</th>
<th>$(PTL/TVBLA)_{t-1}$</th>
<th>$P_{NL}$</th>
<th>$IMP_{t-1} (PM/PTL)_{t-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Reg.</td>
<td>3371.98</td>
<td>-15.56</td>
<td>-9.22</td>
<td>-1.85</td>
<td></td>
</tr>
<tr>
<td>North-east Reg.</td>
<td>1185.19</td>
<td>0.19</td>
<td>-9.22</td>
<td>-1.85</td>
<td>5.26</td>
</tr>
<tr>
<td>Lake States Reg.</td>
<td>1507.56</td>
<td>-0.16</td>
<td>-9.22</td>
<td>-1.85</td>
<td>6.03</td>
</tr>
<tr>
<td>Corn Belt Reg.</td>
<td>2280.64</td>
<td>-2.56</td>
<td>-9.22</td>
<td>-1.85</td>
<td></td>
</tr>
<tr>
<td>Northern Plains Reg.</td>
<td>1781.60</td>
<td>0.89</td>
<td>-4.01</td>
<td>-9.22</td>
<td>-1.85</td>
</tr>
<tr>
<td>Appalachian Reg.</td>
<td>2472.50</td>
<td>-2.60</td>
<td>3.25</td>
<td>-9.22</td>
<td>-1.85</td>
</tr>
<tr>
<td>South-east Reg.</td>
<td>2322.46</td>
<td>-10.56</td>
<td>-9.22</td>
<td>-1.85</td>
<td>-4.43</td>
</tr>
<tr>
<td>Delta States Reg.</td>
<td>1252.53</td>
<td>0.14</td>
<td>-9.22</td>
<td>-1.85</td>
<td></td>
</tr>
<tr>
<td>Southern Plains Reg.</td>
<td>1672.66</td>
<td>0.15</td>
<td>-9.22</td>
<td>-1.85</td>
<td></td>
</tr>
<tr>
<td>Mountain States</td>
<td>2430.90</td>
<td>-13.99</td>
<td>-5.30</td>
<td>-9.22</td>
<td>-1.85</td>
</tr>
</tbody>
</table>

In the regional demand for total labor functions, the most significant variables included the technological index, non-farm wage rate, lagged index of mechanical power on farm, lagged ratio of composite farm wage rate to total value of land and buildings per acre and lagged ratio of machinery prices to farm labor wages.

The results for the 10 farm production regions show a close similarity to the national results. Therefore, the general effects of each set of independent variables need not be repeated again. However, the regional analysis revealed that technological advancement has exerted differing
Table 13. Elasticities computed at the means of the variable for total farm labor demand

<table>
<thead>
<tr>
<th>Names of variables</th>
<th>Notation</th>
<th>Elasticities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technological rate for Pacific Reg.</td>
<td>A(t)</td>
<td>-0.180</td>
</tr>
<tr>
<td>Technological rate for North-east Reg.</td>
<td>A(t)₂</td>
<td>0.273</td>
</tr>
<tr>
<td>Technological rate for Lake States Reg.</td>
<td>A(t)₃</td>
<td>-0.002</td>
</tr>
<tr>
<td>Technological rate for Corn Belt Reg.</td>
<td>A(t)₄</td>
<td>-0.017</td>
</tr>
<tr>
<td>Technological rate for Northern Plains Reg.</td>
<td>A(t)₅</td>
<td>0.014</td>
</tr>
<tr>
<td>Technological rate for Appalachian Reg.</td>
<td>A(t)₆</td>
<td>-0.010</td>
</tr>
<tr>
<td>Technological rate for Southeast Reg.</td>
<td>A(t)₇</td>
<td>-0.105</td>
</tr>
<tr>
<td>Technological rate for Delta States Reg.</td>
<td>A(t)₈</td>
<td>0.002</td>
</tr>
<tr>
<td>Technological rate for Southern Plains Reg.</td>
<td>A(t)₉</td>
<td>0.002</td>
</tr>
<tr>
<td>Technological rate for Mountain Reg.</td>
<td>A(t)₁₀</td>
<td>-0.367</td>
</tr>
<tr>
<td>(P_{TL}/TVBLA) for Northern Plains Reg.</td>
<td>(P_{TL}/TVBLA)</td>
<td>-0.076</td>
</tr>
<tr>
<td>(P_{TL}/TVBLA) for Appalachian Reg.</td>
<td>(P_{TL}/TVBLA)</td>
<td>0.024</td>
</tr>
<tr>
<td>(P_{TL}/TVBLA) for Mountain States Reg.</td>
<td>(P_{TL}/TVBLA)</td>
<td>-0.152</td>
</tr>
<tr>
<td>Nonfarm wage rate</td>
<td>P_{NL}</td>
<td>-1.057</td>
</tr>
<tr>
<td>Lagged index of mech. power</td>
<td>IMP_{t-1}</td>
<td>-0.201</td>
</tr>
<tr>
<td>(P_M/P_{TL}) for North-east Reg.</td>
<td>(P_M/P_{TL})_{t-1,2}</td>
<td>0.067</td>
</tr>
<tr>
<td>(P_M/P_{TL}) for Lake State Reg.</td>
<td>(P_M/P_{TL})_{t-1,3}</td>
<td>0.042</td>
</tr>
<tr>
<td>(P_M/P_{TL}) for South-east Reg.</td>
<td>(P_M/P_{TL})_{t-1,7}</td>
<td>-0.052</td>
</tr>
</tbody>
</table>
effects in reducing the total farm labor demand in the various regions. In those areas such as the Pacific, Southeast and Mountain regions where the agriculture sector was depressed, the effects were more evident than in other regions.

Regional demand for hired farm labor: The same types of analyses were performed for the regional demand function for hired farm labor as for the total farm labor. However, most of the coefficients were insignificant due to the fact that there was high multicollinearity among the technological index, time trend and lagged ratio of farm wage rates to the value of land and building per acre. Consequently the original regional model (which was proposed in the last chapter) for the hired farm labor was revised as follows:

\[
D_{HLt} = b_0 + \sum_{i=1}^{m-1} b_i P_{Ni} + d Y_{Ft-1} + \sum_{i=1}^{m-1} e Y_{Ft-1,i} + f(P_M/P_{TL})_{t-1} + \sum_{i=1}^{m-1} g(P_M/P_{TL})_{t-1,i} + \epsilon_t
\]

All variables are as described in the previous chapter. All variables of the demand for hired farm labor function which proved statistically significant are reported in Table 14.

To illustrate the broader aspects of regression results from the model, the coefficients and variables for 10 farm production regions in the United States also are presented in Table 15. It provides estimates for the demand of hired farm labor functions in each of the 10 farm production regions. Thus, the one aggregate equation was used to derive 10 different and complete equations, one for each region.
### Table 15. Regression coefficients for the regional hired farm labor demand

<table>
<thead>
<tr>
<th>Region</th>
<th>Constant</th>
<th>$P_{NL}$</th>
<th>$Y_{Ft-1}$</th>
<th>$(P_M/P_{TL})_{t-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Reg.</td>
<td>407.04</td>
<td>-1.22</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>North-east Reg.</td>
<td>407.04</td>
<td>-1.22</td>
<td>-2.01</td>
<td>-</td>
</tr>
<tr>
<td>Lake States Reg.</td>
<td>211.30</td>
<td>-1.22</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Corn Belt Reg.</td>
<td>407.04</td>
<td>-1.22</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Northern Plains Reg.</td>
<td>152.53</td>
<td>-1.22</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Appalachian Reg.</td>
<td>407.04</td>
<td>-1.22</td>
<td>3.55</td>
<td>1.78</td>
</tr>
<tr>
<td>South-east Reg.</td>
<td>204.15</td>
<td>-1.22</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Delta States Reg.</td>
<td>204.04</td>
<td>-1.22</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Southern Plains Reg.</td>
<td>204.04</td>
<td>-1.22</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mountain States Reg.</td>
<td>204.04</td>
<td>-1.22</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Table 16. Elasticities computed at the means of the variables for hired farm labor demand

<table>
<thead>
<tr>
<th>Names of variables</th>
<th>Notation</th>
<th>Elasticities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged ratio of machine prices to farm labor wage for Appalachian Reg.</td>
<td>$(P_M/P_{TL})_{t-1}$</td>
<td>0.082</td>
</tr>
<tr>
<td>Overall nonfarm wage rate</td>
<td>$P_{NL}$</td>
<td>-0.077</td>
</tr>
<tr>
<td>Coeff. of $Y_{Ft-1}$ for North-east Reg.</td>
<td>$Y_{Ft-1}$</td>
<td>-0.081</td>
</tr>
<tr>
<td>Coeff. of $Y_{Ft-1}$ for Appalachian Reg.</td>
<td>$Y_{Ft-1}$</td>
<td>0.110</td>
</tr>
</tbody>
</table>
tivities in the demand for hired labor with respect to weighted net farm income and the ratio of farm machinery prices to farm labor wages than other regions. The Appalachian region has a depressed agriculture sector. Farm laborers are more sensitive in comparing the farm wage rates and the non-farm wage rates. Farmers also are more sensitive in comparing the farm wage rates to machinery prices. Net farm income relative to non-farm income could be one of the many yardsticks for farm operators and farm laborers to check their future in farming.
VI. THE COMPUTER SIMULATION MODEL OF THE DEMAND FOR FACTORS (NATIONAL MODEL)

A. Simulation of Factors Demand Under the Existing Economic Structure

1. Simulation of the historical period and model validation

In this study, a computer simulation model is used for explanatory or positive analysis. The primary concern here is to explain how the structure of the demand for factors in agriculture behaves. Conclusions or predictions implied by data generated by this model must be subjected to direct empirical observation for either verification or refutation. Verification lends support to the model as a whole. It implies that the underlying assumptions in the model are adequate to explain the behavior of the actual system.

