Linear programming models of interregional competition for economic planning of Thai agriculture

Chirapanda Suthiporn

Iowa State University

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Linear programming models of interregional competition for economic planning of Thai agriculture

by

Suthiporn Chirapanda

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of The Requirements for the Degree of DOCTOR OF PHILOSOPHY

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Major: Agricultural Economics

Approved:

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For the Major Department

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For the Graduate College

Iowa State University
Ames, Iowa

1972
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CHAPTER I: INTRODUCTION

A Brief Description of the Economy

Thailand has as her neighbors Burma, Malaysia, Laos and Cambodia. She occupies roughly 200,000 square miles. The total population was estimated at 35.8 millions in 1970 (32, p. 334). Its net rate of growth is usually taken to be 3.1% per annum. Officially, the country is divided into four regions: North, Northeast, Central Plain and South. Altogether there are 71 provinces of varying sizes, some of which are shown in Figure 1.

Typically a subsistence economy, Thailand has some 80% of her population in the agricultural sector, producing rice as the major crop. In 1966-68, agriculture on the average contributed only 31.2% of the gross domestic product at 1960 prices (79, p. 19). Intuitively, the ratio of the returns to the average agricultural and the average nonagricultural worker must be considerably less than unity. On the whole, average income per capita is low; in 1969 it totaled to about baht\(^1\) 3,068 in terms of current prices\(^2\). According to the 1962-63 figures, 48.4% of all families earned a yearly income of less than B 3,000 but the average family income for the entire economy was B 7,448 (72, p. 422). This indicates that the inequality of the income distribution is fairly substantial.

\(^1\) Baht 21.00 = U.S. $1.00. From here on, baht is denoted simply by B.

\(^2\) Calculated from the table given in (32, p. 334). National income in 1969 was B 106.59 billion while the total population was estimated at 34.74 millions.
Figure 1. Thailand by official regions

<table>
<thead>
<tr>
<th>Number</th>
<th>Name of province</th>
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<tbody>
<tr>
<td>1</td>
<td>Chiang Mai</td>
</tr>
<tr>
<td>2</td>
<td>Nakhon Sawan</td>
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<tr>
<td>3</td>
<td>Bangkok</td>
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<tr>
<td>4</td>
<td>Kanchanaburi</td>
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<tr>
<td>5</td>
<td>Chon Buri</td>
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<td>6</td>
<td>Chanthaburi</td>
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<td>7</td>
<td>Chumphon</td>
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<tr>
<td>8</td>
<td>Phuket</td>
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<tr>
<td>9</td>
<td>Songkhla</td>
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<tr>
<td>10</td>
<td>Khon Kaen</td>
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<tr>
<td>11</td>
<td>Ubon Ratchathani</td>
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<td>12</td>
<td>Nakhon Ratchasima</td>
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In 1966 the level of the gross national product at current prices (revised estimate) toppled the B 100 billion mark for the first time. It was B 130.84 billion in 1964 (4, p. 97). The average annual rate of growth in the gross domestic product from 1960-67 was 7.1% (79, p. 19). Massive foreign capital inflow, partly from U.S. military spending, somewhat favorable foreign trade, and economic and political stability are among the factors responsible for such high rate of growth. Net capital inflow amounted to B 1.95 billion in 1967, making a balance of payments surplus of B 1.27 billion (73, p. 363). Export prices did not tend to decline over time, though they fluctuated a lot. Table 1 contains export price indexes of some commodities from 1964-1970. It can be seen from the table that while the price of rice, rubber and kenaf fell in 1970, that of corn and tin rose. Sporadic fluctuations in export prices, therefore, helped thwart any secular decline in value of total exports.

Table 1. Export price indexes of some commodities (1963 = 100)^

<table>
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<tr>
<th></th>
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<tbody>
<tr>
<td>Rice</td>
<td></td>
<td>96</td>
<td>95</td>
<td>110</td>
<td>130</td>
<td>146</td>
<td>119</td>
<td>99</td>
</tr>
<tr>
<td>Rubber</td>
<td></td>
<td>93</td>
<td>93</td>
<td>90</td>
<td>73</td>
<td>70</td>
<td>94</td>
<td>79</td>
</tr>
<tr>
<td>Tin</td>
<td></td>
<td>128</td>
<td>156</td>
<td>154</td>
<td>151</td>
<td>137</td>
<td>154</td>
<td>158</td>
</tr>
<tr>
<td>Maize (corn)</td>
<td></td>
<td>108</td>
<td>108</td>
<td>111</td>
<td>110</td>
<td>94</td>
<td>100</td>
<td>122</td>
</tr>
<tr>
<td>Kenaf</td>
<td></td>
<td>107</td>
<td>122</td>
<td>120</td>
<td>96</td>
<td>82</td>
<td>107</td>
<td>98</td>
</tr>
</tbody>
</table>

^Source: (32, pp. 332-333).

Perhaps the slow rate of inflation constitutes itself as a major reason why the economy has been stable and able to sustain a high rate of growth. Taking 1963 as the base year, the consumer price index rose fairly steadily and was 115 and 116 in 1969 and 1970 respectively (32, p. 34). It can be
inferred then that the rate of inflation is about 2-3% per annum. Nonetheless, the supply of money narrowly defined to be the sum of currency and demand deposits held by the public, was rising at a yearly rate of 9-10% since 1960. The fact that it did not give any impetus to a high inflation rate can be partly attributed to the enlargement of the so-called money economy. Later, the role of money in economies like Thailand will be discussed and emphasized in its importance with regard to economic development and planning.

Thus far in the 1960's economic stability and prosperity prevailed over the economy. There is, however, no denial that economic ills still exist and are widespread. Since 1952, trade balance was always in the red and even though payments imbalances so far managed to finance it, future prospects are not optimistic. With the Vietnam war winding down and decreased foreign aid, the subsequent loss in foreign exchange earnings will be likely to render the economy highly vulnerable to forces of instability (48, pp. 75-76).

The Objectives of the Study

With the above information as a background, the main objectives of the study may be generally stated as:

1) To examine various types of mathematical models which are applicable for planning purposes within the realm of Thai agriculture.

2) To identify factors that are detrimental to the economic development of Thai agriculture, and thus to identify the type of models most appropriate to meet the problems posed.
3) To develop an operational linear programming model of interregional competition that minimizes the requirements of uncollected data and, at the same time, that is useful for the purposes of short-run planning of agriculture.

4) To formulate another operational linear programming model which, unlike the first, incorporates changes in technologies not represented in time series data and several resources including water supplies.

The first model, which may be called a short-run planning model, is formulated such that it can be used:

1) To determine how much of farm commodities should be produced in each carefully defined producing region so that the total supply of each commodity is consistent with the total demand for it, and so that the total costs of production and transportation are minimized without violating the land restraints.

2) To determine the optimal location and amount of surplus arable land available for other productive activities.

3) To examine the effects on production planning of changes in the distribution of domestic and foreign demands and in the total supply of land in certain producing regions.

4) To evaluate the extent to which agricultural diversification can be carried out so that the goals of the Third Five Year Plan for 1971-76 are met.

5) To estimate future requirements of farm commodities and the optimal pattern of production among producing regions under
prespecified conditions, e.g. under a situation in which the rate of population growth is reduced to 2.5% per annum.

6) To incorporate into the model those stochastic and probabilistic elements that are always present.

The flexibilities of the second or long-term planning model permit us, in addition to the above 1-6:

7) To evaluate the extent of underemployment and unemployment under a changed structure and also to evaluate alternatives for rural employment among regions.

8) To determine quantitatively the needs for farm water supplies during different periods of the year.

9) To examine the effects of irrigating more land on the optimal pattern of resource allocation among producing regions.

10) To specify the location or region in which investment projects, principally in irrigation, should be made to meet farm needs.

11) To develop water pricing and land tax policies such that the distribution of wealth between owners of irrigated and nonirrigated land is more equitable.

12) To determine whether water resources are adequate to meet the total national water demand during different periods of the year, especially in the summer months.

13) To determine credit needs to meet necessary farm operating expenses with a longer-run view that the government institutional machinery set up to provide credit would eventually pave the way to the needed land reform.
CHAPTER II: GENERAL MATHEMATICAL MODELS OF ECONOMIC PLANNING

Mathematical models have been used in a number of countries. They are a product of economic theory and the set of mathematical tools which proves itself manipulatable to the economists. When an economic hypothesis is developed and expounded, it is necessary to explain verbally the fundamentals on which the hypothesis rests and the results and implications to which it leads. In so doing, the pioneering economist transmits his findings to the rest of the economics profession. Verbal arguments are an effective means to convince economists when they are about to receive firsthand knowledge. Take, for example, a case of determining the optimal rate of capital accumulation. Assume that there exists a social welfare function which depends solely on per capita consumption. Over a specified period of time, per capita capital must grow from, say, $k_0$ to $k_1$. The problem is to find the optimal rate of savings in such a way that the discounted social welfare over time is maximized, subject to a constraint that the rate of growth in per capita capital falls in line with the rate of per capita savings after the effect of the population growth is accounted for. The optimal rate of savings is found to be that rate at which the marginal product of per capita capital equals the sum of the social discount rate and the rate of population growth. This conclusion warrants an explanation as to why it must prevail under the conditions we set up. If it fails to hold, the economy will tend to operate either at an overcapacity rate which violates one of the constraints or, at an undercapacity rate which clearly implies that the social welfare is not maximized over time, even though none of the constraints is violated.
The conclusion may exclusively be mathematically presented and explained. Indeed, the entire problem can be stated and solved abstractly in mathematical terms. But mathematics alone do not provide the logic that descriptive economics can. On the other hand, descriptive economics lacks the touch of elegance, brevity and simplicity. Thus to build a "good" economic model, the logic of economics has to be blended with the necessary mathematical tools. Without the use of mathematics, economics faces literally an uphill task not only of finding solutions to its problems but also of how to get there. In the previous example, we may intuitively know the solution offhand. But to systematically show how it is obtained is extremely difficult if the methods of solving, i.e. the calculus of variations, the control theory approach and dynamic programming are not available. Along the same line of the argument, maximization of an individual's utility subject to his budget constraint is less simple without using the Lagrangian multipliers.

The role that mathematics plays in economics is therefore vitally important in the development of economic theory. Economic hypotheses must be subjected to repeated tests before they are decidedly accepted as a part of economic theory. These tests arise from applying the hypotheses to the real world situation. They indicate the extent to which a particular class of real world data can be explained by the stated hypotheses. Applications and tests of these hypotheses thus require generally the knowledge of statistics which permits us to realize the limits of the applicability and to evaluate the reliability of the tests conducted. For example, a statistically fitted linear demand function does not provide best linear unbiased estimates of the parameters if the
Gauss-Markov assumptions do not hold. When the random components in the function are autocorrelated, the t test on the estimated value of the parameters is based on the fact that only the asymptotic variance of the random components and, hence, of the estimate of the parameters can be estimated. The associated statistic is sometimes known as an approximate t or a quasi t. In general, statistics lends us a set of tools which we can employ with certain qualifications to assess how good an economic model is.

We have seen that in order to formulate a model, we need to acquire some knowledge of mathematics and statistics apart from economics. Each of these branches of science performs in its own way — quite different from the rest — in developing or helping to develop economic theory. Yet their roles are complementary and integrating. Economic models of planning which will be described below belong to a particular class of models. They attempt to roughly but adequately represent a set of conditions which prevail in the real world. These conditions may be thought of as variables which are either exogenous or endogenous. Controlled or instrumental variables and, in general, all those variables which are independent of, or are not determined by, other variables specified in the model are exogenous. Strictly speaking, all variables are interrelated and thus endogenous. But, for analytical purposes, it is by far more advantageous to categorize variables. In particular, we may wish to investigate the effects on endogenous (dependent) variables when some exogenous (independent or predetermined) variables are changed. It follows that, within any planning framework or in any decision making process, the interrelationships among relevant variables need be more or less
accurately known, as they would indicate the extent to which the objective of a plan can be realized.

We shall describe a general input-output model. Estimation of the coefficients and applications of the model are briefly made. Next, a general linear programming model is outlined. Some specific types, e.g. integer programming, are also explained. Econometric models of agriculture are then mentioned. A small econometric model of Thai agriculture is formulated which can be applied in the real world. Although these models are mostly dealt with in static terms, economic dynamics are important and, therefore, are treated to some extent.

General Input-output Models

Assume that the economy is divided into n sectors, each producing only one commodity. Each sector requires output of some or all other sectors as its inputs and produces to satisfy the demands generated by them. If $a_{ij}$ is the amount of the commodity of the $i^{th}$ sector required by the $j^{th}$ sector to produce a unit of the $j^{th}$ commodity, then the matrix $A$ which consists of $a_{ij}$'s may be called the matrix of input-output coefficients, where $i$ and $j = 1, \ldots, n$. If $X_j$ is the gross output of the $j^{th}$ sectors, then it is clear that, from our definition above, in equilibrium

$$
\begin{align*}
X_1 &= a_{11}X_1 - a_{12}X_2 - \cdots - a_{1n}X_n = 0 \\
X_2 &= a_{21}X_1 - a_{22}X_2 - \cdots - a_{2n}X_n = 0 \\
X_3 &= a_{31}X_1 - a_{32}X_2 - \cdots - a_{3n}X_n = 0 \\
&\vdots \\
X_n &= a_{n1}X_1 - a_{n2}X_2 - \cdots - a_{nn}X_n = 0
\end{align*}
$$

[2.1]
This system of equations represents nothing but Walras' law — that aggregate demand and aggregate supply are equal and that, if any one market (sector) is not in equilibrium, there must be at least one other also not in equilibrium. That is to say, if the right-hand side of one of the equations in the above system is not zero, there must be another equation whose right-hand side is nonzero. We may write [2.1] as

\[(I-A)X = \emptyset\]  

[2.2]

where

- \(I\) is an \(n \times n\) identity matrix
- \(\emptyset\) is an \(n\)-dimensional null vector
- \[X = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{bmatrix}\]
- \[A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}\]

\(X_j\) and \(a_{ij} \geq 0\) for all \(i\) and \(j\)

This is known as the Leontief closed input-output model. It is closed because it is defined to include the household as well as the foreign trade sector. If \((I-A)\) is nonsingular, the only solution for \(X\) is zero. Therefore, in order for [2.2] to have a nonzero solution, the determinant \(|I-A|\) must be zero; that is, one of the equations in [2.2] must be a linear combination of the rest of the equations in the system. To find a nonzero solution, the value of one of the \(X_j\)'s, say \(X_g\), is
specified to be $x_s$ where $1 \leq s \leq n$ and then substituted into [2.2]. The $s^{th}$ equation is deleted from the system; [2.2] can then be rewritten as

$$(I-A^*)x^* = a_s x_s \tag{2.3}$$

where

$I$ is an $(n-1) \times (n-1)$ identity matrix

$X^*$ is an $(n-1)$-dimensional vector whose elements are

$$x_1, x_2, \ldots, x_{s-1}, x_{s+1}, \ldots, x_n$$

$A^*$ is the $A$ matrix without the $s^{th}$ row and column, hence of order $(n-1) \times (n-1)$

$a_s$ is an $(n-1)$-dimensional vector whose elements are

$$a_{1s}, a_{2s}, \ldots, a_{ns}$$

$x_s$ is a known quantity

If $(I-A^*)^{-1}$ exists, then the solution $X^*$ is given by

$$X^* = (I-A^*)^{-1}a_s x_s \tag{2.4}$$

To insure that $X^*_j's \geq 0$, the Hawkins-Simon condition (24) must hold. From this we are led to the so-called Leontief open input-output model, which is designed to find how much each economic sector should produce to satisfy the bill of final demands. The household sector is not included in this model but appears in the bill of final demands. The "open" version can be expressed as

$$(I-A)X = Y \tag{2.5}$$

where
I and A are \((n-1)\times(n-1)\)

\(X\) and \(Y\) are \((n-1)\times1\)

\(X_j\)'s and \(Y_j\)'s \(\geq 0\) for \(j = 1, \ldots, n-1\)

I, A and X are similarly defined as above, except that the household sector is excluded. \(Y\) is a vector for the bill of final demands which expresses how much of each commodity the economy demands. It can be seen that \([2.5]\) is nearly identical with \([2.3]\). If \((I-A)\) is nonsingular and the Hawkins-Simon condition holds, the optimal solution of \(X\) is given by

\[ X = (I-A)^{-1}Y \]  

[2.6]

Knowing \(Y\) and \(A\), \(X\) can easily be calculated. The fundamental idea underlying the input-output models is very simple and can be extended to a multiperiod analysis.

The following model restricts itself to represent largely agriculture, though it can be extended to incorporate the entire economy. The objective is to seek an intertemporal pattern of optimal product mix over a planning horizon of \(T\) periods. For each \(t\)\(^{th}\) period, the final demand for each of the \(n\) farm commodities is specified. We wish to know how much each of these commodities should be produced in order to satisfy its demand.

Let \(X_{it}\) be the amount of the \(i\)\(^{th}\) commodity which is supplied to meet the demand for it by the end of the \(t\)\(^{th}\) period. Let \(Y_{it}\) be the amount of the \(i\)\(^{th}\) commodity which is demanded at the end of the \(t\)\(^{th}\) period by, firstly, the consumer sector which may include net export and, secondly, the stock required for production in the following \((t+1)\)\(^{st}\) period. \(i = 1, 2, \ldots, n\) and \(t = 1, 2, \ldots, T\).
If $A$ is the matrix of the input-output coefficients, then $X$ is such that

$$(I-A)X = Y$$  \hspace{1cm} [2.7]$$

where

$I$ is an $nT \times nT$ identity matrix  

$A$ is a block-diagonal matrix of the order $nT \times nT$, with each block representing a particular technology in the corresponding time period

$$
\begin{bmatrix}
X_{11} \\
X_{21} \\
\vdots \\
X_{nT}
\end{bmatrix}
= 
\begin{bmatrix}
Y_{11} \\
Y_{12} \\
\vdots \\
Y_{nT}
\end{bmatrix}
$$

$X_{it} \geq 0$ for all $i$ and $t$

Following the definition of $A$, if $A_t$ is the $n \times n$ technological matrix, prevailing in the $t^{th}$ period, then $A$ is block-diagonal with $A_1, A_2, \ldots, A_n$.

The solution for [2.7] is not apparent because $Y$ contains unknown commodity stocks. In fact, $Y = C + S$ where $C$ and $S$ are vectors of final consumption and stock requirements respectively. Assume $S$ to be proportional to $X$. In particular, let $s_{it} = b_{i,t+1}X_{i,t+1}$ where $s_{it}$ is the stock of the $i^{th}$ commodity required at the end of the $t^{th}$ period; $b_{i,t+1}$ is a known nonnegative constant. This assumption states that the stock
requirement in the current period is determined by the amount to be produced in the following period.

We have

\[ Y = C + S \]  \hspace{1cm} [2.8]

\[ = C + BX \]  \hspace{1cm} [2.9]

where

\[
C = \begin{bmatrix}
C_{11} \\
C_{21} \\
\vdots \\
C_{nT}
\end{bmatrix}
\]

\[
S = \begin{bmatrix}
S_{11} \\
S_{21} \\
\vdots \\
S_{nT}
\end{bmatrix}
\]

\[
B = \begin{bmatrix}
\emptyset & B_2 & \emptyset & \cdots \\
\emptyset & \emptyset & B_3 & \cdots \\
\emptyset & \emptyset & \emptyset & \cdots \\
\vdots & \vdots & \vdots & \ddots \\
& & & & B_T \\
& & & & \emptyset
\end{bmatrix}
\]

\[
B_{t+1} = \begin{bmatrix}
b_{1,t+1} & 0 & 0 & \cdots \\
0 & b_{2,t+1} & 0 & \cdots \\
\vdots & \vdots & \ddots & \cdots \\
& & \ddots & \emptyset \\
& & & b_{n,t+1}
\end{bmatrix}
\]

\[ \emptyset \text{ is an nxn null matrix} \]
Substituting [2.9] into [2.7], we obtain

\[(I-A)X = C + BX\]

\[[I-(A + B)]X = C\]

i.e., \[X = [I-(A + B)]^{-1}C\] \hspace{1cm} [2.10]

If the Hawkins-Simon condition holds and \([I-(A + B)]\) is nonsingular, [2.10] is optimal. The goal which this model attempts to accomplish may be restated as: To find optimal production arrangements consistent with the demands such that the agricultural sector is in equilibrium in each time period and that, by the end of the planning period, some certain specified amount of capital stocks is left over for future consumption and production purposes.

One difficulty inherent in the model is the fact that the amount of commodity stocks at the beginning of the planning period cannot be controlled. If it were fixed, production in the first period may not be consistent with the corresponding demand requirements, since it is determined by the stocks of the last period. To overcome this difficulty, it may be assumed that the stocks at the beginning of the first period are sufficient for production during that period.

The input-output models are based on a number of assumptions, some of which are stated above. The most crucial assumption is the constancy or fixity of the technical coefficients. This is not taken to mean simply that the production technology changes over time. These coefficients are not really given constants for any one time period but do vary with some uncontrolled factors, e.g. the weather. It frequently appears that,
after discounting for the time trend, the input-output coefficients show marked fluctuations. This problem brings us to another type of model: the stochastic input-output model, in which A is no longer fixed but random, although Y is still known with complete certainty.

C may be estimated in three obvious ways. First, it may be specified quite independently of other considerations by the policy making body, e.g. 300,000 metric tons of soybeans by 1976. Secondly, it may be simply projected into the future, given time series data on consumption and other nonstock uses. The third method is more acceptable, in which case C is thought to be theoretically dependent on a number of variables. The functional form is specified and then statistically estimated. From this, by preassigning the value of independent variables, future requirements can be evaluated. B can be estimated by acquiring the knowledge about factor productivities. For example, if it is known that about 9.3 kgs of rice seeds are needed to grow 280 kgs of paddy rice, the corresponding b coefficient in the matrix, B, is 9.3/280 or 0.033 and the stock requirement at the current period is 0.033 times whatever the output of the next period. An introduction of new improved seeds with higher yield will certainly reduce the b coefficient and an adjustment must be accordingly made on the matrix, B.

Estimation of the a_{ij}'s is restricted, without loss of generality, to a simple case of sugar production by sugar cane. Assume that, during the \( t \)th period, \( z_{1t} \) tons of sugar cane have been used to produce \( z_{2t} \) tons of sugar by the sugar industry. Hence, \( z_{1t}/z_{2t} \) is the conversion factor which indicates how much sugar cane is needed to produce a ton of sugar. Over time, \( z_{1t}/z_{2t} \) is not constant but may be postulated to be a function
of time, representing technical change, and unidentifiable or random components; that is:

\[ \frac{z_{1t}}{z_{2t}} = f(k, t, e_t) \] \[ \text{[2.11]} \]

where

\( k = \text{constant} \)
\( t = \text{time} \)
\( e_t = \text{error associated with the } t^{th} \text{ observation} \)

An operational functional form may be expressed as

\[ \frac{z_{1t}}{z_{2t}} = k + ct + e_t \] \[ \text{[2.12]} \]

By the method of the simple least squares, \( k \) and \( c \) can be estimated and subsequently \( \frac{z_{1t}}{z_{2t}} \). This \( \frac{z_{1t}}{z_{2t}} \) is the input-output coefficient, representing the estimated amount of sugar cane required by the sugar industry in order to produce a ton of sugar. This procedure is repeated for other production activities until all \( a_{ij} \)'s are estimated. The solution for \( X \) follows from [2.6].

The input-output model of agriculture offers several interesting comments. Resources and primary commodities not included explicitly in the model are assumed to be sufficiently available. Otherwise the model cannot operate and consequently has no practical value in planning. The fact that the model allows for only one production process for each production activity implies that, if there were more than one process, the choice must be made independently of the model. It seems more desirable to let the model select the best (least cost) technology by
itself, for it would utilize information inherent in itself more fully in establishing a selection criteria. Linear programming can incorporate more than one production process and, at least in this aspect, is superior to the input-output technique.

Consider the case where $A$ is no longer fixed but a matrix of random variables. For illustrative purposes, let us return to the previous example of sugar production. Replacing $c$, $k$ and $e_t$ in [2.12] by their estimates, we have

$$\frac{(z_{1t}/z_{2t})}{\hat{c}_t} = \hat{k} + \hat{e}_t$$

[2.13]

The left-hand side of [2.13] is the value of the input-output coefficient, adjusted for the effect of time. It is not a constant, since the right-hand side contains the estimated error component. When it comes to actual applications, $A$ may be replaced by its expected value, $\bar{A}$. In [2.13], $E(\hat{k} + \hat{e}_t) = E(\hat{k}) = k$ since $E(e_t) = 0$, following the Gauss-Markov assumptions about least squares estimators. $\hat{k}$, together with the time effect, thus becomes a part of $\bar{A}$. This leads to the same estimate of $A$ given earlier.

A more interesting way of dealing with the stochastic $A$ is to assume $\hat{k}$ to follow some probability distribution. If $e_t$ is identically and independently distributed as normal with mean zero and unknown variance $\sigma^2$, then $\hat{k}$ will also be identically and independently distributed as normal with mean $k$ and variance

$$\lambda^2 \sigma^2 = \frac{\sigma^2}{\sum_{t=1}^{m} \frac{z_t^2}{\Sigma_{t=1}^{m} (z_t - \bar{z})^2}}$$
where $\bar{t}$ is the mean of $t$, $t = 1, \ldots, m$, and $\lambda^2$ is an obvious notation. If $\hat{\sigma}^2$ is the estimate of $\sigma^2$, then

$$\frac{\hat{k} - k}{\lambda \hat{\sigma}} \sim t \text{ with } m-1 \text{ degrees of freedom}$$

The $(1-\alpha)\times 100\%$ confidence intervals for $k$ are given by

$$\text{Prob} \left[ k - \lambda \sigma t_\alpha \leq \hat{k} \leq k + \lambda \sigma t_\alpha \right] = 1 - \alpha$$

i.e. Prob $[k_0 < k < k_1] = 1 - \alpha$

where $t_\alpha$ is such that, for $0 \leq \alpha \leq 1$,

$$\text{Prob} \left[ |t| < t_\alpha \right] = 1 - \alpha$$

Each of $k_0$ and $k_1$ is then added with the effect due to time and substituted appropriately in $A$. This process is done similarly to other elements of $A$. If $A$ is $n \times n$, up to $2^n$ different sets of $A$ can be found, since there are two values for each element. Corresponding to each set, a solution for $X$ may be computed, depending on the nonsingularity of $(I-A)$. Since a maximum of $2^n$ different solutions can be obtained, the choice over which of these planning formulations should be followed offers a real difficulty without a specific decision making criterion. We may group among these solutions into classes and determine what class(es) occurs most frequently. This is the way by which the field is narrowed down. A random selection may then be made.

Admittedly, the above method is very approximate and it does not insure feasibility and optimality of the solution. It is plausible up to the point where it is recognized that uncertainties always prevail. Another method exists which is concerned with the derivation of the
probability distribution of individual X's. Some measures of centrality, e.g. means or modes, can serve as a basis for making a policy choice. This method, apparently more efficient and requiring less computational effort, is described in detail in Babbar (2, pp. 854-869).

One of the difficulties in the input-output model is that, when fixed on time series data regarding estimation, it restricts planning possibilities to "what has prevailed in the past." With the conventional input-output model we not only lose much flexibility in interregional possibilities of shifting crop distribution and land allocation, but also are unable to evaluate specific projects within the context of economic planning.

However, if we are willing to assume that there is only one resource to be economized, then the input-output model can be readily transformed into a linear program. This property enables us to deal with multiple processes if such problem arises. It is intuitive, and can be proved, that the optimal feasible solution to the corresponding linear program is also optimal and feasible for the original input-output model. Barring the possibility of joint products, linear programming will choose among various processes those which cost the least. The least-cost combination will always be optimal, irrespective of the size of the final demands, because having only one scarce resource implies that relative prices cannot change once optimality is determined and maintained. This is known as the substitution theorem (13, pp. 224-226).
Linear Programming Models

Linear programming offers a more flexible approach to economic planning problems. It allows for the incorporation of inequality constraints and specifies the objective function to be maximized (or minimized). In general, a linear programming maximization model can be expressed compactly as

To maximize \( c'X \)

subject to \( AX \leq b \)

and \( X \geq 0 \) \[2.14\]

where

- \( X \) is \( n \times 1 \)
- \( A \) is \( m \times n \)
- \( b \) is \( m \times 1 \)
- \( c \) is \( n \times 1 \)

An example of the above model is: To find how much \( X \) should be produced in order to maximize the net revenue obtained from sales of \( X \) less production and marketing costs, subject to the constraints that resources used must be no larger than some specified limit \( b \). \( A \) is a matrix of the technical coefficients. Each \( a_{ij} \) in \( A \) tells us how much of the \( i^{th} \) resource is required to produce a unit of the \( j^{th} \) commodity. If \[2.14\] is a primal linear program, its dual may be stated as

To minimize \( b'Y \)

subject to \( A'Y \geq c \)

and \( Y \geq 0 \) \[2.15\]

where \( Y \) is \( m \times 1 \) and \( A, b \) and \( c \) are as before.
The corresponding example of the dual is as follows: To determine \( Y \) such that the total factor costs are minimized, subject to the constraints that per unit cost must be at least equal to per unit net revenue. \( Y \) is really a vector of shadow prices. If any resource is not all used in production, i.e. if optimization requires less than the amount available, its shadow price falls to zero. One of the fundamental theorems in linear programming is that the value of the objective function corresponding to the optimal feasible solution of the primal linear programming problem and of its dual is identical; that is, if \( X_0 \) and \( Y_0 \) are solutions to [2.14] and [2.15] respectively, \( c'X_0 = b'Y_0 \).

Knowing all \( A, b \) and \( c \), the linear programming problem can be solved in a number of ways. For \( m \) or \( n \leq 2 \), it may be solved by the graphical method or often merely by inspection. For \( m \) and \( n > 2 \), it is easier to use the simplex or revised simplex method. These methods are described elsewhere (5, pp. 75-97; 27; 30, pp. 138-160).

As for estimation of the parameters of the model, \( A \) may be estimated in the same way as outlined in the input-output models. Certain elements in \( A \) may be known from past experience; \( b \) and \( c \) may be either given or estimated. Linear programming has a wide range of applications, one of which is to find an optimal resource allocation and production distribution among regions of an economy such that the demand in each region is met and that the costs of production and transportation are minimized. This is a model of interregional competition with which we will deal extensively later. For this reason, the estimation of \( A, b \) and \( c \) is postponed.

A number of refinements have been made to linear programming both in theory and as a research tool. In some instances, the solution to a
linear programming problem is required to be integer. For example, a fraction of a tractor is physically meaningless and if in fact the solution gives rise to this, rounding off numbers does not insure optimality nor feasibility. To obtain an optimal feasible solution calls for the method of integer linear programming.

We may wish to investigate the effect of changes in the value of $b$ or $c$. In [2.14], $c$ may be the net revenue vector and $X$ indicates how much of the commodities should be produced. If one of the elements in $c$ takes on a series of values, $X$ is certain to change. Putting it differently, this is a problem of developing a steplike supply function in which we want to know how the supply of a commodity changes when its net price changes from one level to another. The study about changes in $b$ and $c$ is known as parametric linear programming. Methods of finding a solution for integer and parametric linear programming problems may be found elsewhere (30, pp. 499-504 and pp. 555-561).

Linear programming is based on a number of assumptions: proportionality or constant returns to scale, divisibility and additivity or independence among activities. When the assumption on divisibility is violated, i.e. when the solution is required to be integer, integer linear programming results. Under conditions of nonconstant returns to scale to which linear programming cannot be applied, the method of nonlinear, e.g. quadratic programming, may be sought for in finding an optimal solution. Statistical estimation on the parameters of the model again reinforces the fact that they are not constants but have both means and variances. To allow for variations in $A$, $b$ and $c$, linear programming is modified. Three general methods are available: stochastic linear programming,
chance-constrained programming and two-stage programming under uncertainty. Stochastic linear programming is concerned with the problem of approximating the distribution function of the objective function when it is at its optimum. Chance-constrained programming considers the objective and the constraints as having a certain probability of occurrence. The original problem can then be transformed to a nonlinear programming problem which may be solved by using the Kuhn-Tucker optimality conditions. The last approach to linear programming with random elements, two-stage programming under uncertainty, involves a minimization of a penalty cost which is incurred when some constraints are violated. We shall consider all these approaches in more detail later in Chapter VI.

Econometric Models

Econometric models are superior to the previous types of mathematical models in some ways. Whereas the input-output models are not so flexible as to allow for optimization of some general economic criterion and whereas linear programming in itself has no economic content, though it has extensive economic implications, econometric models do exhibit causal relationships among economic variables in such a manner that they enable us to throw some light onto the effect on the economic structure of a change in one or more variables. An econometric model consists of a set of equations which may be structural, definitional or in equilibrium form. A simple demand-supply model may be exemplified as

\[ Q_d = f(\text{own price, price of closely substitutables, tastes, income, etc.}) \]  

[2.16]
\[
Q_s = f(\text{own price, factor price, etc.}) \quad [2.17]
\]

\[
Q_d = Q_s \quad [2.18]
\]

The first two equations are the demand and supply functions respectively. They tell us what variables are important in determining the demand for, and the supply of, a commodity. Equation [2.18] expresses an equilibrium condition. Leftover stocks can easily be incorporated to make the model more realistic. With this simple model in mind, we can proceed to build a larger model.

The following is an attempt to construct an econometric model of Thai agriculture which would be operational in the sense that it is applicable and, when applied, would yield valuable quantitative information about how the economic mechanism of the largely specialized agriculture operates.

We shall start off with building up a model for rice and, from there, generalize to an aggregate model of agriculture. Rice trade appears to be as complex as trade in any other commodity can be. Paddy rice produced at the farm level flows through several channels, notably the middlemen, the rice mills, the wholesalers and the retailers, before it finally is consumed. As it passes from hand to hand, its price increases and this has led to an allegation that the business media serving between the producers and the ultimate consumers make disproportionately large profits, while the producers themselves do not receive the share of farm income rightly accrued to them.