Koopmans (74, p. 134) has suggested historical and forecasting verification as two alternative approaches for testing the degree to which data generated by computer simulation models conform to observed data. Further, among several approaches to historical verification, Clarkson (12, p. 34) has suggested one of the most difficult and rigorous methods. The model as a whole, as he suggested, can be subjected to statistical tests by matching the time-series of the variables under consideration. In this way a measure of 'goodness of fit' can be obtained and the model as a whole can be confirmed on its ability to predict the time series.

Of course, no model is expected to fit the data exactly; the question is whether the residual errors are sufficiently small to be tolerable and sufficiently unsystematic to be treated as random.
Concerning the goodness of fit in attempting to fit data generated by computer simulation experiments to actual time series data, Cohen and Cyert (16) have suggested three general testing procedures. One of the procedures suggested by them is to regress the generated time-series on actual time-series data, and then proceed to check whether the resulting equations have intercepts which are not significantly different from zero and slopes which are not significantly different from unity.

In this study, the behavioral and definitional relations developed in the previous chapters for national models were rewritten in computer language. Given the time-series data for the exogenous variables and the lagged endogenous variable at the beginning of the time period (1924), the endogenous variables for the entire historical period (1924-1965) were then automatically generated by the recursive model without any additional constraints. The generated time-series data were, then regressed on the respective actual time-series. The results are presented as follows: Where all variables were defined in Chapter V:

\[
\begin{align*}
\hat{S}_{Pt} &= 6.03 + 0.95 S_{Pt} \quad R^2 = 0.93 \\
\hat{Q}_{t1}^2 &= 0.66 + 0.99 Q_{t1}^2 \quad R^2 = 0.99 \\
\hat{Q}_{t2}^2 &= 1.82 + 0.97 Q_{t2}^2 \quad R^2 = 0.97 \\
\hat{P}_{Rt} &= 17.50 + 0.84 P_{Rt} \quad R^2 = 0.95 \\
(P_{R}/P_{P})_t &= 18.31 + 0.83 (P_{R}/P_{P})_t \quad R^2 = 0.94 \\
(Y_{Pt})_t &= 2903.72 + 0.70 Y_{Pt} \quad R^2 = 0.75 \\
\hat{P}_{Mt} &= 19.62 + 0.79 P_{Mt} \quad R^2 = 0.75
\end{align*}
\]
\[ \hat{Q}_{Mt} = 167.23 + 0.95 Q_{Mt} \quad R^2 = 0.93 \]
\[ \hat{X}_R = 5.53 + 0.94 X_{Rt} \quad R^2 = 0.94 \]
\[ \hat{(P_M/P_R)_t} = 14.69 + 0.82 (P_M/P_R)_t \quad R^2 = 0.91 \]
\[ \hat{Q}_{MEl} = 132.71 + 0.95 Q_{MEl} \quad R^2 = 0.95 \]
\[ \hat{Q}_{TLt} = 236.16 + 0.96 Q_{TLt} \quad R^2 = 0.96 \]
\[ \hat{P}_{TLt} = 2.48 + 0.97 P_{TLt} \quad R^2 = 0.96 \]
\[ \hat{(P_{TL}/TVLAB)_t} = 2.07 + 0.98 (P_{TL}/TVLAB)_t \quad R^2 = 0.95 \]
\[ \hat{Q}_{HLt} = -13.18 + Q_{HLt} \quad R^2 = 0.98 \]
\[ \hat{Q}_{FLt} = 234.39 + 0.95 Q_{FLt} \quad R^2 = 0.95 \]
\[ \hat{Y}_{WFT} = 2908.36 + 0.71 Y_{WFT} \quad R^2 = 0.77 \]
\[ \hat{Q}_{BIt} = 28.23 + 0.96 Q_{BIt} \quad R^2 = 0.97 \]
\[ \hat{Q}_{MIt} = 70.74 + 0.91 Q_{MIt} \quad R^2 = 0.89 \]
\[ \hat{(P_M/P_{TL})_t} = 7.07 + 0.91 (P_M/P_{TL})_t \quad R^2 = 0.89 \]

Out of the twenty variables which were tested, the coefficient of the
determinant ranges from 0.75 to 0.99. The intercepts vary from 0.66 to
2908 and depend on the different units of measurement for each variable,
and the slopes vary from 0.70 to 0.99 quite close to unity. The production
response function has the best fit, whereas the definitional net farm in-
come function has the least.

The actual and predicted time-series of the quantities demanded for
five kinds of resources are presented on Figures 3 to Figure 9. As can
be visualized from these figures, the height and turning point are reason-
ably well predicted.
Figure 3. Actual and predicted values of total farm machinery purchases for the United States.
Table 8. Regression equation and related statistics for regional farm buildings demand

<table>
<thead>
<tr>
<th>Names of variables and statistics</th>
<th>Notation</th>
<th>Statistics and regression coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall regression 'F' ratio</td>
<td>$F$</td>
<td>601.51</td>
</tr>
<tr>
<td>Coefficient of determination</td>
<td>$R^2$</td>
<td>0.992</td>
</tr>
<tr>
<td>Durbin-Watson statistic</td>
<td>$d$</td>
<td>1.870**</td>
</tr>
<tr>
<td>Overall intercept</td>
<td>$b$</td>
<td>463.91</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(9.22)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-42.12)***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-1.59)*</td>
</tr>
<tr>
<td>Diff. in the intercept for Corn State Reg.</td>
<td>$b_3$</td>
<td>-42.12</td>
</tr>
<tr>
<td>Diff. in the intercept for Appalachian Reg.</td>
<td>$b_5$</td>
<td>-70.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-3.29)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-4.09)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-4.58)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-1.49)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-2.38)**</td>
</tr>
<tr>
<td>Price of farm building materials</td>
<td>$P_B$</td>
<td>0.00128</td>
</tr>
<tr>
<td>Stock value of farm buildings</td>
<td>$S_B$</td>
<td>(2.09)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.00128)</td>
</tr>
<tr>
<td>Overall coeff. for $Y_{WFt-1}$</td>
<td>$Y_{WFt-1}$</td>
<td>1.105</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.82)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.100)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-3.24)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.89)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-3.92)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.040)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-1.85)*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.89)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-3.98)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.074)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-3.20)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.103)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-3.92)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.142)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-4.57)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.068)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-2.74)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.61)*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.90)*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.84)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.77)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.55)**</td>
</tr>
</tbody>
</table>

*Please see footnotes under Table 5 for explanation of asterisks.*
Table 8. (Continued)

<table>
<thead>
<tr>
<th>Names of variables and statistics</th>
<th>Statistics and regression coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coeff. of ( E_{R_t-1} ) for Southeast Reg.</td>
<td>( E_{R_t-1,7} ) 6.72 (2.05)**</td>
</tr>
<tr>
<td>Coeff. of ( E_{R_t-1} ) for Delta State Reg.</td>
<td>( E_{R_t-1,8} ) 7.61 (2.31)**</td>
</tr>
<tr>
<td>Coeff. of ( E_{R_t-1} ) for Southern Plains Reg.</td>
<td>( E_{R_t-1,9} ) 8.88 (2.61)**</td>
</tr>
<tr>
<td>Coeff. of ( E_{R_t-1} ) for Mountain Reg.</td>
<td>( E_{R_t-1,10} ) 5.53 (1.19)**</td>
</tr>
</tbody>
</table>

The time trend and price of farm building materials proved to be significant and negative in the equation. The stock value of farm buildings also was significant in explaining the annual gross investment of farm buildings. The magnitudes of adjustment coefficients could not be computed because the regional depreciation rates of farm buildings were not available.

To illustrate the broader aspects of regression results from the model, the coefficients and variables for 10 farm production regions in the United States are presented in Table 9. It provides estimates for farm building demand functions in each of the ten farm production regions. Thus, one aggregate regression equation was used to derive 10 different and complete equations, one for each region.

Elasticities for variables in those equations were calculated at the respective means and are reported in Table 10.

In the farm buildings investment demand functions, the most significant
Table 9. Regression coefficients for the regional buildings investment

<table>
<thead>
<tr>
<th>Region</th>
<th>Constant</th>
<th>Y_{WFt-1}</th>
<th>P_B</th>
<th>T</th>
<th>S_B</th>
<th>ER_{t-1}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Reg.</td>
<td>463.91</td>
<td>0.105</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>-</td>
</tr>
<tr>
<td>North-east Reg.</td>
<td>463.91</td>
<td>0.005</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>11.31</td>
</tr>
<tr>
<td>Lake States Reg.</td>
<td>463.91</td>
<td>0.016</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>7.56</td>
</tr>
<tr>
<td>Corn Belt Reg.</td>
<td>421.79</td>
<td>0.065</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>9.53</td>
</tr>
<tr>
<td>Northern Plains Reg.</td>
<td>463.91</td>
<td>0.016</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>12.05</td>
</tr>
<tr>
<td>Appalachian Reg.</td>
<td>383.26</td>
<td>0.031</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>11.43</td>
</tr>
<tr>
<td>Southeast Reg.</td>
<td>463.91</td>
<td>0.002</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>6.72</td>
</tr>
<tr>
<td>Delta States Reg.</td>
<td>463.91</td>
<td>-0.037</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>7.61</td>
</tr>
<tr>
<td>Southern Plains</td>
<td>463.91</td>
<td>0.037</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>8.88</td>
</tr>
<tr>
<td>Mountain States Reg.</td>
<td>463.91</td>
<td>0.105</td>
<td>-1.49</td>
<td>-4.09</td>
<td>0.00128</td>
<td>5.53</td>
</tr>
</tbody>
</table>
Table 10. Elasticities computed at the means of the variables for farm buildings investment

<table>
<thead>
<tr>
<th>Names of variables</th>
<th>Notation</th>
<th>Elasticities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price of farm building materials</td>
<td>$P_B$</td>
<td>1.37</td>
</tr>
<tr>
<td>Stock values of farm building</td>
<td>$S_B$</td>
<td>0.32</td>
</tr>
<tr>
<td>Lagged weighted income</td>
<td>$Y_{WFT-1}$</td>
<td>0.146</td>
</tr>
<tr>
<td>$Y_{WFT-1}$ for North-east Reg.</td>
<td>$Y_{WFT-1,2}$</td>
<td>0.05485</td>
</tr>
<tr>
<td>$Y_{WFT-1}$ for Lake States Reg.</td>
<td>$Y_{WFT-1,3}$</td>
<td>0.0244</td>
</tr>
<tr>
<td>$Y_{WFT-1}$ for Corn Belt Reg.</td>
<td>$Y_{WFT-1,4}$</td>
<td>0.0837</td>
</tr>
<tr>
<td>$Y_{WFT-1}$ for Northern Plains Reg.</td>
<td>$Y_{WFT-1,5}$</td>
<td>0.01996</td>
</tr>
<tr>
<td>$Y_{WFT-1}$ for Appalachian Reg.</td>
<td>$Y_{WFT-1,6}$</td>
<td>0.058</td>
</tr>
<tr>
<td>$Y_{WFT-1}$ for South-east Reg.</td>
<td>$Y_{WFT-1,7}$</td>
<td>0.0034</td>
</tr>
<tr>
<td>$Y_{WFT-1}$ for Delta States Reg.</td>
<td>$Y_{WFT-1,8}$</td>
<td>0.074</td>
</tr>
<tr>
<td>$Y_{WFT-1}$ for Southern Plains Reg.</td>
<td>$Y_{WFT-1,9}$</td>
<td>0.046</td>
</tr>
<tr>
<td>$Y_{WFT-1}$ for Mountain States Reg.</td>
<td>$Y_{WFT-1,10}$</td>
<td>0.114</td>
</tr>
<tr>
<td>Time trend</td>
<td>$T$</td>
<td>2.16</td>
</tr>
<tr>
<td>Lagged equity ratio for North-east</td>
<td>$ER_{t-1,2}$</td>
<td>0.097</td>
</tr>
<tr>
<td>Lagged equity ratio for Lake States</td>
<td>$ER_{t-1,3}$</td>
<td>0.071</td>
</tr>
<tr>
<td>Lagged equity ratio for Corn Belt</td>
<td>$ER_{t-1,4}$</td>
<td>0.048</td>
</tr>
<tr>
<td>Lagged equity ratio for Northern Plains</td>
<td>$ER_{t-1,5}$</td>
<td>0.159</td>
</tr>
<tr>
<td>Lagged equity ratio for Appalachian</td>
<td>$ER_{t-1,6}$</td>
<td>0.184</td>
</tr>
<tr>
<td>Lagged equity ratio for South-east</td>
<td>$ER_{t-1,7}$</td>
<td>0.1398</td>
</tr>
<tr>
<td>Lagged equity ratio for Delta States</td>
<td>$ER_{t-1,8}$</td>
<td>0.187</td>
</tr>
<tr>
<td>Lagged equity ratio for Southern Plains</td>
<td>$ER_{t-1,9}$</td>
<td>0.111</td>
</tr>
<tr>
<td>Lagged equity ratio for Mountain States</td>
<td>$ER_{t-1,10}$</td>
<td>0.080</td>
</tr>
</tbody>
</table>
variables included the weighted net farm income, equity ratio, time trend, price for building materials and stock value of farm buildings. As expected, regional differences in the farmers' responses with respect to the same set of variables for the farm buildings investment were not significant.

Regional demand for total farm labor: The regression results reported in Table 11 included all variables of the demand for total farm labor function which were found to be statistically significant (see the footnotes for Table 11). The Durbin-Watson statistic indicated that the errors were not autocorrelated in the equation.

The overall coefficient for the technological change index was negative and was significant at 1 percent probability level. The regional differences of the same variable also were significant but with a positive sign. However, the regional regression coefficients, which were the differences between overall and the regional difference, had consistent negative signs.

The weighted net farm income, lagged one year, was tried as an explanatory variable but proved to be nonsignificant. The lagged ratio of composite farm wage rate to total value of building and land per acre were negative and significant for the Northern Plains and Appalachian regions. An inconsistent sign for the Mountain region was found. The positive relations for the lagged ratio of machinery prices to farm labor wages were found for the Northeast and Lake States regions in contrast with the inconsistent sign found for the Southeast region.
Table 11. Regression equation and related statistics for regional total farm labor demand\(^a\)

<table>
<thead>
<tr>
<th>Names of variables and statistics</th>
<th>Notation</th>
<th>Statistics and regression coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall regression 'F' ratio</td>
<td>(F)</td>
<td>1602.06</td>
</tr>
<tr>
<td>Coefficient of determination</td>
<td>(R^2)</td>
<td>0.998</td>
</tr>
<tr>
<td>Durbin-Watson statistics</td>
<td>(d)</td>
<td>1.58**</td>
</tr>
<tr>
<td>Overall intercept</td>
<td>(b_0)</td>
<td>3371.98</td>
</tr>
<tr>
<td>Diff. in the intercept for</td>
<td>(b_2)</td>
<td>-2186.79 (-3.11)***</td>
</tr>
<tr>
<td>North-east Reg.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diff. in the intercept for</td>
<td>(b_3)</td>
<td>-1764.42 (-2.45)***</td>
</tr>
<tr>
<td>Lake States Reg.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diff. in the intercept for</td>
<td>(b_4)</td>
<td>-1091.34 (-1.44)*</td>
</tr>
<tr>
<td>Corn Belt Reg.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diff. in the intercept for</td>
<td>(b_5)</td>
<td>-1590.38 (-1.95)*</td>
</tr>
<tr>
<td>Northern Plains Reg.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diff. in the intercept for</td>
<td>(b_6)</td>
<td>-899.48 (-1.28)*</td>
</tr>
<tr>
<td>Appalachian Reg.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diff. in the intercept for</td>
<td>(b_7)</td>
<td>-949.52 (-1.39)</td>
</tr>
<tr>
<td>South-east Reg.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diff. in the intercept for</td>
<td>(b_8)</td>
<td>-2119.45 (-3.09)***</td>
</tr>
<tr>
<td>Delta States Reg.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diff. in the intercept for</td>
<td>(b_9)</td>
<td>-1699.32 (-2.41)***</td>
</tr>
<tr>
<td>Southern Plains Reg.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diff. in the intercept for</td>
<td>(b_{10})</td>
<td>-941.08 (-1.33)</td>
</tr>
<tr>
<td>Mountain Reg.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall coeff. of A(t)</td>
<td></td>
<td>-15.56 (-2.65)***</td>
</tr>
<tr>
<td>Diff. in the coeff. of A(t) for</td>
<td>(A(t)_2)</td>
<td>15.75</td>
</tr>
<tr>
<td>Northeast Reg.</td>
<td></td>
<td>(2.68)***</td>
</tr>
<tr>
<td>Diff. in the coeff. of A(t) for</td>
<td>(A(t)_3)</td>
<td>15.40</td>
</tr>
<tr>
<td>Lake States Reg.</td>
<td></td>
<td>(2.61)***</td>
</tr>
<tr>
<td>Diff. in the coeff. of A(t) for</td>
<td>(A(t)_4)</td>
<td>13.00</td>
</tr>
<tr>
<td>Corn Belt Reg.</td>
<td></td>
<td>(2.13)***</td>
</tr>
<tr>
<td>Diff. in the coeff. of A(t) for</td>
<td>(A(t)_5)</td>
<td>16.45</td>
</tr>
<tr>
<td>Northern Plains Reg.</td>
<td></td>
<td>(2.76)***</td>
</tr>
<tr>
<td>Diff. in the coeff. of A(t) for</td>
<td>(A(t)_6)</td>
<td>12.96</td>
</tr>
<tr>
<td>Appalachian Reg.</td>
<td></td>
<td>(2.16)***</td>
</tr>
<tr>
<td>Diff. in the coeff. of A(t) for</td>
<td>(A(t)_7)</td>
<td>5.00</td>
</tr>
<tr>
<td>South-east Reg.</td>
<td></td>
<td>(2.54)***</td>
</tr>
<tr>
<td>Diff. in the coeff. of A(t) for</td>
<td>(A(t)_8)</td>
<td>15.70</td>
</tr>
<tr>
<td>Delta States Reg.</td>
<td></td>
<td>(2.66)***</td>
</tr>
</tbody>
</table>