Several studies have been made on the marketing of farm products in different regions. The flow charts of rice from the farm gate to the household sector for eight provinces north of the Central Region and for
eight provinces in the Northeast are reproduced with some minor changes, mainly in translation, from (67, Figure 7, p. 57; 64, Figure 5, p. 18). The new flow charts are given in Figures 2 and 3. In Figure 2, if the amount of paddy rice is set at 100 at the farm level, 25.87 of it flows to the first group of middlemen, 24.47 to the second group, 2.59 to the third group, 22.75 to the local rice mills, 16.56 to the provincial rice mills and 7.76 to the retail rice mills. Similar descriptions can be made on other connecting points (or nodes). As these charts are complex, they have to be modified greatly in order to generate a relatively simple econometric model. Figure 4 is a modification of Figure 2, representing only the main branches of the rice trade flow, whereas similar nodes, e.g. groups of middlemen, are aggregated. Also, Figure 3 may be modified in the same manner. If it can be assumed that Figure 4 approximates the actual trade flow, it is evident that the farm supply of rice is a function of, among other things, what the middlemen and the rice mills offer to pay for or, more logically, the price the producers expect to receive. The demand for paddy rice at the farm gate consists of two components, the demand by the middlemen and the demand by the rice mills. These demand components are determined by a range of factors, since they do not directly satisfy the final demand. For this reason we consider only the final demand components -- the consumer demand and the demand for exports. For the first part of our econometric model we have a supply function, a set of final demand functions, an equilibrium relation and an equation for stocks. On the basis of the theories of the consumer and the firm, these relationships may be expressed as follows:
Figure 2. Flow of rice marketing in eight North Central provinces during June, 1968-May, 1969

A = Farmers
B = First group of middlemen
C = Second group of middlemen
D = Third group of middlemen
E = First group of dealers
F = Local rice mills
G = Provincial rice mills
H = Second group of dealers
I = Retail rice mills
J = Wholesalers
K = Retailers
L = Consumers
M = Exporters
Figure 3. Flow of rice marketing in eight Northeastern provinces during June, 1963-May, 1964

A = Farmers
B = Local middlemen
C = District and provincial dealers
D = Local rice mills
E = District and provincial rice mills
F = Laos
G = Exporters
H = Wholesalers
I = Retailers
J = Consumers
Figure 4. Main branches of the flow as modified from Figure 2
\[ y_1 = f(y_5, x_1, x_2, x_3) \] [2.19]
\[ y_2 = f(y_8, y_9, x_4) \] [2.20]
\[ y_3 = f(x_6, y_{10}) \] [2.21]
\[ y_1 = a(y_2 + y_3) + y_4 \] [2.22]
\[ y_4 = f(x_2) \] [2.23]

where

- \( y_1 \) = the amount of paddy rice supplied at the farm gate
- \( y_2 \) = the amount of milled rice demanded by consumers
- \( y_3 \) = the amount of milled rice exported
- \( y_4 \) = the amount of paddy rice currently in stock for future production
- \( y_5 \) = the price paid to the farmers
- \( y_8 \) = the price paid to the wholesalers
- \( y_9 \) = the price paid to the retailers
- \( y_{10} \) = the price of rice exports
- \( x_1 \) = the weather index
- \( x_2 \) = the amount of paddy rice stock in the immediate past period
- \( x_3 \) = the average price of inputs
- \( x_4 \) = the average per capita real income
- \( x_6 \) = the world price of milled rice
- \( a \) = the conversion factor by which milled rice is converted into paddy rice equivalent
Also, let

\[ y_6 = \text{the price paid to the middlemen} \]
\[ y_7 = \text{the price paid to the rice mills} \]
\[ x_5 = \text{the amount of rice premium paid to the government, plus other expenses incurred in exporting rice} \]

Equations [2.19] through [2.23] are essentially a restatement of [2.16], [2.17] and [2.18]. In particular, [2.19] is the supply function of paddy rice. The price at which farmers receive is made dependent on the system, i.e. it is determined by the market equilibrium condition in [2.22]. Final demands are given in [2.20] and [2.21]. Since consumers do not, in most cases, pay directly to rice farmers, their demand is a function of prices they pay to wholesalers and retailers. This is in accordance with the arrow direction of flow in Figure 4. Equation [2.23] postulates that the amount of stocks by the end of the current period depends upon what has been stocked in the preceding period.

Except the average price of inputs, all prices are dependent variables. As rice flows from farmers to final consumers, its price increases. The extent of the increase depends largely on the market demand-supply conditions surrounding primary producers on the one hand and final consumers on the other hand. Thus it appears reasonable to suppose that the difference in the price paid to farmers and received by the middlemen is a function of the price paid to farmers. This argument applies to other successive price increases. We now have

\[ \Delta y_5 = f(y_5) \]  

[2.24]
\Delta y_6 = f(y_5, y_6) \quad [2.25]

\Delta y_7 = f(y_5, y_6, y_{10}) \quad [2.26]

\Delta y_8 = f(y_5, y_6, y_{10}) \quad [2.27]

where $\Delta$ = incremental price increase such that

\[ y_{i+1} = y_i + \Delta y_i \quad [2.28] \]

\[ i = 5, 6, 7, 8 \]

The reason why $y_{10}$ is included in [2.26] and [2.27] is that exports are in direct competition with domestic demand and thus the export price must exert some influence upon the pricing mechanism. By definition, it is clear that

\[ y_{10} = y_7 + x_5 \quad [2.29] \]


Net income of the farmers is the excess of the total revenue received over the total costs. Assuming that resource use is dependent on production, the total costs are then a function of the amount produced and the average input price. If $y_{11}$ = net income received by farmers,

\[ y_{11} = f(y_1, y_5, x_3) \quad [2.30] \]

Similarly, net income received collectively by middlemen, millers, wholesalers and retailers may be conceived of as dependent on domestic and foreign demands, and incremental price increases.
If \( y_{12} \) = net income of these groups, then

\[ y_{12} = f(y_2, y_3, \Delta y_5, \Delta y_6, \Delta y_7, \Delta y_8) \]  

[2.31]

This completes our model which altogether has 16 equations, 4 of which are contained in [2.28] alone. There are 16 dependent or endogenous variables, represented by the \( y \)'s; the remaining 6 variables are independent or exogenous and represented by the \( x \)'s. More variables may be added, e.g. time to allow for change in technology or tastes insofar as they are appropriate. Some variables are decidedly excluded from the model because of the lack of data, e.g. the costs incurred among middlemen, wholesalers, etc. which logically determine their income. At any rate, added variables often cause considerable additional workload when the model is applied.

In actual statistical estimation, the simultaneous equations may be specified in a linear or log-linear form and then fitted by multiple-stage least squares. Equations [2.19] through [2.30] are all over identified while [2.31] is just identified. The applied model can be used to investigate how variations in the price that farmers receive create price differentials among the interconnecting groups, as rice is delivered ultimately to the consumers or overseas. In other words, it offers as a distinct possibility of determining if a price support program can be successful and evaluating the extent of, if it exists at all, the alleged monopsony profits extracted from subsistence farmers. Two points need to be clarified with regard to the price support program. Firstly, the program itself has been applied in the past, but only sporadically. This justifies our treatment of the rice price as being a dependent variable.
Secondly, if the program is to be maintained on a more permanent basis in the future, the model must be reformulated accordingly whereby price is made a predetermined variable instead.

The econometric model of Thai agriculture follows more or less along the same line as the rice model. Agriculture, as a whole, is thought of as containing two subsectors -- the farm producing subsector and the farm marketing subsector. Two major types of commodities are produced: crops and livestock products. There are then two sets of functions similar to (2.19) through (2.23). Stocks are not included in the model for two reasons. If stocks are assumed to be a simple function of lagged supply, then supply in the current period which is determined by stocks at the end of the last period is dependent on lagged supply. In this case, stocks need not be incorporated explicitly into the model. Another reason is that the time series data on the value of stocks are not available.

Services provided by middlemen, processing firms, wholesalers and retailers are grouped under a single heading for each type of commodities. There are two equations for the total charges for marketing services. Farm income is the excess of farm revenue over farm expenditures. The entire model may be represented by the following 13 equations involving 13 endogenous and 11 exogenous variables.

\[
\begin{align*}
Y_1 &= f(Y_6, Y_7, X_1, X_2, X_3) \\
Y_2 &= f(Y_6, X_7) \\
Y_3 &= f(Y_8, X_3, X_4, X_5, X_{10}) \\
Y_4 &= f(Y_6, Y_7, X_1, X_2, X_3, X_7)
\end{align*}
\]
\[ Y_5 = f(Y_9, X_3, X_6, X_7, X_{11}) \]  
\[ Y_1 + Y_2 = Y_3 + Y_{10} \]  
\[ Y_4 = Y_5 + Y_{11} \]  
\[ Y_6 = f(Y_8) \]  
\[ Y_7 = f(Y_9) \]  
\[ Y_{10} = f(Y_1, Y_2, Y_6, X_3, X_8) \]  
\[ Y_{11} = f(Y_4, Y_7, X_3, X_9) \]  
\[ Y_{12} = f(Y_3, Y_5, X_3, X_5, X_6) \]  
\[ Y_{13} = (Y_3 + Y_5) - Y_{12} \]  

where

- \( Y_1 \) = the retail value of all crops (food, feed and fiber) consumed domestically
- \( Y_2 \) = the value of all crops exported
- \( Y_3 \) = the value of all crops at the farm level
- \( Y_4 \) = the retail value of livestock products
- \( Y_5 \) = the value of livestock products at the farm level
- \( Y_6 \) = the average retail price index of all crops
- \( Y_7 \) = the average retail price index of livestock products
- \( Y_8 \) = the index of the average price received by crop producers
- \( Y_9 \) = the index of the average price received by livestock producers
\( Y_{10} \) = the value of total charges for crop marketing services
\( Y_{11} \) = the value of total charges for livestock marketing services
\( Y_{12} \) = the total farm production cost
\( Y_{13} \) = net farm income received by all farmers

\( X_1 \) = per capita real income
\( X_2 \) = the average retail price index of nonfarm commodities
\( X_3 \) = time
\( X_4 \) = the weather index
\( X_5 \) = the index of the average price that crop producers pay for goods and services used in production
\( X_6 \) = the index of the average price that livestock producers pay for goods and services used in production
\( X_7 \) = the average export price index
\( X_8 \) = the index of costs associated with crop marketing services
\( X_9 \) = the index of costs associated with livestock marketing services
\( X_{10} \) = the value of all crops at the farm level in the preceding period
\( = \) lagged \( Y_3 \)
\( X_{11} \) = the value of livestock products at the farm level in the preceding period
\( = \) lagged \( Y_5 \)

Equations [2.32] and [2.33] are functions of domestic and foreign demands for crops which include food, feed and fiber products. Since consumer expenditures take place in exchange of either farm (crop or
livestock) or nonfarm products, consumer demand for farm products depends, to some extent, on the price of both farm and nonfarm products or their price ratio. Hence, the demand for crops depends on the price indices of crops, livestock products and nonfarm commodities also. The foreign demand for crops has one distinguishing feature unlike [2.21]. The average export price index is assumed to be exogenous. Since Thailand is one of the major suppliers of rice, she is able to influence movements in world price and supply, and this is why the export price of rice may be affected by the domestic price level. But when a number of commodities are considered, this influence disappears so that the average export price level is made independent of the variables within the model. The supply function of crops is given by [2.34] which, as mentioned above, depends on, among other things, lagged supply. Equations [2.35] and [2.36] represent the demand and supply functions of livestock products. Equations [2.37] and [2.38] are definitions which state essentially that the retail value of each type of farm commodities is equal to the value that the producers receive plus the total charges for marketing services.

Equations [2.39] and [2.40] postulate that there is a simple relationship between the retail price index and the index of prices paid to farmers for each type of farm commodities. When the retail price index for a commodity increases, the corresponding farm price is expected to rise also. Alternatively, [2.39] and [2.40] may be replaced by functions expressing a relationship between percentage change in the retail price index and percentage change in the farm price facing farmers. We may postulate in still another way analogous to [2.24] through [2.28] that the portion of the average retail price is a function of the average price
farmers receive. These alternatives are refinements to the model and do not drastically affect its economic interpretation.

Equations [2.41] and [2.42] are, respectively, the value charged for services rendered in marketing crops and livestock products. They depend on the retail value and price of marketed commodities, time and the average marketing costs. Total farm expenditures as incurred to both crop and livestock producers are a function of the farm value they receive, time and the average factor cost. This is given in [2.43]. Actually, if the index of agricultural production (which measures the physical volume of farm commodities produced) is available, total farm expenditures should be made a function of this index rather than the farm value received. Equation [2.44] is an identity showing that net farm income for both crop and livestock producers is the difference between gross farm revenue and farm expenditures.

All equations are at least identified when specified in linear or log-linear form. If some are specified to be linear in unknown parameters but nonlinear in variables, the problem of identification arises since the rank conditions are valid only for all linear cases. The determination of identifiability of these equations has been developed elsewhere (17). With all specified equations at least identified, the model can be fitted by various estimation methods, e.g., multiple-stage least squares. Several uses may be made of such a model. The possibilities of increasing farm income through policy instruments such as subsidized input prices, improved transportation facilities which result in lower marketing costs, and farm price support programs could be investigated and compared. For illustrative purposes, the 13-equation model is represented in a matrix form.
in Table 2. The rows represent the various equations in the model, while the variables are entered as columns. The a's which may be of either signs are coefficients attached to variables indicated in the column headings directly above them. The 1's and -1's are coefficients assigned to variables which are endogenous to the system. It is evident that any row that has only 1's and -1's apart from zeros refers to either an identity or an equilibrium relationship. Suppose that the government wishes to evaluate the effect of a price subsidy program in a form of lower fertilizer costs on agriculture as a whole. Since \( X_5 \) is the index of prices paid by farmers, the program can be translated as to mean a decline in \( X_5 \). From Table 2, there are only two nonzero elements in the \( X_5 \) column, indicating that a change in \( X_5 \) brings about a direct change in two \( Y \) variables. These elements are in rows [2.34] and [2.43]. From row [2.34], \( Y_3 \) is directly affected which, in turn, affects three other variables. This stems from the fact that altogether four elements enter the \( Y_3 \) column. Similar steps may be traced for the effects of the change in these variables. This process can also be conducted for row [2.43] and it is not surprising to find that a change in \( X_5 \) does affect more or less the entire agricultural sector.

In this way, econometric models can be employed as a policy evaluating tool. As for planning purposes, they are useful in that they can be developed to incorporate all sectors of the economy. The degree of importance in intersectoral relationships serves as a criterion by which a policy or a set of policies may be selected in preference to some others. However, when complete detailed planning, e.g. interregional planning, is required, econometric models become tediously large and lacking of proper
Table 2. Econometric model of agriculture in matrix form

<table>
<thead>
<tr>
<th>Equation</th>
<th>$X_1$</th>
<th>$X_2$</th>
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interpretations. The extent of complexities may be too difficult to cope with in equational form. For these reasons, either input-output or linear programming models are sought for. But input-output models have several limitations of their own. For example, there are no constraints on resources used — at least on those resources which do not appear in the models. Linear programming, on the other hand, seems to offer greater flexibilities in formulating a model of interregional planning.
CHAPTER III: THAILAND IN AN INTERNATIONAL ECONOMY

Importance of International Trade in Economic Development

International trade is extremely vital to economic development, for it provides an escape valve for surplus crops and, by trading, industrial goods can be obtained which may be relatively expensive if produced domestically. Imports of heavy equipment and machinery can accelerate the rate of economic development since the need of having first to develop heavy industries, thus exerting more pressure on scarce resources, is eliminated. At some later stage the economy can be geared toward industrialization. From all indications Thailand seems to have been on the verge of that stage, but the opportunity to industrialize which was there had not been taken fully to her advantage.

From Table 3 it is evident that the value of imports increased by far more than that of exports. From 1957-70 imports were rising at an annual rate of some 15%, whereas the rate of the increase in exports was about 7%. No doubt the stagnant growth in exports was partly due to the nature of the exported commodities but, if goods were selectively imported, a considerable portion of foreign exchange could have been saved. For example, the five-year average value of imported foodstuffs during 1961-65 was B 820 million but in 1966 it totaled B 2,173 million, an increase of 165%. For the same periods, the value of alcoholic beverages went up from B 19 million to B 527 million, a spectacular 27-fold increase (73, pp. 330-331). A corrective policy to meet this problem at least in the short run is that some sort of quantitative restrictions be effectively raised on certain imported items and/or import tax be increased.
Table 3. Thai external trade

<table>
<thead>
<tr>
<th>Year</th>
<th>Exports millions of baht</th>
<th>Imports millions of baht</th>
<th>Balance of trade millions of baht</th>
</tr>
</thead>
<tbody>
<tr>
<td>1957</td>
<td>7,540</td>
<td>8,537</td>
<td>- 997</td>
</tr>
<tr>
<td>1958</td>
<td>6,447</td>
<td>8,237</td>
<td>- 1,790</td>
</tr>
<tr>
<td>1959</td>
<td>7,560</td>
<td>8,988</td>
<td>- 1,428</td>
</tr>
<tr>
<td>1960</td>
<td>8,614</td>
<td>9,622</td>
<td>- 1,008</td>
</tr>
<tr>
<td>1961</td>
<td>9,997</td>
<td>10,287</td>
<td>- 290</td>
</tr>
<tr>
<td>1962</td>
<td>9,529</td>
<td>11,504</td>
<td>- 1,975</td>
</tr>
<tr>
<td>1963</td>
<td>9,676</td>
<td>12,803</td>
<td>- 3,127</td>
</tr>
<tr>
<td>1964</td>
<td>12,339</td>
<td>14,253</td>
<td>- 1,914</td>
</tr>
<tr>
<td>1965</td>
<td>12,941</td>
<td>15,433</td>
<td>- 2,492</td>
</tr>
<tr>
<td>1966</td>
<td>14,099</td>
<td>18,504</td>
<td>- 4,405</td>
</tr>
<tr>
<td>1967</td>
<td>14,166</td>
<td>22,188</td>
<td>- 8,022</td>
</tr>
<tr>
<td>1968</td>
<td>13,679</td>
<td>24,103</td>
<td>-10,424</td>
</tr>
<tr>
<td>1969</td>
<td>14,722</td>
<td>25,966</td>
<td>-11,244</td>
</tr>
<tr>
<td>1970</td>
<td>14,772</td>
<td>27,009</td>
<td>-12,237</td>
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</table>

^Source: (4, pp. 43-44).

^The last column is derived from the first two. No provision is given to the imports of nonmonetary goods which amount to well over B 100 millions annually since 1962 (4, p. 68).