\(^a\)Please see footnote under Table 5 for explanations of asterisks.
Table 11. (Continued)

<table>
<thead>
<tr>
<th>Names of variables and statistics</th>
<th>Notation</th>
<th>Statistics and regression coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diff. in the coeff. of A(t) for Southern Plains Reg.</td>
<td>A(t)9</td>
<td>15.71 (2.66)***</td>
</tr>
<tr>
<td>Diff. in the coeff. of A(t) for Mountain Reg.</td>
<td>A(t)10</td>
<td>1.56 (2.62)***</td>
</tr>
<tr>
<td>Coeff. of (P TL/TVBLA) for Northern Plains Reg.</td>
<td>(P TL/TVBLA)</td>
<td>-4.01 (-1.53)*</td>
</tr>
<tr>
<td>Coeff. of (P TL/TVBLA) for Appalachian Reg.</td>
<td>(P TL/TVBLA)</td>
<td>3.25 (1.29)*</td>
</tr>
<tr>
<td>Coeff. of (P TL/TVBLA) for Mountain Reg.</td>
<td>(P TL/TVBLA)</td>
<td>-5.30 (-2.27)**</td>
</tr>
<tr>
<td>Overall coeff. for PNL</td>
<td>PNL</td>
<td>-9.22 (-13.67)***</td>
</tr>
<tr>
<td>Overall coeff. for IMP t-1</td>
<td>IMP t-1</td>
<td>-1.85 (-2.96)***</td>
</tr>
<tr>
<td>Coeff. of (P M/P TL) for Northeast Reg.</td>
<td>(P M/P TL) t-1,2</td>
<td>5.26 (1.49)*</td>
</tr>
<tr>
<td>Coeff. of (P M/P TL) for Lake States Reg.</td>
<td>(P M/P TL) t-1,3</td>
<td>6.03 (1.69)*</td>
</tr>
<tr>
<td>Coeff. of (P M/P TL) for Southeast Reg.</td>
<td>(P M/P TL) t-1,7</td>
<td>-4.43 (-1.43)*</td>
</tr>
</tbody>
</table>

The overall coefficients for non-farm wage rates and lagged index of mechanical power were found to be significant and with consistent negative signs in explaining the demand for total farm labor.

To illustrate the broader aspects of regression results from the model, the coefficients and variables for 10 farm production regions in the United States are presented in Table 12. It provides estimates for total farm labor demand functions in each of the 10 farm production regions. Thus, one aggregate equation was used to derive 10 different and complete equations, one for each region.

Elasticities for variables in those equations were calculated at the respective means and are reported in Table 13.
Table 12. Regression coefficients for the regional total farm labor demand

<table>
<thead>
<tr>
<th>Region</th>
<th>Constant</th>
<th>(A(t))</th>
<th>((P_{TL}/TVBLA)_{t-1})</th>
<th>(P_{NL})</th>
<th>(IMP_{t-1} (PM/PTL)_{t-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Reg.</td>
<td>3371.98</td>
<td>-15.56</td>
<td>-9.22</td>
<td>-1.85</td>
<td></td>
</tr>
<tr>
<td>North-east Reg.</td>
<td>1185.19</td>
<td>0.19</td>
<td>-9.22</td>
<td>-1.85</td>
<td>5.26</td>
</tr>
<tr>
<td>Lake States Reg.</td>
<td>1507.56</td>
<td>-0.16</td>
<td>-9.22</td>
<td>-1.85</td>
<td>6.03</td>
</tr>
<tr>
<td>Corn Belt Reg.</td>
<td>2280.64</td>
<td>-2.56</td>
<td>-9.22</td>
<td>-1.85</td>
<td></td>
</tr>
<tr>
<td>Northern Plains Reg.</td>
<td>1781.60</td>
<td>0.89</td>
<td>-9.22</td>
<td>-1.85</td>
<td></td>
</tr>
<tr>
<td>Appalachian Reg.</td>
<td>2472.50</td>
<td>-2.60</td>
<td>3.25</td>
<td>-9.22</td>
<td>-1.85</td>
</tr>
<tr>
<td>South-east Reg.</td>
<td>2322.46</td>
<td>-10.56</td>
<td>-9.22</td>
<td>-1.85</td>
<td>-4.43</td>
</tr>
<tr>
<td>Delta States Reg.</td>
<td>1252.53</td>
<td>0.14</td>
<td>-9.22</td>
<td>-1.85</td>
<td></td>
</tr>
<tr>
<td>Southern Plains Reg.</td>
<td>1672.66</td>
<td>0.15</td>
<td>-9.22</td>
<td>-1.85</td>
<td></td>
</tr>
<tr>
<td>Mountain States</td>
<td>2430.90</td>
<td>-13.99</td>
<td>-5.30</td>
<td>-9.22</td>
<td>-1.85</td>
</tr>
</tbody>
</table>

In the regional demand for total labor functions, the most significant variables included the technological index, non-farm wage rate, lagged index of mechanical power on farm, lagged ratio of composite farm wage rate to total value of land and buildings per acre and lagged ratio of machinery prices to farm labor wages.

The results for the 10 farm production regions show a close similarity to the national results. Therefore, the general effects of each set of independent variables need not be repeated again. However, the regional analysis revealed that technological advancement has exerted differing
Table 13. Elasticities computed at the means of the variable for total farm labor demand

<table>
<thead>
<tr>
<th>Names of variables</th>
<th>Notation</th>
<th>Elasticities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technological rate for Pacific Reg.</td>
<td>A(t)</td>
<td>-0.180</td>
</tr>
<tr>
<td>Technological rate for North-east Reg.</td>
<td>A(t)₂</td>
<td>0.273</td>
</tr>
<tr>
<td>Technological rate for Lake States Reg.</td>
<td>A(t)₃</td>
<td>-0.002</td>
</tr>
<tr>
<td>Technological rate for Corn Belt Reg.</td>
<td>A(t)₄</td>
<td>-0.017</td>
</tr>
<tr>
<td>Technological rate for Northern Plains Reg.</td>
<td>A(t)₅</td>
<td>0.014</td>
</tr>
<tr>
<td>Technological rate for Appalachian Reg.</td>
<td>A(t)₆</td>
<td>-0.010</td>
</tr>
<tr>
<td>Technological rate for Southeast Reg.</td>
<td>A(t)₇</td>
<td>-0.105</td>
</tr>
<tr>
<td>Technological rate for Delta States Reg.</td>
<td>A(t)₈</td>
<td>0.002</td>
</tr>
<tr>
<td>Technological rate for Southern Plains Reg.</td>
<td>A(t)₉</td>
<td>0.002</td>
</tr>
<tr>
<td>Technological rate for Mountain Reg.</td>
<td>A(t)₁₀</td>
<td>-0.367</td>
</tr>
<tr>
<td>((P_{TL}/TVBLA)) for Northern Plains Reg.</td>
<td>((P_{TL}/TVBLA))</td>
<td>-0.076</td>
</tr>
<tr>
<td>((P_{TL}/TVBLA)) for Appalachian Reg.</td>
<td>((P_{TL}/TVBLA))</td>
<td>0.024</td>
</tr>
<tr>
<td>((P_{TL}/TVBLA)) for Mountain States Reg.</td>
<td>((P_{TL}/TVBLA))</td>
<td>-0.152</td>
</tr>
<tr>
<td>Nonfarm wage rate</td>
<td>(P_{NL})</td>
<td>-1.057</td>
</tr>
<tr>
<td>Lagged index of mech. power</td>
<td>(IM_{t-1})</td>
<td>-0.201</td>
</tr>
<tr>
<td>((P_{M}/P_{TL})) for North-east Reg.</td>
<td>((P_{M}/P_{TL})_{t-1,2})</td>
<td>0.067</td>
</tr>
<tr>
<td>((P_{M}/P_{TL})) for Lake State Reg.</td>
<td>((P_{M}/P_{TL})_{t-1,3})</td>
<td>0.042</td>
</tr>
<tr>
<td>((P_{M}/P_{TL})) for South-east Reg.</td>
<td>((P_{M}/P_{TL})_{t-1,7})</td>
<td>-0.052</td>
</tr>
</tbody>
</table>
effects in reducing the total farm labor demand in the various regions. In those areas such as the Pacific, Southeast and Mountain regions where the agriculture sector was depressed, the effects were more evident than in other regions.

Regional demand for hired farm labor: The same types of analyses were performed for the regional demand function for hired farm labor as for the total farm labor. However, most of the coefficients were insignificant due to the fact that there was high multicollinearity among the technological index, time trend and lagged ratio of farm wage rates to the value of land and building per acre. Consequently the original regional model (which was proposed in the last chapter) for the hired farm labor was revised as follows:

\[
Q_{HL}^D = b_0 + \sum_{i=1}^{m-1} b_i + cP_{Nt} + dY_{Ft-1} + \sum_{i=1}^{m-1} eY_{Ft-1,i} + f(P_{M}/P_{TL})_{t-1}
\]

\[
+ \sum_{i=1}^{m-1} g(P_{M}/P_{TL})_{t-1,i} + U_t.
\]

All variables are as described in the previous chapter.

All variables of the demand for hired farm labor function which proved statistically significant are reported in Table 14.

To illustrate the broader aspects of regression results from the model, the coefficients and variables for 10 farm production regions in the United States also are presented in Table 15. It provides estimates for the demand of hired farm labor functions in each of the 10 farm production regions. Thus, the one aggregate equation was used to derive 10 different and complete equations, one for each region.
Table 14. Regression equation and related statistics for regional hired farm labor demand

<table>
<thead>
<tr>
<th>Names of variable and statistics</th>
<th>Notation</th>
<th>Statistics and regression coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall regression 'F' ratio</td>
<td>$F$</td>
<td>205.32</td>
</tr>
<tr>
<td>Coefficient of determination</td>
<td>$R^2$</td>
<td>0.97</td>
</tr>
<tr>
<td>Durbin-Watson statistics</td>
<td>$d$</td>
<td>1.58**</td>
</tr>
<tr>
<td>Overall intercept</td>
<td>$b_0$</td>
<td>407.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5.56)**</td>
</tr>
<tr>
<td>Diff. in the intercept for Lake States Reg.</td>
<td>$b_3$</td>
<td>-195.74</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-1.57)*</td>
</tr>
<tr>
<td>Diff. in the intercept for Northern Plains Reg.</td>
<td>$b_5$</td>
<td>-254.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-1.49)*</td>
</tr>
<tr>
<td>Diff. in the intercept for South-east Reg.</td>
<td>$b_7$</td>
<td>-202.89</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-1.45)*</td>
</tr>
<tr>
<td>Coeff. of $Y_{Ft-1}$ for North-east Reg.</td>
<td>$Y_{Ft-1,2}$</td>
<td>-2.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-1.61)*</td>
</tr>
<tr>
<td>Coeff. of $Y_{Ft-1}$ for Appalachian Reg.</td>
<td>$Y_{Ft-1,6}$</td>
<td>3.55</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.75)*</td>
</tr>
<tr>
<td>Overall coefficient for $P_{NL}$</td>
<td>$P_{NL}$</td>
<td>-1.22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-2.14)**</td>
</tr>
<tr>
<td>Coeff. of $(P_{M}/P_{TL})$ for Appalachian Reg.</td>
<td>$(P_{M}/P_{TL})_{t-1,6}$</td>
<td>1.78</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.30)*</td>
</tr>
</tbody>
</table>

***Indicates coefficients significant at probability level $0<P<0.01$.
**Indicates coefficients significant at probability level $0<P<0.05$.
*Indicates coefficients significant at probability level $0.05<P<0.20$.

Elasticities for variables in those equations were calculated at the respective means and are reported in Table 16.

The coefficients of all variables, except the coefficient of $Y_{Ft-1}$ for the Northeast region, had the expected sign. There were no significant regional differences about the farm firms' responses on the demand for hired farm labor. However, the Appalachian region showed its high sensi-
Table 15. Regression coefficients for the regional hired farm labor demand

<table>
<thead>
<tr>
<th>Region</th>
<th>Constant</th>
<th>$P_{NL}$</th>
<th>$Y_{Ft-1}$</th>
<th>$(P_M/P_{TL})_{t-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Reg.</td>
<td>407.04</td>
<td>-1.22</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>North-east Reg.</td>
<td>407.04</td>
<td>-1.22</td>
<td>-2.01</td>
<td>-</td>
</tr>
<tr>
<td>Lake States Reg.</td>
<td>211.30</td>
<td>-1.22</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Corn Belt Reg.</td>
<td>407.04</td>
<td>-1.22</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Northern Plains Reg.</td>
<td>152.53</td>
<td>-1.22</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Appalachian Reg.</td>
<td>407.04</td>
<td>-1.22</td>
<td>3.55</td>
<td>1.78</td>
</tr>
<tr>
<td>South-east Reg.</td>
<td>204.15</td>
<td>-1.22</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Delta States Reg.</td>
<td>204.04</td>
<td>-1.22</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Southern Plains Reg.</td>
<td>204.04</td>
<td>-1.22</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mountain States Reg.</td>
<td>204.04</td>
<td>-1.22</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 16. Elasticities computed at the means of the variables for hired farm labor demand

<table>
<thead>
<tr>
<th>Names of variables</th>
<th>Notation</th>
<th>Elasticities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged ratio of machine prices to farm labor wage for Appalachian Reg.</td>
<td>$(P_M/P_{TL})_{t-1}$</td>
<td>0.082</td>
</tr>
<tr>
<td>Overall nonfarm wage rate</td>
<td>$P_{NL}$</td>
<td>-0.077</td>
</tr>
<tr>
<td>Coeff. of $Y_{Ft-1}$ for North-east Reg.</td>
<td>$Y_{Ft-1}$</td>
<td>-0.081</td>
</tr>
<tr>
<td>Coeff. of $Y_{Ft-1}$ for Appalachian Reg.</td>
<td>$Y_{Ft-1}$</td>
<td>0.110</td>
</tr>
</tbody>
</table>
tivities in the demand for hired labor with respect to weighted net farm income and the ratio of farm machinery prices to farm labor wages than other regions. The Appalachian region has a depressed agriculture sector. Farm laborers are more sensitive in comparing the farm wage rates and the non-farm wage rates. Farmers also are more sensitive in comparing the farm wage rates to machinery prices. Net farm income relative to non-farm income could be one of the many yardsticks for farm operators and farm laborers to check their future in farming.
VI. THE COMPUTER SIMULATION MODEL OF THE DEMAND FOR FACTORS (NATIONAL MODEL)

A. Simulation of Factors Demand Under the Existing Economic Structure

1. Simulation of the historical period and model validation

In this study, a computer simulation model is used for explanatory or positive analysis. The primary concern here is to explain how the structure of the demand for factors in agriculture behaves. Conclusions or predictions implied by data generated by this model must be subjected to direct empirical observation for either verification or refutation. Verification lends support to the model as a whole. It implies that the underlying assumptions in the model are adequate to explain the behavior of the actual system.

Koopmans (74, p. 134) has suggested historical and forecasting verification as two alternative approaches for testing the degree to which data generated by computer simulation models conform to observed data. Further, among several approaches to historical verification, Clarkson (12, p. 34) has suggested one of the most difficult and rigorous methods. The model as a whole, as he suggested, can be subjected to statistical tests by matching the time-series of the variables under consideration. In this way a measure of 'goodness of fit' can be obtained and the model as a whole can be confirmed on its ability to predict the time series.

Of course, no model is expected to fit the data exactly; the question is whether the residual errors are sufficiently small to be tolerable and sufficiently unsystematic to be treated as random.
Concerning the goodness of fit in attempting to fit data generated by computer simulation experiments to actual time series data, Cohen and Cyert (16) have suggested three general testing procedures. One of the procedures suggested by them is to regress the generated time-series on actual time-series data, and then proceed to check whether the resulting equations have intercepts which are not significantly different from zero and slopes which are not significantly different from unity.