In view of Thailand as a food surplus country, some foodstuffs purchased from the rest of the world could well be classified as a luxury. As for alcoholic beverages, an increase in import duty is not likely to hurt those domestic consumers who usually belong to high income brackets so as to be able to consume them. With a steady deterioration in the balance of trade deficits and possible unfavorable balance of payments, it appears inevitable that the import policy will be drastically revised. The world monetary crisis in 1971 would work only to hasten the process, for it generated uncertainties over change in exchange rates and serious questioning on the wisdom of the fixed exchange rate system. If anything, it would slow down the movement of capital inflow and thus hamper economic development in the process.
Over the long run, import quotas are nothing but a superficial barrier to trade and free movement of resources; their real contributions to economic growth and welfare are doubtful. Since the economy's exports depend on only a few commodities — namely, rice, rubber, tin and, more recently, corn — it must strive for economic diversification to encounter the danger of export price instabilities with a resultant effect of fluctuations in export receipts. It must also utilize as efficiently as possible labor resources which are cheap and in surplus. In other words, it needs to industrialize in order to lessen the dependence on imports and to save foreign exchange through reduction in the balance of trade deficits.

Nothing so far has been discussed about the role of international institutions and regional cooperation in promoting economic development through international trade. The General Agreement on Tariffs and Trade, the International Monetary Fund and other world bodies have in general benefited the less-developed countries, although to what extent is not at all clear. It is not surprising to find that doubts are sometimes cast upon them in their ability to really solve problems of the Third World (35, pp. 68-100). Since export dependent economies have in the past experienced export price instability either due to overproduction or natural causes such as weather fluctuations, special measures have been introduced. One of these is the international commodity agreements. Their primary aim is to stabilize world prices and regulate international commodity flow. Three distinct types of the commodity agreements are the export quota, the buffer stock and the multilateral contract. Despite numerous difficulties in making a commodity agreement work, the real
underlying question remains: To what extent would it contribute to economic growth of primary exporting countries? The question has aroused much controversy and it seems best to examine the effect of commodity agreements within the context of a mathematical, theoretical model.

A Theoretical Model Analyzing the Effects of International Commodity Agreement on Economic Growth of Primary Exporting Countries

Let A and B be the only countries exporting a commodity, Z, to the rest of the world.

Let \( Q = f(p, \{x\}) \) be a function of its foreign demand where \( Q \) = the total foreign demand for Z, \( p \) = the international price of Z, and \( \{x\} \) = a sequence of independent variables affecting \( Q \).

Let \( q_A \) and \( q_B \) be the amounts of Z available from A and B respectively to meet the foreign demand.

Assume first that there is no commodity agreement between the exporters and the importers. Since there is no restriction on \( p \), an equilibrium price, \( p_e \), would be established after competitive trading such that \( Q = q_A + q_B \), for some appropriately assigned \( \{x_0\} \). If the aggregate production function of Z in B shifts up due to technical advance such that \( q_B \) is now \( \lambda_0 \% \) above the previous level, and if \( Q \) increases by \( \lambda_1 \% \) where \( \lambda_1 < \lambda_0 \), \( p_e \) will fall. It suffices to say that even though \( p_e \) falls, B's export earnings from Z relative to A's are now higher. Variations in the weather also have similar but sporadic effects, and precisely it is the instability in export earnings and fluctuations in price that have led to the evolution of international commodity agreements.

Economic growth is a long-run phenomenon characterized by a secular
rise in national income. At any time \( t \), export earnings are given by \( p_t^e q_{At} \) and \( p_t^e q_{Bt} \) for A and B respectively. For all \( t \), national income can be calculated and hence its rate of growth.

Let us now assume that the trading partners agree to fix the price of Z, say, at the level of \( p_F \). It can be seen that \( p_F \) may or may not be equal to \( p_e \), depending on whether \( Q_F = f(p_F, \{x_o\}) = q_A + q_B \). If \( p_F \neq p_e \), then excess supply is nonzero. Specifically, if \( p_F > p_e \), \((q_A + q_B) - Q_F > 0\). A point which can be inferred from this is that this excess supply for which there is no "escape valve" can represent no other than the cost to the exporting economies. If the governments lower the domestic price to increase consumption, the suppliers have to be compensated for the fallen price, or else they are faced with reduced income, given that the domestic demand for Z is price inelastic. There is a storage cost if the excess supply is stocked rather than allowed to flow through the domestic market. Even if resource transfer is allowed, the adjustment process cannot be implemented without incurring costs. If, on the other hand, \( p_F < p_e \), \( Q_F > (q_A + q_B) \). As \((q_A + q_B)\) is the total amount available, it is clear that \( p_F(q_A + q_B) < p_e(q_A + q_B) \), that is, the exporting countries receive earnings for Z less than would otherwise have been if the international price were market determined.

To the extent that \( p_F \) diverges from \( p_e \), it may then be concluded that national income stands to move in either direction under the international commodity agreement, depending on the net total benefits over total costs. Thus international commodity agreements cannot be said a priori without detailed analysis to stimulate economic growth from the exporters' point of view. World prices of primary commodities under international commodity
underlying question remains: To what extent would it contribute to economic growth of primary exporting countries? The question has aroused much controversy and it seems best to examine the effect of commodity agreements within the context of a mathematical, theoretical model.

A Theoretical Model Analyzing the Effects of International Commodity Agreement on Economic Growth of Primary Exporting Countries

Let A and B be the only countries exporting a commodity, Z, to the rest of the world.

Let \( Q = f(p, \{x\}) \) be a function of its foreign demand where \( Q \) = the total foreign demand for Z, \( p \) = the international price of Z, and \( \{x\} \) = a sequence of independent variables affecting \( Q \).

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Economic growth is a long-run phenomenon characterized by a secular
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then excess supply is nonzero. Specifically, if \( p_F > p_e \), \( (q_A + q_B) - Q_F \) 
> 0. A point which can be inferred from this is that this excess supply 
for which there is no "escape valve" can represent no other than the cost 
to the exporting economies.

If the exporting countries lower the domestic price to 
increase consumption, the cost to domestic consumers can be compensated for the fallen 
price, or else they are faced with a situation given that the domestic 
demand for \( Z \) is price inelastic. This is the case when excess supply is stocked rather 
than the domestic market. Even if resource transfers cannot be 
implemented without incurring other costs, on the other hand, \( p_F < p_e \), \( Q_F \) 
> \( (q_A + q_B) \). As \( (q_A + q_B) \) is the total amount available, it is clear that 
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national income stands to move in either direction under the international 
commodity agreement, depending on the net total benefits over total costs. 
Thus international commodity agreements cannot be said a priori without 
detailed analysis to stimulate economic growth from the exporters' point 
of view. World prices of primary commodities under international commodity
agreements would be more stable but that there is a positive connection between price stability and economic growth in terms of a rise in income is not apparent.

We have restricted ourselves to the case of fixed foreign supplies which may be regarded as a surplus after the domestic needs for Z are satisfied. If the supply of the primary exports is a function of the export price and other factors, the conclusions would be essentially the same because our analysis is demand oriented. On the cost side, the use of storage would become more prominent as it offers itself as a means by which the supply can vary with the independent variables during any given time interval. If, instead of price fixation (buffer stock), the international commodity agreement takes the form of export quotas, the conclusions still hold. The analysis would, however, be different as it concentrates more on quantities and not prices.

An implication of the above analysis is that there is a need for empirical research on the economics of international commodity agreements in which Thailand may participate, or has done so. From a planning point of view, export quotas (or guaranteed minimum price) have a distinct advantage in that they facilitate the specification of how much should optimally be produced and the resulting optimal allocation of resources.

Regional Economic Cooperation as a Long-term Solution

As far as industrialization is concerned, there are often associated problems of market limitations, economic inefficiency, diseconomies of scale and the like, facing less developed nations. In the case of Thailand, the share of the industrial sector in the GNP relative to
agriculture is large, while the bulk of the population remains in the latter sector. Agricultural population potentially has enormous demand for goods and services, but it is rather unfortunate that income and thus the purchasing power are so low that much of the demand is ineffective. If an economy is to industrialize, markets for industrial goods have to be sufficiently found. This paves a way toward regional cooperation among countries. It is visualized that, given adequate economic and political stability, Thailand, Malaysia, the Philippines and Indonesia can form a free trade area with the ultimate goal of a customs union. The idea is not new but no real attempt has been made, largely because all these countries have been, and still are, virtually continuously subject to forces of instability -- political or economic. When more is known about the mechanics of the economic system of these economies and when they can be effectively directed and controlled, regional economic planning models of a free trade area can be formulated and applied (38, esp. Ch. 2).
CHAPTER IV: AGRICULTURE AND ITS PROBLEMS

Historically, Thailand's exports are mainly agricultural and it is doubtless that, without primary commodities, the ability to earn foreign exchange would be greatly deprived of. A partial breakdown in the composition of exports is illustrated in Table 4.

Table 4. Composition of exports (in B millions)^

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<td>Rice</td>
<td>3,424</td>
<td>4,389</td>
<td>4,334</td>
<td>4,001</td>
<td>4,653</td>
<td>3,775</td>
<td>2,945</td>
<td>2,516</td>
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<tr>
<td>Rubber</td>
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<td>2,060</td>
<td>1,999</td>
<td>1,861</td>
<td>1,774</td>
<td>1,816</td>
<td>2,664</td>
<td>2,232</td>
</tr>
<tr>
<td>Tin</td>
<td>741</td>
<td>962</td>
<td>1,166</td>
<td>1,316</td>
<td>1,822</td>
<td>1,510</td>
<td>1,631</td>
<td>1,618</td>
</tr>
<tr>
<td>Maize (corn)</td>
<td>828</td>
<td>1,346</td>
<td>969</td>
<td>1,520</td>
<td>1,355</td>
<td>1,556</td>
<td>1,674</td>
<td>1,857</td>
</tr>
<tr>
<td>Cassava</td>
<td>439</td>
<td>653</td>
<td>676</td>
<td>644</td>
<td>726</td>
<td>772</td>
<td>876</td>
<td>1,223</td>
</tr>
<tr>
<td>Sugar</td>
<td>121.8</td>
<td>211.1</td>
<td>100.5</td>
<td>81.6</td>
<td>37.0</td>
<td>--</td>
<td>46.9</td>
<td>93.7</td>
</tr>
<tr>
<td>Castor seeds</td>
<td>98.3</td>
<td>90.4</td>
<td>65.7</td>
<td>96.2</td>
<td>82.7</td>
<td>82.8</td>
<td>85.9</td>
<td>92.9</td>
</tr>
<tr>
<td>Kenaf &amp; jute</td>
<td>358</td>
<td>495</td>
<td>1,102</td>
<td>1,614</td>
<td>866</td>
<td>674</td>
<td>780</td>
<td>719</td>
</tr>
<tr>
<td>Tobacco</td>
<td>41.2</td>
<td>78.6</td>
<td>88.6</td>
<td>115.0</td>
<td>147.2</td>
<td>198.4</td>
<td>149.5</td>
<td>197.1</td>
</tr>
<tr>
<td>Mung beans</td>
<td>59.1</td>
<td>84.1</td>
<td>117.7</td>
<td>131.4</td>
<td>122.2</td>
<td>131.9</td>
<td>215.3</td>
<td>255.0</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>57.0</td>
<td>49.7</td>
<td>73.9</td>
<td>71.6</td>
<td>36.9</td>
<td>19.7</td>
<td>27.3</td>
<td>28.9</td>
</tr>
<tr>
<td>Soybeans</td>
<td>10.1</td>
<td>9.3</td>
<td>4.5</td>
<td>14.6</td>
<td>15.1</td>
<td>9.3</td>
<td>13.0</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

^Sources: (4, pp. 50-53; 18, p. 341; 63, p. 131).

b n.a. = not available.

More than 40% of the total value of exports are contributed by three major agricultural items, rice, rubber and maize (corn). Nonetheless, agriculture still remains as the most backward sector in the economy. Its share in the GNP is considerably small from the point of view that three-quarters of the entire population still live on farms.

Table 5 shows the extent of the GNP that is attributable to agriculture. Per capita farm income is low but the poverty problem is much more serious when we recognize that regional farm income differences do exist.
Table 5. Agriculture and the GNP

<table>
<thead>
<tr>
<th>Year</th>
<th>GNP at current prices (B millions)</th>
<th>Share of agriculture in GNP (B millions)</th>
<th>Share of agriculture in GNP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>84,291.9</td>
<td>29,382.9</td>
<td>34.9</td>
</tr>
<tr>
<td>1966</td>
<td>101,282.1</td>
<td>36,921.5</td>
<td>36.5</td>
</tr>
<tr>
<td>1967</td>
<td>108,391.8</td>
<td>35,143.1</td>
<td>32.4</td>
</tr>
<tr>
<td>1968</td>
<td>117,578.9</td>
<td>36,962.1</td>
<td>31.4</td>
</tr>
<tr>
<td>1969</td>
<td>130,838.7</td>
<td>41,675.1</td>
<td>31.9</td>
</tr>
</tbody>
</table>

Source: (4, p. 93).

Agriculture is defined to include crops, livestock, fisheries and forestry.

From the results of the sample survey conducted by the National Statistical Office (73, p. 192), about one-fourth of the total farm income went to the Northeastern farmers in 1963. Since roughly one-third of the total farm population live in that region it is clear that, on a per capita basis, the Northeastern farm income was well below the national average. In addition, farmers in the Central Plain received twice as much income as those in the North, although the two regions are equal with regard to the size of the farm population. Thus it appears that per capita farm income is highest in the Central Plain and lowest in the Northeast. A major factor which is responsible for this difference is that most of the land in the Northeast is low in productivity due to soil salinity and lack of proper water control and management.

From the economy's point of view, it is desirable to increase the total farm income relative to the total nonfarm income. With the surplus farm labor problem in mind, one immediately would recommend that a portion of the farm population be transferred to the nonfarm sector at a least possible cost. On the one hand, if too many of the working force left the
farming sector, either food needs to support the enlarged industrial sector might become critical, or the real wage of the average industrial worker would be depressed, or both. On the other hand, if too few entered the nonfarm sector, the return to agricultural labor would still be relatively low and the whole problems of agriculture and thus industrialization would remain just as serious as before. It is the subject of labor transfer between the two sectors to which we now turn.

Optimality of the Rate of Intersectoral Migration

Obviously we wish to find the rate at which the agricultural labor force is transferred to the nonagricultural sector in such a way that per capita income is maximized over a specified time horizon subject to a number of constraints, two of which are that the relative farm to industrial labor earnings is positive but less than unity and that farm income must be at least as large as the subsistence income level.

Let us now consider the agricultural sector. If there is no migration at all, then the agricultural labor force is \( L_0(t) = L_0(0)e^{nt} \) where \( L_0(t) \) is the labor force at the end of the \( t^{th} \) time period, \( L_0(0) \) is the labor force at the end of the \( 0^{th} \) time period, \( n \) is the average rate of growth of the population, and \( t = 1, 2, \ldots, T \), with \( T \) fixed.

Let \( L^*_0(t) \) be the size of the labor force planned to achieve optimality in labor migration. If \( u(t) \) is a fraction of the labor force at the end of the \( t^{th} \) period which is to be transferred out of farming, then

\[
L^*_0(t) = [1 - u(t)] L_0(t) \tag{4.1}
\]

\( u(t) \) depends on \( t \) and may be thought of as the control variable.
The aggregate production function is generally written as

\[ Y_o(t) = g[K_o(t), L_o^*(t)] \]

where

\[ Y_o(t) = \text{aggregate agricultural output at the end of the } t^{\text{th}} \text{ time period} \]

\[ K_o(t) = \text{aggregate variable input at the end of the } t^{\text{th}} \text{ time period} \]

For simplicity it is assumed that variable inputs \( K_o(t) \) and \( L_o^*(t) \) must be combined in a constant proportion at any time, \( t \). This is plausible since, to produce a given level of the main crop, rice, a certain amount of land and labor is needed and the extent of factor substitution in any subsistence economy is far less than in commercialized agriculture, particularly in the view that the use of fertilizers and machinery is very limited. However, the assumption of fixed technical coefficients is not too restrictive because the proportion by which factors are combined is allowed to vary with time and therefore the possibility of technical progress which is crucially important in the course of agricultural development is not neglected.

Consequently, we can write the production function in either of the following forms:

\[ Y_o(t) = c_K(t) K_o(t) \] \hspace{1cm} [4.2]

\[ Y_o(t) = c_L(t) L_o^*(t) \] \hspace{1cm} [4.3]

where \( c_K(t) \) and \( c_L(t) \) are constant technical coefficients of \( K_o \) and labor respectively. Both are dependent on time, \( t \).
As a digression, if \( L^*_o(0) \) is the effective labor force at the end of the period 0, then the amount of unemployment is \( L^*_o(0) - L^*_o(0) \). When \( L^*_o(0) \) is considered as the total farm labor employed, economists could not have been more correct in saying that traditional agriculture is characterized by widespread underemployment and that the average labor productivity is low, while its marginal productivity may even fall below zero. (Sriplung (59), in fact, found the marginal productivity of Thai farm labor in 3 out of 6 areas investigated to be negative.)

As farm labor enters the nonagricultural sector, its labor force increases from \( L_1(t) = L_1(0)e^{nt} \) to \( L_1^*(t) = L_1(0)e^{nt} + u(t)L_0(t) \) where all variables carry the same meanings, except that the subscript 1 denotes the nonagricultural sector. We may then write

\[
L_1^*(t) = [L_1(0) + u(t)L_0(0)]e^{nt} \tag{4.4}
\]

It is here assumed that migration is instantaneous and labor training does not involve time lag.