In this study, the behavioral and definitional relations developed in the previous chapters for national models were rewritten in computer language. Given the time-series data for the exogenous variables and the lagged endogenous variable at the beginning of the time period (1924), the endogenous variables for the entire historical period (1924-1965) were then automatically generated by the recursive model without any additional constraints. The generated time-series data were, then regressed on the respective actual time-series. The results are presented as follows: Where all variables were defined in Chapter V:

\[
\begin{align*}
\hat{S}_{Pt} &= 6.03 + 0.95 S_{Pt} & R^2 &= 0.93 \\
\hat{Q}_{t1} &= 0.66 + 0.99 Q_{t1} & R^2 &= 0.99 \\
\hat{Q}_{t2} &= 1.82 + 0.97 Q_{t2} & R^2 &= 0.97 \\
\hat{P}_{Rt} &= 17.50 + 0.84 P_{Rt} & R^2 &= 0.95 \\
\hat{(P_R/P_P)}_t &= 18.31 + 0.83 (P_R/P_P)_t & R^2 &= 0.94 \\
\hat{(Y_F)}_t &= 2903.72 + 0.70 Y_{Ft} & R^2 &= 0.75 \\
\hat{P}_{Mt} &= 19.62 + 0.79 P_{Mt} & R^2 &= 0.75
\end{align*}
\]
Out of the twenty variables which were tested, the coefficient of the
determinant ranges from 0.75 to 0.99. The intercepts vary from 0.66 to
2908 and depend on the different units of measurement for each variable,
and the slopes vary from 0.70 to 0.99 quite close to unity. The production
response function has the best fit, whereas the definitional net farm in­
come function has the least.

The actual and predicted time-series of the quantities demanded for
five kinds of resources are presented on Figures 3 to Figure 9. As can
be visualized from these figures, the height and turning point are reason­
ably well predicted.
Figure 3. Actual and predicted values of total farm machinery purchases for the United States
Figure 5. Actual and predicted values of other farm machinery purchases for the United States.
Figure 6. Actual and predicted values of farm building investment for the United States
Figure 7. Actual and predicted numbers of total farm employees for the United States.
Figure 8. Actual and predicted numbers of hired farm employees for the United States
Figure 9. Actual and predicted numbers of family farm employees for the United States.
In general, the performance of the model in reproducing the historical period was deemed satisfactory considering the degree of accuracy needed for each variable.

2. Simulation of alternative historical demand for factors

Total agricultural production in the United States has been increasing rapidly over the past three decades. The production index increased from 51 in 1924 to 115 in 1965, but the total of the inputs in agriculture has been increasing at a lower rate. The composition of the inputs, however, has been changing markedly. The input of labor, which used to be the largest item, has been declining rapidly. The input of labor (in terms of persons employed) was 13 million in 1924 to only 5.6 million in 1965. The input of capital measured in real value rose, offsetting the decline in labor, from 1924 to 1965. The index of stock value of productive farm assets rose from 110 in 1924 to 180 in 1965 with the 1957-1959 average of 100.

Agriculture supply is believed to be excessive in relation to demand as a result of excessive inputs of productive factors in agriculture. Current programs to reduce production do not, in fact, control agriculture supply (the position of the supply curve) and leave the position of the supply curve unaffected. The over-production problem is only pushed back and not solved. The production control programs, at most, will reduce the current short-run problem, namely the excessive supply of farm products, while the basic long-run problem of inelastic inputs supply in agriculture, mainly an excessive supply of farm labor and management, remains unsolved.
The basic long-run problem appears in the form of low price and low income per farmer relative to those in other industries. The fact that prices remain low, in the face of massive and expensive government programs designed to raise them, means to some advocates that the efforts need to be further increased (15) in order to increase the prices and hence, solve the agriculture problem.

Still others believe that the real problem in agriculture is overcapacity resulting from rapid and widespread adoption of new technology in agricultural production and that measures to support agricultural prices and incomes do not relieve this, but instead make it worse (103).

The basic problem of agriculture should be an adjustment problem resulting from continued overproduction of farm products relative to the demand and excessive supply of farmers (46, 103, pp. 43-44).

The increase in agricultural production does not result from any increase in acreage. The overproduction results mainly from rapid technological advances and the addition and substitution of capital resources. The inelastic demand for farm products has limited the total U.S. gross farm income to a slow rise. With the elastic supply and the farmers' increased demand in the quantity of commercial inputs, the net effect of using more efficient production techniques is to decrease total national net farm income. Along with the overproduction of farm products, the inelastic supply of factors, especially the labor and management, keeps income per farmer declining further.

The effects of both production control and the technological advances on the parameters of the existing economic structure will be developed in the following two sections. However, the main emphasis is to illustrate the
meaning of the supply and demand elasticities found in the last chapter and to illustrate broadly some of the adjustments that would occur rather than to trace the exact implications of free market and technological effects.

a. Alternative rate of technological change

The technological strides in agriculture have caused the supply of agricultural products to be shifted ahead faster than the increases in demand (46). These technological gains (at an annual average rate of 0.03%, see Chapter V), in association with the low price elasticity of demand for agricultural commodities (0.51, see the last chapter), create downward pressure on resource returns in agriculture.

Public investment in research has had an important part not only in increasing production functions in agriculture but in fostering low relative prices of commercial inputs. Economic development with the ability to produce capital items at low prices along with increased returns to laborers is a factor in increasing capital substitution for labor.

The problem of low returns in agriculture arises from the transfer of resources which are in excess supply in agriculture. By the nature of land, labor, and impediments to the movement of these resources from agriculture, the presence of excess resources in the form of land and labor adds to depressed economic conditions in agriculture.

The technological index was a significant explanatory variable in the production response function as explained in the last chapter. The production response elasticity with respect to technology was computed as 0.15.

Had the technological advancement in agriculture increased at a
slower rate (say at one half of the prevailing rate which is at an annual average rate of 0.03 percent, see description of A(t) in Chapter V, Section 1) and ceteris paribus, the problem of excessive supply of commodities in agriculture would have been reduced to some extent. By the parameters computed for technological index A(t) in the last chapter, the demand for total labor is likely to increase and the demand for farm machineries to decrease.

The national recursive model was simulated with the computed parameters in the last chapter. The simulated results for the demand of factors for selected years are presented in Table 17.

The results showed that the decrease in the demand for total farm machines varied approximately from 1 to 30 percent in different years. The increase in the demand for total farm labor varied approximately from 1 to 10 percent in different years. The effects on the demand in farm building investments were unnoticeable.

In addition, the results showed that the drop in machinery demand was largely due to the drop in demand for motor vehicles. This included the tractor, truck and the automobile. The percentage decrease in total farm machines was far higher than the percentage increase in the demand for total farm labor. While the demand for total farm labor and family farm labor increased, the demand for hired labor decreased.

Different rates of technological advancement, as indicated by these results, have quite different impacts on both the magnitude and composition of the demand for factors in agriculture. Consequently, it affected the returns for factor and hence, the net farm income. The latter will be investigated briefly in the next section.
Table 17. Simulated results for the demand of factors under the lower rate of technological changes (one-half of the prevailing rate)\(^a\)

<table>
<thead>
<tr>
<th>Year</th>
<th>QMT(^b)</th>
<th>QMT(^c)</th>
<th>QMV(^b)</th>
<th>QMV(^c)</th>
<th>QTL(^b)</th>
<th>QTL(^c)</th>
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\(^a\)All values are in terms of a million dollars, except QTL and QHL are in thousands of persons.

\(^b\)Simulated results under the prevailing system.

\(^c\)Simulated results under the lower rate of technological changes (one half of the prevailing rate, i.e. 0.015% per year).
b. Free market system  

Direct measurement of income changes induced by government programs is difficult, if not impossible. In this study, the possible effects on income and factors demand of the following types of government activity have been dealt with:

(1) price-support programs, which, of course, have altered price relationships as well as the general level of farm commodity prices;

(2) allotment and land-retirement programs; and

(3) direct-payment programs.

The first two of these three programs were combined to formulate the policy index, $G_t$, in estimating the structure parameters in the last chapter.

The formulation of the policy index can be briefly summarized as follows: During those years when acreage allotment or production controls are in force with flexible price support, the value of $-1$ is given. If price supports are fixed, with rigid support of 85 percent or over, the value of $+1$ is given. Years when soil bank and subsequent agriculture adjustment act provisions are in force, an additional $-1$ is given. The values are summed to the index $G_t$.

In simulating the effects on income and factors demand under the existing structure without the above-mentioned government activities, the time-series $G_t$ had been replaced with zero-value and further the amount of the government direct payments were subtracted from the net farm income. The results were presented in Table 18.
Table 18. Simulated results for the net farm income$^a$

<table>
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<tr>
<th>Variable</th>
<th>Year</th>
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<th>$\overline{Y}_F^c$</th>
<th>$\overline{Y}_F^d$</th>
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$^a$All values are in terms of a million dollars.

$^b$Simulated results under prevailing market system.

$^c$Simulated results under one half of the prevailing technological rate.