Let the aggregate production function for the industrial sector be

\[
Y_1(t) = f[K_1(t), L_1^*(t)] \tag{4.5}
\]

It is homogeneous, continuous and twice-differentiable so that factor substitution is possible. A production function of the Cobb-Douglas type is an example.

National income is, by definition,

\[
Y(t) = Y_o(t) + Y_1(t) \tag{4.6}
\]
Capital is derived from two main sources: domestic and foreign. Therefore, the total available capital may be expressed as

\[ K(t) = K_g(t) + K_f(t) \]

\[ = K_d + K_f \]

where

\( K_d \) = domestic capital
\( K_f \) = foreign capital

The total net investment at any time, \( t \), is given by

\[ I = \frac{dK(t)}{dt} = \dot{K} = \text{net } I_d + \text{net } I_f \]

where

\( I_d \) = domestic investment
\( I_f \) = foreign investment

and the dot above the variable \( K \) indicates the first derivative of \( K \) with respect to time.

In equilibrium, gross domestic investment is the amount equal to domestic savings which may be assumed to be proportional to national income. If \( s \) is the average and marginal propensities to save, then

\[ \text{gross } I_d = sY(t) \]

Assuming that total capital depreciates by a constant annual rate of \( \delta \), we have
net $I = sY(t) + I_f - \delta K(t) \quad [4.11]$

If $y_o(t)$ and $y_1(t)$ are per capita farm and nonfarm incomes respectively, then

$$Y(t) = y_o(t) L^*_o(t) + y_1(t) L^*_1(t) \quad [4.12]$$

From [4.7], by differentiating with respect to $t$,

$$I = \frac{dK(t)}{dt} = \dot{K}_o + \dot{K}_1 \quad [4.13]$$

where $\dot{K}_i = \frac{dK_i}{dt}$, $i = 0, 1$

$\dot{K}_i$ is the amount of investment being channeled to the $i^{th}$ sector.

Since [4.2] and [4.3] are equivalent, it follows that by taking the first time derivatives,

$$c_k(t)K_o(t) + c_k(t)\dot{K}_o(t) = c_l(t) L^*_o(t) + c_l(t) L^*_1(t) \quad [4.14]$$

From [4.3], $y_o(t) = c_l(t)$ and, consequently,

$$\dot{y}_o(t) = c_l(t) \quad [4.15]$$

As for the nonfarm sector, $y_1(t) = f(\frac{K_1(t)}{L^*_1(t)})$ from [4.5] and

$$\dot{y}_1(t) = \frac{\partial f}{\partial K_1(t)} \frac{\dot{K}_1(t)}{L^*_1(t)} - \frac{\partial f}{\partial L^*_1(t)} K_1(t) \frac{\dot{L}^*_1(t)}{L^*_1(t)} \quad [4.16]$$

Differentiating [4.4] with respect to time,

$$\dot{L}^*_1(t) = [nL_1(0) + \{nu(t) + \dot{u}\} L_0(0)]e^{nt} \quad [4.17]$$
Thus [4.16] becomes

\[ \dot{y}_1(t) = \frac{\partial f}{\partial k_1(t)} \frac{\dot{k}_1(t)}{L_1^*(t)} \]

\[ - \frac{\partial f}{\partial L_1^*(t)} \frac{k_1(t)}{L_1^{*2}(t)} [nL_1(0)+(nu(t)+\hat{u}L_0(0)]e^{nt} \]  

[4.18]

In order to insure that there is an incentive for farm labor to migrate, the relative farm labor earnings must be less than 1.0, i.e.:

\[ 0 < \frac{y_0(t)}{y_1(t)} < 1 \]  

[4.19]

and

\[ y_0(t) \geq \text{subsistence per capita income} \]  

[4.20]

To complete the theoretical model, the objective function is specified to be: to maximize the stream of discounted per capita income over the planning time horizon \((0, T)\). In other words, if \(\rho\) is the rate of discount,

To maximize

\[ \int_0^T e^{-\rho t} [\beta_0(t)y_0(t) + \beta_1(t)y_1(t) + \sigma u^2(t)] \, dt \]

subject to equations [4.11] through [4.15] and [4.18] through [4.20] with initial and terminal values. \(\sigma u^2(t)\) with \(\sigma < 0\) is included in the objective as a penalty against controlled migration. This may incorporate the cost of providing education and vocational training for unskilled farm
labor as well as the cost of any erratic movement away from the optimal path.

A model of this type which makes use of the optimal control theory excels over other types because it contains dynamic elements in a way that no others can successfully do. $u(t)$ tells us how much of the farm labor force should be reduced each period of time in order to prevent average farm income from falling below some minimum level, while not causing excessive deterioration in the income situation in the industrial sector. Furthermore, $u(t)$ is not constant over time but depends partly upon the relative economic growth of the two sectors during any time, $t$, which in turn is determined by the relative rate at which technological advance takes place. This argument can be used to superficially criticize Milton Friedman's stance on the rate of growth of money supply over time. Because his findings indicated that past business cycles had been largely generated by fluctuations in the rate of growth of money supply, he recommended that central authorities keep money supply growing at a constant rate (22, p. 16). If business cycles really follow the path by which the rate of growth of money supply varies, then Friedman's conclusion would hold. But this is not true and, if monetary business cycle theorists were able to correctly identify how the rate of growth of money supply directly and through other lesser determinants affects the tempo of business activity, the optimal rate of growth would certainly vary with time. Since no one seems to be able to do this, it is understandable why Friedman suggested monetary authorities not to do anything which might affect the rate of growth of money supply. Nevertheless, the advocacy of a constant rate of growth may be a little premature.
Being an aggregate model of the optimal rate of intersectoral migration, it purports to show the importance of the two sectors as far as the allocation of labor resources and their earnings are concerned. At the same time, it fails to provide information as to what branches of the nonagricultural sector farm labor should optimally be transferred, at the cost of being a relatively compact and simple model.

The problem of unemployment and underemployment is increasingly critical and being aggravated by the high rate of population growth. Leaving intersectoral migration uncontrolled would create unemployment in some branches of the industrial sector and labor shortage in others. Strictly from a planning viewpoint, provided that the incentive to migrate is adequate, control should be exercised on the allocation of migrated labor among various labor training programs so that additional labor employment is more or less equally distributed according to the needs among industrial occupations.

Apart from underemployment, there are other fundamental problems in agriculture which demand more immediate attention. Economic theory in its general traditional context indicates that producers would be directly responsive to change in product price and would cease their activities altogether if price falls below some level. Within the Thai agricultural setting, this does not seem to hold because farmers have to live on the subsistence crop and may not maximize profits but utility or, even more likely, production to insure a maximal probability of survival in the highly uncertain environment.

One positive solution to the problems of agriculture is to diversify agricultural economic activities. Risks are then spread so that income
stability can be maintained. However, agricultural diversification has so many problems of itself to overcome, which will be discussed at some considerable length in relation to economic planning. The whole agricultural problems may be summarily categorized into one major problem: how to activate potentially dynamic elements which exist in the traditional agriculture so that they can contribute substantially to economic development of agriculture and the economy as well.

An Economic Survey of Some Selected Commodities

Although there is a fairly wide range of agricultural commodities produced, attention will be directed toward some perennial crops only. Perishable fruits and vegetables are important and, from the production point of view, are more profitable under certain conditions. Being perishable, they need to be marketed quickly. Marketing and transport facilities are poor for a large part of the country. Because of risks and uncertainties, the chance of survival for an average Thai farmer is lessened if only a small portion of his resources is devoted towards subsistence crop production. Farmers do grow fruits and vegetables, but mainly for home consumption purposes. A shift in production to these commodities would be drastic and undesirable, however, at least from short-term economic planning viewpoint. Agricultural diversification in production of commodities belonging to more or less the same category is feasible, easier to administer and implement, and less costly both in the actual diversification process and in investment in providing information and farming knowledge.
Rice

Rice is produced in all provinces, although a major part comes from the Central Plain. Rice shortages often occur in the Northeast which is usually susceptible to extreme weather conditions. Two methods of production are available: transplanting and broadcasting. The latter method is less time consuming but more costly in terms of seed use. However, it draws less labor to produce and therefore is mainly used in the Central Region where the opportunity cost of farm labor is relatively high. Rice may be of the glutinous or nonglutinous (white) type but, for our purposes, no distinction will be made except in few cases.

The price of rice is low and subject to violent fluctuations from year to year. In 1955 the government, taking advantage of the usually high world price of rice, placed a premium in a form of export tax on various grades exported. Historically, rice premiums provided about one-tenth of the total government revenue. At times when the domestic price of rice was depressed as a result of an exceptionally good harvest, the central authorities relied heavily on a price support program to improve the price level. They often met with little success both because of the sheer volume of rice to be supported and because the administrative body directly responsible for the program (Farmers' Aid Committee) was inadequately financed and inefficient (4, pp. 36-38). More recently in late 1970, as a result of overproduction, prices fell and this forced the government to fix minimum prices for paddy white and glutinous rice. The program was not effectively carried out until February of the following year when farmers had already sold most of their paddy rice at low prices. It is thus not surprising to find that, in the first eight months of 1971,
the average wholesale price of first grade paddy rice was, for the first
time in at least three years, below $1,000 per metric ton (4, p. 86).
But the problem of rice surplus was precipitated not only by overproduction
but also by the fall in the export demand. To remain competitive in the
world market, the government finally in April, 1971 abolished the premium
on most grades of rice exports. The action clearly helped cushion the
effect of the large supply of rice on its domestic price.

In the 1960's the quantity and value of rice exported did not vary
appreciably. Most Thai rice went to Hong Kong, Malaysia and Indonesia.
These countries provided at least one-third of the total proceeds from
rice exports. With a possible exception of Hong Kong and Singapore, it
cannot be expected that the same importing countries will continue to
purchase rice at a level rivaling the past. New technologies in rice
production, particularly in improving seeds and introducing new better
varieties, e.g. the IR type, can within the foreseeable future raise
domestic production up to a point that rice imports are no longer needed.
From Table 4 it is evident that the value of the total rice exports was
declining since 1968. A new trend has been set and is likely to continue.

Despite the fact that the price of paddy rice varied substantially
from year to year and that the rice premium tended to keep it low, there
is little evidence that rice farmers have significantly shifted their
main farming activities to production of some other commodities. Table 6
presents the time series data on the wholesale price of paddy rice, land
planted and total rice production. Land planted and production rose over
the 1967-70 period, whereas the wholesale price fell during the same
period. Thus the increase in the production of other commodities was made possible partly by bringing unused land into cultivation.

Table 6. Price, land use and production of rice

<table>
<thead>
<tr>
<th>Year</th>
<th>Average wholesale price of grade 1 paddy rice (B per metric ton)</th>
<th>Land planted for rice (million rais)</th>
<th>Paddy rice production ('000 tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961</td>
<td>985</td>
<td>38.62</td>
<td>8,176</td>
</tr>
<tr>
<td>1962</td>
<td>1,172</td>
<td>41.62</td>
<td>9,279</td>
</tr>
<tr>
<td>1963</td>
<td>1,031</td>
<td>41.26</td>
<td>10,029</td>
</tr>
<tr>
<td>1964</td>
<td>874</td>
<td>40.87</td>
<td>9,558</td>
</tr>
<tr>
<td>1965</td>
<td>912</td>
<td>40.49</td>
<td>9,218</td>
</tr>
<tr>
<td>1966</td>
<td>1,282</td>
<td>45.66</td>
<td>11,846</td>
</tr>
<tr>
<td>1967</td>
<td>1,343</td>
<td>40.06</td>
<td>9,595</td>
</tr>
<tr>
<td>1968</td>
<td>1,239</td>
<td>44.68</td>
<td>10,772</td>
</tr>
<tr>
<td>1969</td>
<td>1,211</td>
<td>47.73</td>
<td>13,346</td>
</tr>
<tr>
<td>1970</td>
<td>1,157</td>
<td>48.76</td>
<td>13,401</td>
</tr>
</tbody>
</table>

^Source: (4, pp. 81 and 86).

^About 2.5 rais = 1 acre.

Another implication is that the supply response of farmers to changes in price may not be positive. By using a distributed lag model involving autocorrelated errors, Chirapanda (8) found the supply function of rice for the period 1952-1967 to be

$$\ln Y_t = 3.969 + 1.375 \ln W_t + 0.284 \ln M_t + 0.486 \ln Z_t + 0.084 \ln Y_{t-1} - 0.360 \ln P_{t-1}^* - 0.349 \ln P_{t-1}^*$$

$$r^2 = 0.9$$

where
\[
Y = \text{total rice output} \\
W = \text{the weather index} \\
M = \text{the financial development index} \\
Z = \text{the labor input} \\
P^{*1} = \text{the price of paddy rice deflated by the cost of living index} \\
\quad \text{for } t \leq 9, \\
\quad 0 \text{ for } t > 9 \\
P^{*2} = \text{the price of paddy rice deflated by the consumer price index} \\
\quad \text{for } t > 9, \\
\quad 0 \text{ for } t \leq 9 \\
t = 0, 1, \ldots, 15
\]

The figure in brackets underneath the coefficient of each parameter is the \( t \) value associated with that particular coefficient. From the equation above, the short-run price elasticity of supply is \( -0.349 \) for the period 1952-67 which implies a long-run price elasticity of \( -0.322 \). The negative supply response to changes in price defies traditional economic theory but nonetheless deserves careful consideration when it comes to agricultural planning. This study contradicts earlier findings by Behrman (6), who concludes that rice farmers behave positively to changes in price. Apart from criticisms which can be made on the statistical method used, there are several reasons why his conclusions may be faulty. Theoretically, to insure a maximum chance of survival, farmers presumably would aim to minimize risks. In a multicommodity world, they would minimize the total income variance which is a function of income variances arising from several farming activities. They may choose a certain farming strategy which maximizes return.
among the worst outcomes of all possible strategies, as game theory suggests. This would tend to lead to mixed farming whereby two or more commodities are produced. For Thai agriculture, alternatives to rice farming are extremely limited, given the status quo. Ignorance of alternative farming practices and imperfect knowledge as to the relative profitabilities, viz., relative price ratios of various crops as well as a wide range of other factors, inhibit farmers to shift from or diversify their rice production. If the marginal rate of product substitution is zero, and while the rural population increases at the rate of 3% a year, the optimal policy to follow is to produce as much as possible. The bulk of the output produced is stored over the year for household consumption. The residual is then offered for sale in the market. Under these circumstances, farmers attempt to maximize output and not profits as always assumed in traditional economic theory of the firm. On the other hand, if they aim to maximize utility whose function may be heavily dependent on leisure and, to a much lesser extent, on income from output production, a rise in price of rice may raise income up to a certain level so that any additional income is foregone in favor of more leisure. Then output production actually falls.

An implication which emerges from this analysis is that, with or without the price support program directed toward rice, production will tend to increase if farmers do not diversify their activities. Farm income is not likely to rise over time and, even if it is to rise, it would certainly require excessive government expenditures. To avoid or minimize this problem, greater efforts should be made to educate farmers on alternative profitable farming activities. Adequate funds have to be
provided to smooth the diversification process. Part of the funds may be obtained by scaling down the price support program. Since different regions have different relative productive advantages of one commodity over another in terms of costs, it is most appropriate to determine what commodities and by how much should be produced in each region so that the total costs to the economy are minimized. The results should form a basis on which agricultural diversification is carried out. Thus, careful and deliberate regional economic planning is imperative.

Maize

The sweet varieties of maize are produced on a small scale but widely throughout the economy. They are largely domestically consumed and economically unimportant. On the other hand, the hard varieties draw favorable response from the farmers as they can be used for industrial purposes as well as an input (feed grains) to other farming activities. As the domestic economy is not yet geared to accommodate the maize supply of this type, much is exported overseas. It should be noted that the figures given on maize below refer to the hard varieties only.

Maize production represents one of the rare examples in the history of Thailand’s economic development. It was first encouraged by the government authorities in the Northeastern areas. However, owing to several factors, e.g. climatic conditions unsuitable for raising maize and apparently relative cost advantage in producing kenaf whose price soared in the early sixties because of an increased world demand, the Northeastern farmers shifted to kenaf production. The main maize producing area is now contained in the upper part of the Central Region.
which accounts for some 80% of the national production. For the economy as a whole, the increase in maize production was spectacular. The production grew from an annual average of 8,200 tons during the years 1937-46 to nearly 2 million tons in 1970. From 1960 to 1967, the annual rate of growth was close to 20%. With future domestic and foreign demands on the increase, the rate of growth in maize production will almost certainly be sustained at a high level.

Roughly 90% of maize produced is exported. Of this, 60% finds its way to the Japanese market. Other major importing countries are Taiwan, Singapore, Malaysia and Hong Kong. Although maize exports fluctuate from year to year, the annual rate of increase in both value and quantity averaged about 10% in the sixties. On this basis, it is believed that maize will soon outstrip rice as the major export item.

Cassava

Cassava is produced for both human and animal consumption. It may be marketed in a raw form as cassava roots or manufactured and sold as cassava flour. Much of cassava production is directed toward meeting export demand. The low domestic demand is attributed to the fact that cassava is relatively expensive as an animal feed and that farmers are unaware of cassava as a possible feed use.

Cassava production increased by five times during 1957-1967. It is fairly evident that the increase was stimulated partly by the price which farmers received. As a consequence, when the market price of cassava fluctuated, its production also tended to fluctuate. At present the level of cassava root production is about 3 million tons.
The area of production concentration is in the eastern part of the Central Region. The four major provinces are Chon Buri, Rayong, Prachin Buri and Chachoengsao. Roughly 60% of the total production comes from these provinces. On a regional basis, the Central Region supplies about 85%, while the Northern Region contributes very little — about 1% of the economy's total cassava production. The remainder is supplied in a roughly equal amount by the other two regions.

Cassava is exported in four main forms: shredded or sliced, flour, meal and waste. Historically, most cassava exports have been in the flour form, but recently cassava meal is much more demanded. One of the reasons is that sliced cassava and cassava flour contain a high percentage of impurities, such as sand. Since these products are also more expensive, it is not surprising to find that the increase in the value is less in proportion to the increase in the quantity of the total cassava exports. The rate of growth of cassava products exported in physical terms is approximately 13% per annum during 1962-1969. Most of the exports are sold to West Germany, the Netherlands and the United States.

The future outlook for cassava is fairly bright. Export earnings are likely to increase as the quality of the exports improves. The domestic demand for cassava as feed uses is potentially great but, within the foreseeable future, the economic importance of cassava still rests on overseas demand.

**Sugar cane**

Sugar cane, depending on the type, may be directly consumed or processed as sugar. Here we are more interested in the type of sugar cane
that serves as an input to the sugar industry. Sugar cane is produced widely throughout the economy. The leading producing areas lie in the Central Plain, in particular around Chonburi and Kanchanaburi.

On the national basis, the total production reached 4 million tons by 1957 and fluctuated around that level from then on until 1967. In that year, the average wholesale price went up by 40% over the level that prevailed the year before (63, p. 60). This seems to stem from the high domestic demand. As a result, little (50 tons in sugar) was exported in 1968. Production then began to increase and is now well over 7 million tons.

About 80% of sugar produced is consumed locally; the remaining is either stocked or exported. Exporting sugar has not been easy as its world supply tends to exceed demand. Thailand, hoping to gain a secure overseas channel for her exports at attractive prices, decided to join the International Sugar Agreement in 1969 and was given a yearly export quota of 36,000 tons. However, the authorized quota was about one-third of the total surplus sugar. A few years later, when she could not effectively cope with the surplus situation, she left the ISA.

Because of the difficulties in finding export markets, it seems appropriate for some sugar cane planters to shift to other farming activities. Possibilities of increasing the domestic demand, for example, by lowering sugar prices or through substituting sugar-contained imports such as confectioneries, should be explored. The prospects appear to be fairly good, considering that the income elasticity of the demand for sugar for the economy is estimated to be about 1.0 (82, p. 143). In any case, an ideal situation would be to produce sugar cane just enough to satisfy
domestic and foreign demands. Given the variable nature of the amounts produced and demanded, it is desirable to cushion the effects that this may have on domestic prices, e.g. through the use of a buffer stock. With positive storage costs, the buffer stock which is already in operation in Thailand should be set at some optimal level, that is, it should minimize the costs incurred and whatever unfavorable effects that would occur had there been no buffer stock.

**Castor beans**

Castor beans belong to the oil seed category. They are produced mainly for export purposes. As their price tends to fluctuate over time, their production has shown no tendency to increase. Virtually all castor bean exports are shipped to Japan where they are then processed into oil.

Prachuap Khiri Khan and Ratchaburi in the Central Region and Nakhon Ratchasima in the Northeastern Region are among the main producing provinces. Both the Northern and the Southern Region contribute little to the castor bean economy. Taken together, they account for less than 10% of the total production.

Castor bean exports present a number of familiar problems. They are mainly in the raw, unprocessed form and therefore bring low prices. Emphasis should be shifted to exporting of castor oil, as two advantages are evident. First, castor oil is more expensive than its bean equivalents. Secondly, it can be stored for a much longer period. New markets should also be sought to reduce the degree of dependence on Japan as the only main outlet for castor beans. Japan which buys some 95% of the castor bean exports could easily exercise monopsonistic exploitation if it wished to.
Kenaf and jute

These two fiber crops have similar uses, although they are physically unlike. They are used to make ropes, gunny sacks, cloths, etc. Kenaf is much rougher but is more widely grown in Thailand since it can withstand relatively drier conditions. Little kenaf and jute were produced toward the end of the 1950's. From 1960 on, their production began to increase more rapidly. The main economic factors in this expansion lie in that export prices were favorable and general production knowledge had sufficiently spread among farmers. By the end of 1969, about 350,000 tons of washed kenaf and jute were produced, some 75% of which were exported.

Kenaf is grown mostly in the Northeast, while jute is grown in the Central Region in areas around Phichit, Uttaradit and Samut Sakhon. The South produces almost no kenaf or jute.

Almost all jute is domestically used in the production of fine ropes and as a material to improve the stretching strength of gunny sacks which require kenaf as their main fiber. Gunny sacks are now exported but most kenaf exports are in the raw form. India, Japan and some European countries, notably the United Kingdom, Belgium and France, are the main markets for kenaf and jute exports. Since Thailand produces relatively more kenaf and because kenaf is inferior to jute with regards to their uses, the volume and value of exports depend largely on the ability to produce in Pakistan since it is the world's major jute supplier. Continued efforts to improve quality and to lower the production costs, e.g. by making available ample water supply, are called for if Thailand is to remain competitive in the world market on a stable level.
Tobacco

Two tobacco varieties are grown: local and Virginia. The local variety is much more popular because of demand and price conditions. It is about three times as productive, although the Virginia variety brings twice as high a price to the tobacco growers. Tobacco production has been fairly stable in the last ten years, expanding at a rate of 2-3% per annum. In 1970 it has been estimated that 93,000 tons of dried tobacco leaves were produced.

Tobacco is produced widely throughout the economy. However, nearly one-half of total production comes from the North. The main producing areas include Chiang Rai, Lampang, Nan and Phrae. Tobacco is largely consumed in Thailand but its exports in both manufactured and unmanufactured forms bring some 200 million bahts in revenue in each of the last few years. West Germany, Japan and the United Kingdom account for more than one-half of tobacco exports in value. The low nicotine content in the tobacco contributes to the fact that Thailand receives generally high prices for its tobacco exports. In contrast, there are traces of DDT and this constitutes a real threat to the export business. Thus, it is recommended that extensive control on the use of DDT be exercised. At the same time, research should also be made to develop a new type of tobacco plant which is more resistant to diseases, while maintaining other qualities.

Mung beans

Mung beans are consumed primarily as food. In the 1950's and early 1960's, the total mung bean production increased slowly, reaching a
turning point in 1962. A year later, production went from 53,700 tons to 116,000 tons. This two-fold increase was accounted for largely by the doubling of the land planted in the Central Region. Mung beans are produced in almost every province, but the area of concentration lies in the upper part of the Central Region which supplies some two-thirds of the total output.

A large portion of mung beans produced is exported overseas. The total mung bean exports increased by three times over the last ten years. In 1970 the volume of mung beans exported was 89,727 tons, valued at over 250 million bahts. As the trend indicates, the future prospect for mung bean exports looks bright.

**Groundnuts**

Groundnuts have numerous uses. They may be consumed directly or indirectly through other edible and nonedible forms, e.g. groundnut oil. They are also used as an animal feed. Despite these uses, groundnut production has not shown a distinct tendency of expansion. One of the major reasons is that groundnut prices have fluctuated from year to year around 4 bahts/kilogram on a shelled basis. In 1970 the total unshelled groundnut production was estimated at 190,000 tons, still short of the record high of 219,000 tons reached in 1961.

Groundnuts are produced in most parts of the country. The major producing provinces include Nakhon Sawan, Chiang Mai, Phrae, Phitsanulok and Nakhon Ratchasima.

About 90% of groundnut exports -- mainly in shelled form -- are shipped to other Asian markets including Japan, Hong Kong, Malaysia and
Singapore. Groundnut cake, meal and oil are also exported, though in small quantities. The future outlook for exports is not bright, as in recent years they have been declining both in terms of price and volume.

Soybeans

Soybean production has increased significantly in the last decade. In 1960, 25,600 tons were harvested but by 1970 the total production rose to 65,000 tons. The leading soybean producing area is concentrated around Nakhon Sawan, Phichit and Sukhothai. Little is grown in the South and Northeast.

Most soybeans produced are consumed domestically. The major export markets include Malaysia and Singapore which absorb approximately nine-tenths of the total exports. The prospects for a future increase in the demand for soybeans are good in view of their many uses. To develop soybeans as a major export crop, steps must be taken to lower production and marketing costs. This may imply partial mechanization of agriculture or a more widespread introduction of new, more productive seeds. At the same time, potential overseas markets, particularly Japan, should also be explored.
CHAPTER V: LINEAR PROGRAMMING MODELS OF INTERREGIONAL COMPETITION

The three main types of mathematical models have been treated in a somewhat unbalanced way in Chapter II. Input-output and econometric models have been discussed at length and specific examples given for illustrative purposes. In this chapter we shall consider linear programming models which incorporate interregional competition in detail with respect to their formulation and estimation of technical coefficients and other quantities. The models, largely theoretical, are operational in the sense that they can readily be applied once the needed data become sufficiently accumulated. The lack of statistical data, notably on production costs (by region, at least), prevents not only actual application of the models but also the flow of quantitative economic knowledge that can be deduced from them. Two major types of programming models are distinguished here.

The first is intended for short-term interregional planning of agriculture. By the nature of being short term, it is formulated such that it minimizes the requirements of uncollected data. If these data become available, the model can then be immediately applied. As a consequence, it is heavily based on the past. For example, as we shall see, the technical coefficients are estimated from the time series data as far back as 1963. Technical advance is allowed only insofar as the past trend indicates.

The second type of model is concerned with long-term planning. Here the past is thought to bear little or no relationship with the future. In the short run, this is not true but, in the long run, time
permits technological change to be abrupt in the sense that whatever the events that will occur between the present and the period under long-term planning are not as much influenced by the past as by man himself. Technological change can be visualized to include extensive use of fertilizers, better and proper water control and management, water storage construction as well as mechanization. In the long-term planning model, it is recognized that several factors tend to inhibit economic growth of agriculture and agricultural diversification can be more successful if scarce resources are made available for farm use.

The incorporation of new technologies does not, however, make long-term planning independent of short-term planning. Apart from comparison purposes, a great deal can be learned from the results of short-term planning and what they imply. Doubts may be cast on long-term planning along with the new technologies it is supposed to incorporate if its results appear to diverge so much from short-term planning.

Let us now turn to the formulation of the general model for short-term planning of agriculture.

Model Formulation

Production activities

In our model, eleven farm commodities are considered, all of which play a role in foreign trade. They are:

- rice
- maize (corn)
- cassava
- sugar cane
- castor beans
- jute
- kenaf
- tobacco
- mung beans
- groundnuts
- soybeans
A brief survey of each commodity has been given in Chapter IV with reference mainly to its significance in relation to Thailand's economic growth and stability. Table 7 indicates the end products of each commodity which are ready to be consumed or exported.

Table 7. Product form of primary commodities consumed and exported

<table>
<thead>
<tr>
<th>Primary commodity</th>
<th>End products for immediate domestic consumption</th>
<th>End products for immediate exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddy rice</td>
<td>Milled rice</td>
<td>Milled rice</td>
</tr>
<tr>
<td>Maize (corn)</td>
<td>Maize grain</td>
<td>Maize grain</td>
</tr>
<tr>
<td>Cassava roots</td>
<td>Cassava flour</td>
<td>Shredded or sliced cassava, cassava flour, meal and waste</td>
</tr>
<tr>
<td>Sugar cane</td>
<td>Centrifugal and refined sugar</td>
<td>Centrifugal and refined sugar</td>
</tr>
<tr>
<td>Castor beans</td>
<td>Castor oil</td>
<td>Castor seeds</td>
</tr>
<tr>
<td>Kenaf and jute</td>
<td>Fiber products, e.g. gunny sacks, ropes</td>
<td>Kenaf and jute, and gunny sacks</td>
</tr>
<tr>
<td>Tobacco</td>
<td>Tobacco</td>
<td>Tobacco</td>
</tr>
<tr>
<td>Mung beans</td>
<td>Mung beans</td>
<td>Mung beans</td>
</tr>
<tr>
<td>Unshelled groundnuts</td>
<td>Shelled groundnuts and groundnut oil</td>
<td>Shelled groundnuts, groundnut cake and meal</td>
</tr>
<tr>
<td>Soybeans</td>
<td>Soybean oil and meal</td>
<td>Soybean cake and meal</td>
</tr>
</tbody>
</table>

It should be noted that even though all primary commodities are exported, some have to be imported in processed form to meet domestic demand. For example, soybean cake and meal are exported but soybean oil is imported. Since our model deals with only one form of each commodity,
traded commodities have to be converted into the same form as produced commodities. Some conversion rates are provided in Table 8.

Table 8. Conversion rates for different product forms of primary commodities

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Conversion Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ton of paddy rice</td>
<td>0.60 ton of milled rice</td>
</tr>
<tr>
<td>1 ton of cassava roots</td>
<td>0.392 ton of cassava flour</td>
</tr>
<tr>
<td>1 ton of sugar cane</td>
<td>0.03 ton of centrifugal sugar</td>
</tr>
<tr>
<td>1 ton of centrifugal sugar</td>
<td>0.92 ton of refined sugar</td>
</tr>
<tr>
<td>1 ton of unshelled groundnuts</td>
<td>0.60 ton of shelled groundnuts</td>
</tr>
<tr>
<td>1 ton of unshelled groundnuts</td>
<td>0.28 ton of groundnut oil</td>
</tr>
<tr>
<td>1 ton of soybeans</td>
<td>0.13 ton of soybean oil</td>
</tr>
</tbody>
</table>

^Sources: Mainly, (18 and 63). Others are estimated by the author.

Producing regions

Thailand is delineated into 23 producing regions on the basis of agro-climatic conditions. Characteristically, the average temperature in the Northern Region, ranging from 24° C to 26° C, is below the national average, whereas the average temperature in the Central Region is above. Rainfall is heavy in parts of the country, especially in the South. Although the Northeast receives, in general, as much rain as the Central Region, its agricultural productivity is limited for two reasons. The Northeastern soil is mainly sandy and thus its water holding capacity is limited. A number of irrigation projects have been completed and several more are under construction, but the problem of transferring water to individual farms still largely remains. Secondly, the frequency
of rainfall is irregular. On some parts rainfall is at times so heavy that it results in floods while, in other parts, rainfall is sparse throughout the year. Figure 5 shows the extent of rainfall for the entire economy in 1966. It is essentially reproduced from the map at the end of the section on Area, Geography and Climate in (72).

The variabilities in both temperature and rainfall among different regions throughout the year point out the fact that the pattern of farm product mix differs for any two regions. For example, jute is little grown in the North and the South, while kenaf production is concentrated mainly in the Northeast. Conceptually, the delineation should be done strictly on the basis of the differences in the abilities to produce among regions. Temperature, rainfall and soil types are only some of the main attributes to these differences. Consideration has to be given to the fact that certain commodities must be processed within a relatively short time duration after they are produced. For example, kenaf can be grown on relatively dry land but processing (washing) it requires ample water supplies. Thus, where water is scarce, kenaf production is limited. Moreover, if our planning model is to be useful for administrative purposes, the delineation must be such that each producing region contains a number of adjacent provinces and any one province belongs to one and only one producing region. This is desirable from yet another point of view. Statistical data on areas planted and harvested and commodity production, which are needed to calculate the technical coefficients, are available on provincial basis. Producing regions are also contained wholly in one of the four official regions.
Figure 5. Average rainfall in 1966

- 800-1,000 mm
- 1,000-1,400 mm
- 1,400-2,000 mm
- 2,000-2,800 mm
- 2,800-4,000 mm
- > 4,000 mm
Of the 23 producing regions, 3 are in the Northern Region, 11 in the Central Region, 3 in the Southern Region and the remainder in the Northeastern Region. Provinces contained in each of these producing regions are as follows:

<table>
<thead>
<tr>
<th>Producing region #1</th>
<th>Producing region #8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiang Mai</td>
<td>Suphan Buri</td>
</tr>
<tr>
<td>Mae Hong Son</td>
<td>Nakhon Pathom</td>
</tr>
<tr>
<td></td>
<td>Ratchaburi</td>
</tr>
<tr>
<td>Producing region #2</td>
<td>Producing region #9</td>
</tr>
<tr>
<td>Chiang Rai</td>
<td>Kanchanaburi</td>
</tr>
<tr>
<td>Phrae</td>
<td></td>
</tr>
<tr>
<td>Nan</td>
<td></td>
</tr>
<tr>
<td>Producing region #3</td>
<td>Producing region #10</td>
</tr>
<tr>
<td>Lampang</td>
<td>Bangkok</td>
</tr>
<tr>
<td>Lamphun</td>
<td>Thon Buri</td>
</tr>
<tr>
<td></td>
<td>Nonthaburi</td>
</tr>
<tr>
<td>Producing region #4</td>
<td>Pathum Thani</td>
</tr>
<tr>
<td>Tak</td>
<td>Ayutthaya</td>
</tr>
<tr>
<td>Sukhothai</td>
<td>Nakhon Nayok</td>
</tr>
<tr>
<td>Uttaradit</td>
<td>Saraburi</td>
</tr>
<tr>
<td>Producing region #5</td>
<td>Producing region #11</td>
</tr>
<tr>
<td>Kamphaeng Phet</td>
<td>Chachoengsao</td>
</tr>
<tr>
<td>Phitsanulok</td>
<td>Prachin Buri</td>
</tr>
<tr>
<td>Producing region #6</td>
<td>Producing region #12</td>
</tr>
<tr>
<td>Uthai Thani</td>
<td>Samut Sakhon</td>
</tr>
<tr>
<td>Nakhon Sawan</td>
<td>Samut Songkhram</td>
</tr>
<tr>
<td>Phichit</td>
<td>Samut Prakan</td>
</tr>
<tr>
<td>Phetchabun</td>
<td></td>
</tr>
<tr>
<td>Producing region #7</td>
<td>Producing region #13</td>
</tr>
<tr>
<td>Chai Nat</td>
<td>Chon Buri</td>
</tr>
<tr>
<td>Sing Buri</td>
<td>Rayong</td>
</tr>
<tr>
<td>Lop Buri</td>
<td>Chanthaburi</td>
</tr>
<tr>
<td>Ang Thong</td>
<td>Trat</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Producing region #14</td>
<td></td>
</tr>
<tr>
<td>Phetchaburi</td>
<td></td>
</tr>
<tr>
<td>Prachuap Khiri Khan</td>
<td></td>
</tr>
</tbody>
</table>
Producing region #15
Chumphon
Ranong
Phang-nga
Phuket
Krabi
Trang

Producing region #16
Surat Thani
Nakhon Si Thammarat
Phathalung

Producing region #17
Satun
Songkhla
Pattani
Yala
Narathiwat

Producing region #18
Khon Kaen
Chaiyaphum
Loei

Producing region #19
Nong Khai
Sakon Nakhon
Udon Thani

Producing region #20
Kalasin
Maha Sarakham
Roi Et

Producing region #21
Nakhon Phanom
Ubon Ratchathani

Producing region #22
Nakhon Ratchasima

Producing region #23
Buri Ram
Surin
Si Sa Ket

These producing regions are graphically shown in Figure 6.