$^d$Simulated results under the free market system.
The initial effects of support programs supposedly had been to alter price relationships among commodities as well as to maintain a somewhat higher level of product price than otherwise might have prevailed. However, as indicated in the Table 19, the latter effect did not last long. Starting from 1955, the commodity prices were slightly higher (approximately 3 percent) when the government activities of those above-mentioned were absent. This was due to the fact that substantial increases in the personal disposable income and a bit increased in the per capita food consumption had more than offset the negative effect of increasing commodity supply on price level. Furthermore, the functions of government programs greatly reduced the excess supply and indirectly raised the price level. It also had the effect of stabilizing the price fluctuations or even limiting the upward movement of price levels. The later effect was brought about through the governmental attempts to equate the supply and demand of commodities and by the psychic effects the farmers had received for their unfavored position to bargain. When prices were not allowed to fluctuate, producers were not able to determine which line of production the market favored. The effect had been further compounded by the atomistic nature of the agriculture commodity market.

The simulated results for free market indicated that price levels would have been 2 to 3 percent higher from 1956 to 1965 if there were no governmental activities such as soil bank, market quotas and flexible price support. However, the net farm income, as indicated in Table 18, would have been substantially lower (4 to 30 percent) had there been no government support programs, since it involved a large amount of direct payments made by the government. The simulated results under the slower technologi-
cal advancement (one half of the prevailing rate) indicated, as in Table 18, that net farm income increased 1 to 4 percent more than under the prevailing rate. It is as expected that the slower technological advancement will reduce the excessive supply and hence increase the price level which is one of the components to determine the net farm income.

In the absence of support programs, the prices of those factors with an inelastic supply schedule such as total farm labor declined relative to those with more elastic supply schedules such as farm machines. Prices of factors that are largely 'cost determined' and hence, have relatively flat supply schedules, declined much less than prices of factors which have few alternative uses outside of agriculture and therefore have supply schedules which are steeply declined. As indicated in Table 19, the ratio of farm machine prices to composite farm wage rates declined 0.1 to 0.5 percent.

Changes in the price ratio between factors and the reduction in net farm income had caused the changes in composition of factors demanded. As indicated in Table 20, the demand for total farm machines had increased less than 1 percent whereas the demand for total farm labor had decreased from 1 to 8 percent under the simulated free market system. The demand for farm building investments also decreased from 1 to 4 percent due to the decrease in net farm income under the simulated free market system.

B. Projection of National Demand for Factors, 1980

1. Estimation of exogenous variables

Certain assumptions about the national economy are required for making the projections. The projection of the national demand for factors was
Table 19. Quantity produced and the commodity and factor prices simulated under the free market system

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<tr>
<th>Year</th>
<th>QSA^b</th>
<th>QSA^c</th>
<th>QSB^b</th>
<th>QSB^c</th>
<th>PR^b</th>
<th>PR^c</th>
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^a All values are in index form (1957-59=100).
^b Simulated results under prevailing market system.
^c Simulated results under the free market system.
Table 20. Simulated results for the demand of factors under the free market system$^a$

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<td>12799.0</td>
<td>12349.5</td>
<td>10854.7</td>
<td>9629.4</td>
<td>9423.4</td>
<td>8173.5</td>
<td>7501.9</td>
<td>7503.9</td>
<td>7226.7</td>
<td>6779.2</td>
<td>6074.2</td>
<td>5414.7</td>
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<tr>
<td></td>
<td>QHL$^b$</td>
<td>3441.7</td>
<td>3118.5</td>
<td>3044.6</td>
<td>2681.4</td>
<td>2184.0</td>
<td>2199.4</td>
<td>2019.9</td>
<td>1890.4</td>
<td>1927.2</td>
<td>1926.7</td>
<td>1991.7</td>
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<td></td>
<td>QHL$^c$</td>
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<td>3118.5</td>
<td>3044.6</td>
<td>2681.4</td>
<td>2186.1</td>
<td>2201.1</td>
<td>2021.1</td>
<td>1891.1</td>
<td>1927.5</td>
<td>1915.7</td>
<td>1992.4</td>
<td>1685.7</td>
<td>1439.0</td>
</tr>
<tr>
<td></td>
<td>QBI$^b$</td>
<td>311.9</td>
<td>285.4</td>
<td>150.2</td>
<td>266.5</td>
<td>552.5</td>
<td>1054.7</td>
<td>919.5</td>
<td>827.1</td>
<td>816.3</td>
<td>792.9</td>
<td>787.7</td>
<td>776.3</td>
<td>765.0</td>
</tr>
<tr>
<td></td>
<td>QBI$^c$</td>
<td>311.9</td>
<td>285.4</td>
<td>150.2</td>
<td>266.5</td>
<td>552.5</td>
<td>1054.7</td>
<td>919.5</td>
<td>827.1</td>
<td>816.3</td>
<td>792.9</td>
<td>787.7</td>
<td>776.3</td>
<td>765.0</td>
</tr>
</tbody>
</table>

$^a$All values are in the unit of a million dollars except QTL and QHL which are in terms of a thousand persons.

$^b$Simulated results under prevailing market system.

$^c$Simulated results under the free market system.
made for the year 1980 under the following assumptions: (1) it is assumed that the past trends in productivity and technological development will continue; (2) there will be no general war and the foregoing general economic environment of 1946 to 1965 are going to prevail; (3) national economic growth is projected at approximately the same rate as the actual growth rate which occurred from 1946 to 1965; (4) an unemployment rate of 4.5 percent (which is lower than 1965 level of 5.7 percent) and an interest rate of 6.0 percent (which is higher than 1965 level of 5.3 percent) were assumed to be sustained through 1980; (5) the midpoint of the Census Bureau's high and low population projection for 1980 (255 million); (6) there will be a government policy of no greater restriction in agricultural output than there has been in the past; and (7) weather condition (index) will be that of the 1963 to 1965 average from 1966 through 1980; (8) the level of per capita food consumption will remain at the 1965 level through 1980.

It is necessary to project all of the exogenous variables to the year 1980 in order to use the model developed and the parameters estimated in the national model.

In this study, based on assumption (2), four regressions were fitted for each exogenous variable for the 1946 to 1965 period with one independent variable in each regression. The four different independent variables used were: (a) time variable (T); (b) log of time variable (\(\log_{10} T\)); (c) square root of time variable (\(\sqrt{T}\)); and (d) square of time variable (\(T^2\)). One out of the four regressions, which has the best fit and highest F-ratio, is then chosen to generate the respective exogenous variable.
The historical data for each exogenous variable also was plotted in order to check whether the time trend was well represented by the regression chosen.

The regressions chosen for representing the time trend of exogenous variables are presented below. All variables have been described in the last sections.

\[ AF_{t-1} = -30.01 + 2.21 T \quad R^2 = 0.98 \quad F = 1073.69 \]

\[ PB_t = -65.20 + 92.70 \log_{10} T \quad R^2 = 0.75 \quad F = 54.78 \]

\[ SB_t = -4558.51 + 549.35 T \quad R^2 = 0.69 \quad F = 39.98 \]

\[ PP_t = 92.72 + 0.18 T \quad R^2 = 0.71 \quad F = 32.28 \]

\[ P_{IST_t} = -377.07 + 267.01 \log_{10} T \quad R^2 = 0.91 \quad F = 188.71 \]

\[ ER_{t-1} = 25.68 + 0.25 T \quad R^2 = 0.64 \quad F = 31.78 \]

\[ MSH_{t-1} = -134.23 + 28.96 T \quad R^2 = 0.76 \quad F = 36.42 \]

\[ LP_t = -87.21 + 24.75 \sqrt{T} \quad R^2 = 0.96 \quad F = 465.42 \]

\[ P_{NLt} = -54.45 + 2.68 T \quad R^2 = 0.97 \quad F = 665.68 \]

\[ TVLBAt = -94.16 + 3.45 T \quad R^2 = 0.90 \quad F = 166.90 \]

\[ (P_R/P_P)_t = -10.39 + 62.19 \log_{10} T \quad R^2 = 0.90 \quad F = 154.41 \]

\[ Y_{Dt} = -366.03 + 2.10 T \quad R^2 = 0.94 \quad F = 273.98 \]

\[ SM_t = -147118.23 + 95210.98 \log_{10} T \quad R^2 = 0.88 \quad F = 130.30 \]
2. Simulated endogenous variables

The projected values of factors demand for 1966, 1970, 1975 and 1980 (as well as actual values for 1946 and 1965) for the national model are presented in Table 21. All of the projected values are deflated by the wholesale price index and in terms of a million dollars except labor demands which are in terms of a million persons.