**Consuming regions**

There are 11 consuming regions, each of which is made up of a number (at least one) of contiguous producing regions. Geographical location is provided in Figure 7. Each producing region is wholly contained in one and only one consuming region. Consuming regions are selected on the basis that each of them has an established regional center which distributes farm commodities among surrounding areas and which, in many cases, processes them as well. Table 9 indicates the producing regions contained in each consuming region and also the associated main regional center.
Figure 6. The 23 producing regions
Figure 7. The 11 consuming regions
Table 9. Consuming regions and their regional centers

<table>
<thead>
<tr>
<th>Consuming region #</th>
<th>Producing region # contained</th>
<th>Regional center</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,3</td>
<td>Chiang Mai</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Chiang Rai</td>
</tr>
<tr>
<td>3</td>
<td>4,5</td>
<td>Phitsanulok</td>
</tr>
<tr>
<td>4</td>
<td>6,7</td>
<td>Nakhon Sawan</td>
</tr>
<tr>
<td>5</td>
<td>8,9,10,11,12,14</td>
<td>Bangkok</td>
</tr>
<tr>
<td>6</td>
<td>13</td>
<td>Chon Buri</td>
</tr>
<tr>
<td>7</td>
<td>15,16</td>
<td>Nakhon Si Thammarat</td>
</tr>
<tr>
<td>8</td>
<td>17</td>
<td>Songkhla</td>
</tr>
<tr>
<td>9</td>
<td>18,19</td>
<td>Udon Thani</td>
</tr>
<tr>
<td>10</td>
<td>20,21</td>
<td>Ubon Ratchathani</td>
</tr>
<tr>
<td>11</td>
<td>22,23</td>
<td>Nakhon Ratchasima</td>
</tr>
</tbody>
</table>

Resource constraints

Doubtless there are numerous resources used in commodity production, e.g. land, labor, production credits, fertilizers, etc. If they are scarce, there is then a constraint for each resource used in production of each commodity in each producing region. It follows that if there are p scarce resources, there are up to $p \times 10 \times 23 = 230p$ constraints imposed on resource utilization. We, nevertheless, consider land as the only scarce resource, not only because the data for other resources are lacking but also because the way in which the technical coefficients are estimated suffices land use as the only set of resource constraints. The latter point will be clearer when the estimation of the technical coefficients is discussed.

Not all of the land in any producing region is available for agricultural uses. Moreover, cultivable land does not imply that it can be suitably utilized by production of any one farm commodity. Since we assume no a priori knowledge about potential availabilities of land for
farm purposes, it is intuitively obvious that land may be employed up to the maximum historical amount. There is a distinct possibility that the maximum of historically planted land fails to take into account the fact that land has several competing uses. For example, in 1966 the amount of land planted for mung bean production reached 105,152 rais -- the highest during 1962-1968 -- for producing region #7. In that same year, 10,591 rais were used to produce sugar cane, falling from a record high of 15,681 rais in 1962. This decrease might have been due to a switch from sugar cane to mung bean production. For our model, the amount of land available is 105,152 rais and 15,681 rais for mung bean and sugar cane activities respectively. Thus, it gives no recognition with regard to the alternatives in which land may be allocated. To overcome this impasse, another constraint may be adjoined. In addition to the above constraints on land availabilities, the sum of land used in individual activities cannot exceed the maximum of the sum of land historically determined. Since, during 1962-1968, the total amount of land devoted to produce both commodities was at its peak in 1966, this maximum would then be 105,152 + 10,591 = 115,743 rais. However, the introduction of additional constraints considerably increases the size of the model. An alternative to this is that we may assume the problem to be negligible. Since only about one-fourth of the country's total land is brought into cultivation, the increase in land use for any one commodity may occur not at the expense of other commodities but may be attributed to land reclamation instead. We assume this to be the case for our model.
Costs of production and transportation

The lack of data on production costs by province or, for our purposes, by producing region for each commodity under consideration prohibits our model from actual applications. To estimate these costs, the amount of various inputs used such as land in rais, labor in man-hours, fertilizers in kilograms/rai together with their prices must be known. However, the data on these variables are sparse on the national level and far more so on the provincial level. This presents a major obstacle regarding the estimation of production costs, since there is really no other way by which resource use and price may be found to reflect regional differences. Production cost data are available only for the case of rice, and even for rice, few provinces are covered. The study has been carried out on a yearly basis by the National Statistical Office since 1969. Some of the results of the 1971 survey are printed in Table 10.

Table 10. 1971 costs of paddy rice production by official regions\(^a\)
(per Kwien\(^b\))

<table>
<thead>
<tr>
<th>National average</th>
<th>Northern region</th>
<th>Northeastern region</th>
<th>Central region</th>
<th>Southern region</th>
</tr>
</thead>
<tbody>
<tr>
<td>B 1,004.86</td>
<td>B 810.33</td>
<td>B 1,072.66</td>
<td>B 1,017.04</td>
<td>B 1,234.95</td>
</tr>
</tbody>
</table>

\(^a\)Source: (70, p. 6).

\(^b\)One Kwien = 1,010 kilograms of paddy rice.

These results show that the variations in the production costs due to the differences among official regions must be substantial. A breakdown of these costs into various components will further show that the
regional differences are much greater and do not follow the same sort of pattern that we can use to infer about production costs of other commodities. Furthermore, even if we come to a stage where something can be inferred, the problem of identifying the differences due to producing regions in which we are interested is still far from being solved.

Commodity transfer among provinces occurs in several ways. Trucks, rails, and carts as well as barges are used to transport goods from one point to another. Although trucks appear to be the chief means of transportation, it is recognized that there are numerous places, especially remote villages, which are quite inaccessible by them. Small animal carts and bicycles have to be used instead. The costs of transportation required for our model are those among consuming regions. Commodity flows from one producing region to another within the same consuming region are assumed to incur no costs. When commodities are shipped to another producing region in a different consuming region, it is assumed that they must proceed via assigned regional centers. The transportation costs therefore exist only among these centers.

**Final demands**

The final demand for a commodity may be divided into two parts: domestic and foreign. The general procedure in estimating these demand components has been briefly discussed in Chapter II on input-output models. Since much of the provincial data does not exist, the estimation and subsequent projections are based mainly on the population size. The final domestic demand for most commodities in each consuming region thus
varies with the size of the population in that region. Given sufficient data, it could be made a function of other variables as well, e.g. regional income. This would make the model more realistic and less subject to errors.

The foreign sector is regarded as an extra consuming region. Commodity movements into and out of it are exports and imports respectively. To be consistent with the traditional tendency and with the goal of minimizing the use of foreign exchange, we are primarily interested with commodity exports. In our model, the total actual number of consuming regions is now 12.

The Statement of the Model

For simplicity, let us assign a number to each commodity of interest. This is shown in Table 11.

Table 11. Numbers assigned to primary commodities

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>1</td>
</tr>
<tr>
<td>Maize</td>
<td>2</td>
</tr>
<tr>
<td>Cassava</td>
<td>3</td>
</tr>
<tr>
<td>Sugar cane</td>
<td>4</td>
</tr>
<tr>
<td>Castor beans</td>
<td>5</td>
</tr>
<tr>
<td>Jute</td>
<td>6</td>
</tr>
<tr>
<td>Kenaf</td>
<td>7</td>
</tr>
<tr>
<td>Tobacco</td>
<td>8</td>
</tr>
<tr>
<td>Mung beans</td>
<td>9</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>10</td>
</tr>
<tr>
<td>Soybeans</td>
<td>11</td>
</tr>
</tbody>
</table>

All commodities are regarded as being processed locally before they are marketed for final consumption, except commodities #3, 4, 6, 7 and 8
which are processed in some or all of certain consuming regions, namely, 5, 6, 9, 10 and 11. By letting $\gamma = \{1,2,5,9,10,11\}$ and $\theta = \{3,4,6,7,8\}$, we aim to minimize

$$Z = \sum_{i,j} c_{ij} x_{ij} + \sum_{k,k'} \sum_{k \neq k'} t_{ikk'} x_{ikk'}$$

subject to

$$a_{ij} x_{ij} \leq b_{ij} \text{ for all } i \text{ and } j \quad [5.2]$$

$$x_{ik} \geq d_{ik} + \sum_{k'} \left( x_{ikk'} - x_{ik'k} \right) \quad \text{for } i \in \gamma \text{ and all } k \neq k' \quad [5.3]$$

$$\sum_{j \in \gamma} x_{ij} = x_{ik} \quad \text{for } i \in \gamma \text{ and all } k \quad [5.4]$$

$$\sum_{j \in \gamma} x_{ij} = \sum_{k} x_{ikk} \quad \text{for } i \in \theta \text{ and all } k \quad [5.5]$$

$$\sum_{k} x_{ikk} \leq g_{ik} \quad \text{for } i \in \theta \text{ and all } k' \quad [5.6]$$

$$\sum_{k} q_{ik'} x_{ikk} = \sum_{k} y_{ik'}' \quad \text{for } i \in \theta \text{ and all } k' \quad [5.7]$$

$$\sum_{k'} y_{ik'}' \geq d_{ik} \quad \text{for } i \in \theta \text{ and all } k \quad [5.8]$$
All X's and Y's ≥ 0

j = 1, 2, ..., 23

k, k' = 0, 1, ..., 11

k'' = 5, 6, 9, 10, 11

j, k, as shown in Table 9

c_{ij} = the costs of producing the i^{th} commodity within the j^{th} producing region

X_{ij} = the amount of the i^{th} commodity produced in the j^{th} producing region

t_{ikk'} = the costs of transporting the i^{th} commodity from the k^{th} to k'\textsuperscript{th} consuming region, k \neq k'

X_{ikk'} = the amount of the i^{th} commodity transported from the k^{th} to k'\textsuperscript{th} consuming region

t_{ikk''} = the cost of transporting the i^{th} commodity from the k^{th} to k''\textsuperscript{th} consuming region

p_{ik''} = the costs of processing the i^{th} commodity in the k''\textsuperscript{th} consuming region

X_{ikk''} = the amount of the i^{th} commodity transported from the k^{th} to k''\textsuperscript{th} consuming region

t_{ik''k} = the costs of transporting the i^{th} commodity from the k''\textsuperscript{th} to k^{th} consuming region

Y_{ik''k} = the amount of the i^{th} commodity transported from the k''\textsuperscript{th} to k^{th} consuming region

a_{ij} = the amount of land required to produce a unit of the i^{th} commodity in the j^{th} producing region
\[ b_{ij} = \text{the amount of land available for production of the } i^{th} \text{ commodity in the } j^{th} \text{ producing region} \]

\[ X_{ik} = \text{the amount of the } i^{th} \text{ commodity produced in the } k^{th} \text{ consuming region} \]

\[ d_{ik} = \text{the amount of the } i^{th} \text{ commodity demanded in the } k^{th} \text{ consuming region} \]

\[ g_{ik}'' = \text{the maximum amount of the } i^{th} \text{ commodity that can be processed in the } k''^{th} \text{ consuming region} \]

\[ q_{ik}'' = \text{the conversion factor by which the } i^{th} \text{ commodity is converted into processed form in the } k''^{th} \text{ consuming region} \]

The objective function [5.1] states that the total costs incurred are equal to the sum of the costs of production, transportation, processing and transportation for processed commodities. Constraints imposed on the model are [5.2] through [5.8]. In [5.2] the amount of land used must not exceed its availabilities. In [5.3] the supply of each commodity must at least be equal to its demand in each consuming region plus net exports to other consuming regions. [5.4] simply expressed an identity that the supply of each commodity in each consuming region is the sum of what is produced in all producing regions contained in it. [5.5] applies to those commodities that have to be transported for processing. It states that the sum of each commodity in each consuming region to be transported elsewhere for processing is equal to the amount produced in that region. According to [5.6], the total amount of any commodity to be processed cannot exceed the maximum capacity of the processing plants. A link
between raw and processed commodities is provided in [5.7]. The last relation [5.8] is similar to [5.3].

Potentially, there are $253 \times_{ij}$'s, $792 \times_{ikk}$'s, $300 \times_{ikk''}$'s and $275 \times_{ikk'''}$'s, making a total of 1,620 variables. For the constraints, there are 253 in [5.2], 72 each in [5.3] and [5.4], 60 each in [5.5] and [5.8], and 25 each in [5.6] and [5.7]. Thus the model has altogether 567 constraints. The actual number of variables and constraints, however, will be lower, as not all commodities are produced in certain regions.

We now turn to the problems of how to estimate the parameters of the model and the demands for each commodity considered.

Method of Estimation

The technical coefficients

From [5.2] in which $a_{ij}$ is the amount of land in the $j$th producing region used to produce a unit of the $i$th commodity, if $L_{ij}$ and $Y_{ij}$ are the amount of land planted and the amount produced in the $j$th producing region in the production of the $i$th commodity, then $L_{ij}/Y_{ij}$ would certainly give some indication as to what the value of $a_{ij}$ would be. Since it is in our interests to apply the linear programming model at some future point in time for planning purposes, we need to include a trend factor in the estimation of $a_{ij}$'s. It is postulated that

$$L_{ij}/Y_{ij} = \mu_{ij} + \lambda_{ij}t + \nu_{ij} \quad [5.9]$$

where

$\mu_{ij}$ and $\lambda_{ij}$ are constant but unknown.
\( t = \) the time trend \\
\( u_{ij} = \) the random error, satisfying the condition \( u_{ij} \sim \text{IID} (0, \sigma^2) \)

The time series data are limited but seem to be available from 1963 to 1968. Under these circumstances, \( t \) can be 63, 64, ..., 68. [5.9] can then be fitted by using simple least squares, thus estimating \( \mu_{ij} \) and \( \lambda_{ij} \). If we wish to project our model for 1976 and 1980, these technical coefficients have to be projected. One way is to put \( t = 76 \) and 80 in the estimated equation. The projected technical coefficients in 1976 and 1980 are then given by

\[
\hat{a}_{ij1976} = \hat{\mu}_{ij} + \hat{\lambda}_{ij}(76)
\]

\[
\hat{a}_{ij1980} = \hat{\mu}_{ij} + \hat{\lambda}_{ij}(80)
\]

respectively.

An alternative way of projecting is to test if \( \hat{\lambda}_{ij} \) is statistically significant from zero, assuming the normality about errors. If it is not, we may conclude that there appears to be no trend and the trend term may be dropped from the equation. \( a_{ij} \) is then estimated by \( \hat{\mu}_{ij} \) alone, and is constant for all \( t \). If \( \hat{\lambda}_{ij} < 0 \), and it is believed that new technologies will eventually within the planning period avert the negative time trend, \( \hat{\lambda}_{ij}t \) may for our purposes be deleted from the regression equation. The contention that the deletion is plausible is reinforced by the fact that the data used do not discriminate other factors which contribute to annual yield differences than land. In time, it is expected that these other factors will work favorably toward a nonnegative time trend. An implication arising from this is that since the way in which technical
coefficients are estimated does not reflect only land use, it is not necessary to adjoin additional constraints on other resources such as water supply. This is a major reason that land is made the only resource limited in supply.

Land availabilities

Based on the 1963-68 data, some producing regions do not produce all commodities being considered. For example, no kenaf has been produced in producing region #17. The amount of land potentially available is not known prior to detailed nationwide investigation, but may be approximated conservatively by the maximum amount historically used. To simplify our planning model, any productive activity employing less than 500 rais of land annually during the 1963-68 period is regarded as insignificant and excluded from the model. Table 12 provides the details on the number of constraints actually imposed as well as the amount of land available. Altogether, there are 224 constraints on resource use alone.