By 1980 the total labor demand will decrease 57 percent of the 1965 level, and the total farm machines demand will increase 12 percent of the 1965 level. Among the components of the total labor demand, the family farm labor will decrease most, approximately 80 percent of the 1965 level; whereas the hired farm labor will decrease at a lower percentage of 66 percent. The farm building investments will decrease 25 percent of the 1965 level by 1980 in real value. It is generally consistent with the results of Scott's study on the demand for investment in farm buildings.
<table>
<thead>
<tr>
<th>Year</th>
<th>Actual</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
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<tr>
<td>Total farm labor</td>
<td>10295.0</td>
<td>5609.0</td>
<td>5270.9</td>
<td>4477.8</td>
<td>3464.1</td>
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<td>Hired farm labor</td>
<td>2189.0</td>
<td>1484.0</td>
<td>1401.6</td>
<td>1280.4</td>
<td>1116.8</td>
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<tr>
<td>Family farm labor</td>
<td>8106.0</td>
<td>4125.0</td>
<td>3869.2</td>
<td>3197.4</td>
<td>2347.3</td>
</tr>
<tr>
<td>Total machinery</td>
<td>1564.3</td>
<td>4190.1</td>
<td>4202.2</td>
<td>4281.8</td>
<td>4367.3</td>
</tr>
<tr>
<td>Motor vehicles</td>
<td>848.7</td>
<td>2183.3</td>
<td>2179.6</td>
<td>2210.6</td>
<td>2240.5</td>
</tr>
<tr>
<td>Other farm machines</td>
<td>715.6</td>
<td>2006.8</td>
<td>2222.6</td>
<td>2271.2</td>
<td>2326.8</td>
</tr>
<tr>
<td>Farm buildings</td>
<td>1137.7</td>
<td>704.0</td>
<td>732.7</td>
<td>679.3</td>
<td>600.1</td>
</tr>
</tbody>
</table>

\(^a\)All of the values are deflated by the wholesale price index and in terms of a million dollars except labor demands which are in terms of a thousand persons.
VII. SUMMARY AND CONCLUSIONS

The main objective of this study was to describe and analyze the resource structure of American agriculture. Results of the study have been discussed pertaining to the specific objectives, i.e. estimating structural coefficients in aggregate demand and supply equations of resources, projecting future quantities, determining aggregate product supply and implications of policy alternatives. The quantitative results and the structural parameters presented in this study referred to specific types of investment: farm machinery, farm labor and the farm buildings. The farm machinery was further subdivided into two categories: farm motor vehicles and other farm machinery. Farm labor was also further subdivided into two categories: hired labor and family labor.

The dynamic nature of production, hence dynamic resources demand (as the derived demand) in agriculture has been emphasized and was integrated explicitly with the spatial interrelationships to formulate the proposed econometric model. However, due to the data limitations, the final models for empirical testing were separated into the national and the regional models.

National models were fitted from 1924 to 1965. Regional resources demand functions were fitted for the period of 1946 to 1965.

National model has recursive features and was estimated with least squares and the modified autoregressive least squares techniques. Functions were fitted using annual original data.

Regional models were estimated with the multiple regression techniques.
in combination with the covariance and algebraic combinations of dummy variables.

The national model and the parameters of the model after statistical estimation were used for simulation and projection. The historical values for investment were simulated with the model developed and the parameters estimated in order to verify the model. Further, the resources demand under the slower rate of technological advancements (one half of the prevailing rate) and the free market system were simulated. The projection of national resources demand was made up to the year 1980.

In general, the results for the United States as a whole and the ten selected farm regions obtained from the analysis appeared to conform to the rationale presented for the specification of the resources demand functions and causal relationships presented in Chapters III and IV. The general impression is that the analysis was successful, although some shortcomings can be cited. The recursive model has well described the dynamic natures of the farmers decision processes of production and resources demand in the United States. If the quarterly time series data were available better empirical results could be expected than the annual time series data used in this study.

The results for both national and regional investigations of the demand for farm resources have been discussed in Chapters V and VI. These need not be repeated in detail again. However, a few general comments on the results might give a general picture for the quantitative results and the interrelationships between farm and non-farm sectors.

The empirical demand equations provide meaningful estimates of the response of input demand quantities to own-price and product price. The
input demand equations indicate that historic trends cannot contribute entirely to declining own-price relative to output price. Much of the secular rise in demand for machinery, for example, is associated with other input price, improvements in input quality and other variables not specifically identified in the demand equations. The analysis further indicates that the growth in machinery inventories is consistent with substitutability with labor. That is, the prices of labor have increased relative to machinery prices. However, the substitutability is more than unity. The percentage decrease in farm labor demand was higher than the percentage increase in farm machinery demand as indicated in Chapter IV.

The input demand functions estimated in this study further suggested that there are strong non-price influences such as the technological improvements, equity ratio and the time trend. In some instances the forces other than price overshadow the price effects. Even drastic reductions in farm prices may not be able to offset the input increasing effects of these forces, as for example, on the machinery demand. It follows that one cannot be too optimistic about the ability of the price system to cope with the resource and income adjustments needed in agriculture.

Increasing prices paid by farmers for inputs also have some impact on the declining net farm income observed (as relative to that of non-farm sectors) and have induced the need for resource adjustments. During the period from 1924 to 1965, prices paid by farmers for items used in production, including interest, taxes and wage rates, increased 51 percent in nominal price and 8 percent in real price with both 1957-1959 average as 100. Rising input prices like falling output prices depress the net farm
income. This, to some extent, puts additional burdens on the price mechanism to cope with needed adjustments.

Some implications of direct supports for farm prices, $p_F$, without controls or diversionary purchases are apparent from the estimated supply elasticities. The output increasing effect of price supports act against the intended purpose. It is apparent that because of the inelastic demand for farm products, the intended price and income benefits to farmers would soon be dissipated unless farm output is controlled. However, as the simulation results indicate, the net farm income would have been substantially lower (4 to 30 percent in different years) had there been no government support programs.

The functions estimated in this study also provide quantitative measures of the influence of non-farm variables such as wage rates, unemployment rates and technology etc., on the farm economy. The input supply equations of farm machinery and farm labor indicate the relationship between farm input prices and non-farm wages and prices. The results indicate that a one percent increase in non-farm wage rates is associated with more than one percent increase in farm wage rates. Similarly, a one percent increase in the wholesale price of iron and steel tends to be reflected in a 0.34 percent increase in farm machinery prices.

A very high supply elasticity of farm machinery was found in this study. The result was consistent with the hypothesis that machinery supply is highly elastic. Although the result indicated that it was less than perfectly elastic, it did show that price was relatively unresponsive to quantity changes in the short-run. It can be inferred from this result that farmers are price takers (quantity a function of price) and manufacturers are price setters (price a function of quantity). The impacts of
non-farm sectors on farm sectors have been manifested by the technological advancements through the elastic machinery supply function. Changes in the non-farm variables will determine the cost and amount of farm machinery prices and the demand. As a substitutional factor for farm labor, the magnitude of farm machinery demanded affects, to quite a great extent, the amount of farm labor employed. Machinery prices have effects on prices paid by farmers, hence the net farm income. The consequent results of the amount of farm labor remaining on the farm also will determine the per capita net farm income to a considerable extent.

Further effects of the non-farm sector on farm sector could indirectly come through the effects of national disposable income. The average flexibility of disposable income on farm price is 0.25. When economic conditions in the non-farm sectors are depressed, the economic condition in the farm sector will also be depressed. The national disposable income has a greater chance to fall faster than non-farm wage rates due to the downward rigidity of non-farm wages caused by the institutionalized wage structure. The reduced disposable income is more likely to result in unemployed workers than in lower wage rates. The result is that machinery prices and other prices paid by farmers will fall less than the price received by farmers. This also could partially be due to the elastic machinery supply function. The increased unemployment rates might reduce the farm wages further. The consequent increase in the ratio of machinery prices to farm wages further functions to accommodate more labor, as can be visualized by the estimated labor demand functions. The result is more likely that the farm sector will become a shock absorber of depressed
The high correlation between the farm and non-farm sectors also impedes the effectiveness of the agricultural price support programs in bringing the needed resource adjustments.

Other variables which have some elements exogenous to the farm sector and remain to be mentioned are interest rates and the technological effects. The interest rates, however, did not exert a direct significant influence on resource demand in agriculture as can be inferred from this study.

Public investment in research has had an important part not only in increasing production in agriculture but in fostering low relative prices of commercial inputs. Economic development with the ability to produce capital items at low prices along with increased returns to labor is a factor in increasing capital substitution for labor.

The problem of low returns in agriculture arises from the transfer of resources which are in excess supply in agriculture. By the nature of land, labor and impediments to the movement of these resources from agriculture, the presence of excess resources in the form of land and labor adds to depressed economic conditions in agriculture.

If the technological advancement in agriculture increased at one half of prevailing rate (which was computed as annual average rate of 0.03 percent) and ceteris paribus, the results of this study indicated that decrease in the demand for total farm machines varied approximately from 1 to 30 percent in different years. The increase in the demand for total farm labor varied approximately from 1 to 10 percent in different years. The effects on the demand for farm buildings were small or unnoticeable. The net farm income could increase 1 to 4 percent over the prevailing rate.
It is, as expected, the slower technological advancement which will reduce the excessive supply and hence increase the price level which is one of the main components in determining the net farm income.
VIII. BIBLIOGRAPHY


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