Future demand requirements

The estimation of $d_{ik}$'s involves essentially two steps. The first step is to find the demand requirements for each commodity in each consuming region, while the second step is concerned with the foreign demand estimation. Since the data on some commodities are lacking and most commodities are unique in their own way, we shall consider individual demand functions at some length.
<table>
<thead>
<tr>
<th>Producing region</th>
<th>Rice</th>
<th>Maize</th>
<th>Cassava</th>
<th>Sugar cane</th>
<th>Castor beans</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>817,026</td>
<td>21,244</td>
<td>2,892</td>
<td>11,858</td>
<td>3,131</td>
</tr>
<tr>
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<td>1,741,681</td>
<td>164,933</td>
<td>1,606</td>
<td>24,402</td>
<td>7,554</td>
</tr>
<tr>
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<td>45,891</td>
<td>17,781</td>
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<td>69,950</td>
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<tr>
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<td>4,200</td>
<td>52,641</td>
<td>2,816</td>
</tr>
</tbody>
</table>

Total number of land constraints: 23

---

*aSource: Unpublished data obtained through private correspondence with several officials, particularly Mr. Yong Hengtrakul, in the Division of Agricultural Economics, Ministry of Agriculture, Thailand.*
<table>
<thead>
<tr>
<th>Jute</th>
<th>Kenaf</th>
<th>Tobacco</th>
<th>Mung beans</th>
<th>Groundnuts</th>
<th>Soybeans</th>
</tr>
</thead>
<tbody>
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<td></td>
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<td>60,144</td>
<td>530</td>
</tr>
</tbody>
</table>

| 14 | 13 | 23 | 22 | 23 | 16 |
**Demand for rice**

It is intuitively clear from the basic consumer demand theory that the domestic demand for any commodity may be expressed as a function of its own price, the price of its close substitutes, per capita real income and the size of the population. Nonetheless, we shall argue that the domestic demand for rice depends largely on the size of the population. Over time the growth in the domestic demand for rice is mainly determined by the rate of population growth.

The exclusion of the other variables stems partly from the lack of data, especially on provincial basis, but other factors are also of equal importance. Since rice is always the principal source of essential food, it is the governmental policy to keep its price down. The tendency for production to exceed domestic consumption also implies that its price is usually low relative to other cereals. These, together with the fact that rice is preferred to any other commodity in the same class, indicate that there seems to be no close substitutes and that the domestic demand for rice is inelastic with respect to its own price and income. Empirically, it has been found that the coefficient of the income elasticity of the demand for rice is only 0.2 (82, p. 143). Even if Engel's law holds, the percentage of income spent on food is unlikely to change because per capita real income for the Thai economy has not markedly increased in the last decade. With these reasons, the exclusion of other variables than the size of the population is justified.

There are two methods of estimating future domestic demand requirements. First, we may assume that what is not exported nor stocked is consumed domestically. This is then made a function of the population
size. Knowing the average rate of population growth, rice requirements by 1976 and 1980 can be readily calculated. Another method is to assume that rice is consumed in constant amount on per capita basis. If, on the average, a person requires about 250 kgs of paddy rice annually, then rice requirements in the $t^{th}$ year are given by

$$x_1(t) = (0.250)N(t) \quad [5.10]$$

where

$$x_1(t) = \text{the amount of paddy rice required in the } t^{th} \text{ year, in metric tons}$$

$$N(t) = \text{the size of the population}$$

The size of population in each consuming region by the end of 1960 is shown in Table 13. The estimated size for 1976 and 1980 is also given, based on a 3% rate of growth.

Table 13. Population size by consuming region$^a,b$

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<tr>
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</tr>
<tr>
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<td>1,297,777</td>
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<td>2,364,679</td>
</tr>
<tr>
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<tr>
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<td>2,926,688</td>
<td>4,729,820</td>
<td>5,332,718</td>
</tr>
</tbody>
</table>

$^a$Source: Derived from (72, pp. 42-45).

$^b$All figures calculated on basis of an assumed 3% rate of growth.
The figures in Table 13 may be updated as soon as the final results of the 1970 Population Census are published. Basically, the two methods are essentially the same. The first method is more plausible if we have reason to suspect that there are regional differences in per capita consumption and if the extent of data availabilities permit. Barring these the second method is simpler.

Most countries have one common goal to be achieved as far as agriculture is concerned -- that of self-sufficiency. For food deficit countries, international trade is inevitable for survival. Where varieties of food can be imported, they tend to find a combination of these varieties which minimizes loss of foreign exchange and is consistent with domestic food requirements. These points are worth keeping in mind, especially when we come to deal with the estimation of the future demand for rice by the rest-of-the-world sector.

We assume that the rest-of-the-world sector wishes to consume some given amount of cereals in calories, say, \( K \) at any time, \( t \). If the supply of these cereals produced domestically is \( k_1 \), then the amount of cereals which has to be imported is \( k_o = K - k_1 \).

Let us suppose that cereals to be imported can be subdivided into three main categories, rice, wheat and others. The last category includes maize, rye, oats, etc. If \( a_1, a_2 \) and \( a_3 \) are rates of conversion from these categories into calorie equivalents respectively, then

\[
k_o = a_1 y_1 + a_2 y_2 + a_3 y_3 \quad \text{[5.11]}
\]

where
$y_1 = \text{the quantity of rice imported}$

$y_2 = \text{the quantity of wheat imported}$

$y_3 = \text{the quantity of other cereals imported}$

It is now assumed that the foreign sector has a goal of minimizing the cost of importing these food items. Then it aims

To minimize $p_1y_1 + p_2y_2 + p_3y_3$ \hspace{1cm} [5.12]

subject to [5.11]

where

$p_i$ is the international price of the $i^{th}$ commodity, $i = 1, 2, 3$

We form the Lagrangian function as follows:

$L = p_1y_1 + p_2y_2 + p_3y_3 + \lambda[k_0 - a_1y_1 - a_2y_2 - a_3y_3]$ \hspace{1cm} [5.13]

Minimizing $L$, we have

$$\frac{\partial L}{\partial y_1} = \frac{\partial p_1}{\partial y_1} - \lambda a_1 = 0$$ \hspace{1cm} [5.14]

$$\frac{\partial L}{\partial y_2} = \frac{\partial p_2}{\partial y_2} - \lambda a_2 = 0$$ \hspace{1cm} [5.15]

$$\frac{\partial L}{\partial y_3} = \frac{\partial p_3}{\partial y_3} - \lambda a_3 = 0$$ \hspace{1cm} [5.16]

$$\frac{\partial L}{\partial \lambda} = k_0 - a_1y_1 - a_2y_2 - a_3y_3 = 0$$ \hspace{1cm} [5.17]

From [5.14] and [5.15], by eliminating $\lambda$,
From [5.14] and [5.16], by eliminating λ,

\[ y_1 \frac{\partial p_1}{\partial y_1} = \frac{\alpha_1}{\alpha_2} [p_2 + y_2 \frac{\partial p_2}{\partial y_2}] - p_1 \]  

[5.18]

Adding [5.18] and [5.19] and dividing by \(2\frac{\partial p_1}{\partial y_1}\) throughout, we obtain

\[ y_1 = \frac{1}{2} \cdot \frac{1}{\frac{\partial p_1}{\partial y_1}} \left[ \frac{\alpha_1}{\alpha_2} [p_2 + y_2 \frac{\partial p_2}{\partial y_2}] - \frac{\alpha_3}{\alpha_3} [y_3 \frac{\partial p_3}{\partial y_3}] - 2p_1 \right] \]  

[5.20]

If \(p_1\) can be assumed to be a linear function in \(y_1\) for \(i = 1, 2, 3\), then \(\frac{\partial p_1}{\partial y_1}\) is constant and the foreign demand for rice, \(y_1\), may be expressed as a linear function in \(y_2, y_3, p_1, p_2\) and \(p_3\). This follows from equation [5.20].

A logically correct procedure in determining the foreign demand for rice would be to find foreign demands for wheat and other cereals which are partially dependent upon the demand for rice. These demand functions, together with an identity represented by [5.11], form a set of simultaneous equations. Nonetheless, for our purposes on hand, other demand functions are ignored and we estimate the foreign demand for rice only. Quantities such as \(y_2\) and \(y_3\) are treated as though they are independent variables.

The above analysis assumes the domestic supply of cereals, \(k_1\), to be
completely unaffected by world prices. The urgency of the problem of food shortage and the desire for self-sufficiency are not felt, nor allowed for in the demand function for rice. To make our function more complete and realistic, we may introduce two more variables: one reflecting agricultural policy of food importing countries and the other, the rate of growth of domestic supply of cereals. An immediate effect of this is that $k_1$ is now permitted to vary in response to movements in these variables. Since Thailand is but one of the countries exporting rice, the foreign demand for Thai rice depends, to some extent, on the prices at which Thailand and her competitors offer for sale. Since other cereals are of minor importance, they are ignored when we finalize an explicit form of the foreign demand function.

Even though Thailand's main rival appears to be the United States, Burma and Mainland China at times hold a significant share of the world market for rice. Thus Thai rice is sold in direct competition with that of other exporters, while its price is matched against the price of others and the price of wheat paid by Thailand's potential cereal importers. Since Hong Kong, Singapore, Malaysia, India and Japan are among the major importers of Thai rice, the foreign demand function facing Thailand which can be fitted may be written as

$$y_{lt} = f(X_{1t}, X_{2t}, \ldots, X_{7t}, t)$$  \[5.21\]

where

$y_{lt}$ = the amount of rice exported in thousand tons

$X_{1t}$ = the deflated price of rice exported in bahts/ton
\[ X_{2t} = \text{the deflated price of U.S. rice exported in dollars/100 lbs} \]
\[ X_{3t} = \text{the amount of wheat imported by the above-mentioned major importers in thousand tons} \]
\[ X_{4t} = \text{the deflated price of wheat imported in dollars/ton} \]
\[ X_{5t} = \text{the amount of rice imported by these importers from countries other than Thailand in thousand tons} \]
\[ X_{6t} = \text{the deflated price of rice imported in dollars/ton} \]
\[ X_{7t} = \text{the rate of increase in cereal production within the ECAFE region} \]
\[ t = \text{time} \]

The subscript \( t \) on the variables indicates the quantity taken in the \( t^{th} \) period. As the U.S. is Thailand's main rival in selling surplus rice, \( X_{2t} \) is included in [5.21]. The deflation is made by using the average of the consumer price indices for Hong Kong, Singapore, Malaysia, India and Japan. Since the ECAFE region very well covers the countries to which Thai rice is sold, it is reasonable to accept \( X_{7t} \) as reflecting the rate of growth of domestic supply of cereals in rice deficit countries. The variable representing the extent of agricultural policy in these countries is not included in the function because of the difficulty in quantification. One of the major rice importers, Indonesia, is not considered for the reason that she experienced extreme economic and political instability during the mid-60's. This upheaval is not expected to recur within the foreseeable future.
Demand for maize

The domestic maize requirements in 1976 and 1980 are estimated by using the past growth rate achieved during 1962-70. They could be a lot higher if we recognize that industries which require maize as their primary input, such as animal feeding, are still in their infancy. The total projected requirements are then divided on the population basis into individual requirements of the 11 consuming regions. On the export side, we consider only the major importing countries of Thai maize: Hong Kong, Singapore, Malaysia, China (Taiwan) and Japan. The foreign demand for maize is thought of as being a function of the ratio of the price Thailand receives for her maize exports to the price these major importers pay for maize imported from countries other than Thailand, \( X_{1t} \), the quantity of maize imported from other countries than Thailand, \( X_{1t} \), and time, \( t \). That is, if \( y_{2t} \) is the amount of maize exported by Thailand, then

\[
y_{2t} = f(X_{1t}, X_{2t}, t) \tag{5.22}
\]

Demand for cassava

Cassava roots may be consumed directly by livestock. However, they have to be processed into flour before they are ready for human consumption. Since the use of cassava as animal feed is not extensive, we assume that all cassava roots are processed first before they are marketed. Processing plants are located in Chonburi and the surrounding area (consuming region #6). Future requirements may be projected on the basis of the population size.

Because cassava is exported in many forms, it is difficult to compare prices among exporting countries. Even if it may be argued that conversion
into one form permits comparison, Thai cassava exporters have not been able to consistently maintain the same degree of quality over the years. For this reason the foreign demand for cassava roots or root equivalents is made a function of time only. Knowing the growth rate of cassava exports, the foreign requirements by the end of 1976 and 1980 can be approximated.

**Demand for sugar cane**

The domestic demand for sugar cane is based on the population size. Roughly, from 1962-70 data on sugar cane production, cane sugar production and exports, 6 kgs of cane sugar are consumed yearly per capita. From the same data, about 30 tons of sugar cane are needed to produce a ton of cane sugar. These figures help project future domestic and foreign demand for sugar cane. Since sugar refineries are located in consuming regions #5 and #6, all sugar cane produced elsewhere must be transported to these regions for processing.

The foreign demand is a function of the ratio between Thai and Filipino sugar cane export prices, and time. The selection of the Philippines as Thailand's major competitor stems from the fact that the two countries are similar, regarding sugar cane production, and are also close in terms of distance. The function is, however, not expected to statistically fit well because of the existence of the International Sugar Agreement which distorted the market mechanism.

**Demand for castor beans**

The size of the population in various consuming regions again provides a guide as to how much castor beans will be domestically demanded. Since
Japan buys most of the castor beans exported, the demand for them depends on the export price deflated by the Japanese wholesale price indices, and time.

**Demand for jute and kenaf**

Jute and kenaf requirements for domestic consumption are evaluated on the basis of the past rate of growth. The export demand for them is dependent on the ratio of the average price of jute and kenaf exports paid to Thailand and the average export price paid to the major jute producer, Pakistan, and time.

**Demand for tobacco**

The domestic tobacco requirements may be projected on the basis of the past growth rate. All dried tobacco leaves are manufactured in consuming region #5. On the export side, the foreign demand for tobacco is assumed to depend on the ratio of prices paid for Thai and United States tobacco exports, and time.

**Demand for mung beans**

The domestic requirements for mung beans are estimated on the population basis, while the export requirements are determined by the past rate of growth in mung bean export performance.

**Demand for groundnuts**

Approximately 4 kgs of unshelled groundnuts are consumed per capita annually. From this we may calculate the future groundnut requirements in each consuming region. The price ratio of Thai and Nigerian shelled groundnut exports and the time trend determine the amount of Thai shelled
groundnuts exported. Since Nigerian exports capture a major portion of the world groundnut market, their price bears an indication as to what the world price would be. As India is a major exporter of groundnut cake and meal in the East, the foreign demand for these products as far as Thailand is concerned may be postulated to be a function of the ratio of average prices paid to Thailand and India. The projected shelled groundnut and groundnut cake and meal export requirements are then converted into unshelled equivalents. The total of these requirements is the amount of unshelled groundnuts which must be produced to meet foreign demand.

**Demand for soybeans**

The domestic requirements of soybeans are determined by the rate of growth achieved in the past, while the export requirements are dependent on the ratio of the average Thai and United States soybean export price, and time. Soybean cake and meal are also exported but only in small quantities and therefore are ignored.

**Transportation costs**

Freight rates differ not only among but also within the means of transportation. They depend on the volume, value as well as the weight of the load. Truck freight rates increase as the road conditions deteriorate and as the difference in importance between the points of destination involved increases. This calls for a distinction between economic and geographical distances. However, in view of continued improvements in roads and truck use, the costs of transportation between any two regional centers may be approximated by the actual distance between them multiplied by the average truck rate in bahts per ton per
kilometer. With more information, modifications could be made. For example, the total costs of transportation may be expressed as a function of the total distance actually covered, the time it would take (which distinguishes the transportation means), and the conditions of the road or canal.

Production costs

We may divide the costs of producing a unit, say, a ton of a commodity, into six major components. These are the costs of seedlings, pesticides, fertilizers, machinery, labor and other miscellaneous items. If these costs are denoted by $x_1, x_2, \ldots, x_6$ respectively, then the total costs of production are given by $\sum_{i=1}^{6} x_i$. For projection purposes, they are not expected to remain constant all the time. Instead it is as reasonable to assume that they will rise over time as it is to suspect a secular decline through expansion in farm size and economies of scale. Since the planning period ends at most by 1980, it could be considered as a short span of time and the costs of production may be assumed to rise as the yield increases. If $t$ is the base year at which $x_i$'s are estimated, then in the $(t+n)^{th}$ year the projected costs of production could be thought of, for first approximations, as increasing by the same percentage as the increase in yield. If $a_{ij}(t)$ is the amount of land required to produce a unit of the $i^{th}$ commodity in the $j^{th}$ producing region in the $t^{th}$ year, and $a_{ij}(t+n)$ has a similar meaning for the $(t+n)^{th}$ year, then $a_{ij}(t)/a_{ij}(t+n)$ indicates the increase in productivities. Thus, if $c_{ij}(t+n)$ is the costs of producing a ton of the $i^{th}$ commodity in the $j^{th}$ producing region during the $(t+n)^{th}$ year, it is postulated that
Planning Aspects of the Model

The model represented by [5.1] through [5.8] may be rewritten as

To minimize \( Z = c_1^i x_1 + c_2^i x_2 + t_1^i x_3 + t_2^i x_4 \)  \[5.24\]

subject to

\[
\begin{align*}
Ax_1 & \leq b \quad [5.25] \\
x_5 & \geq d_1 - J_2 x_2 \quad [5.26] \\
J_1 x_1 & = x_5 \quad [5.27] \\
J_6 x_1 & = J_7 x_3 \quad [5.28] \\
J_3 x_3 & \leq g \quad [5.29] \\
QJ_3 x_3 & = J_5 x_4 \quad [5.30] \\
J_4 x_4 & \geq d_2 \quad [5.31]
\end{align*}
\]

All \( x \)'s \leq \emptyset

where

\[
\begin{align*}
c_1' &= \begin{pmatrix} c_{1,1} & c_{1,2} & \cdots & c_{11,23} \end{pmatrix} \\
c_2' &= \begin{pmatrix} t_{1,0,1} & t_{1,1,0} & \cdots & t_{11,11,10} \end{pmatrix}
\end{align*}
\]
\[ t_1' = (t_{3,0,5} + p_{3,5}, t_{3,1,5} + p_{3,5}, \ldots, t_{8,11,11} + p_{8,11}) \]

\[ t_2' = (t_{3,5,0}, t_{3,5,1}, \ldots, t_{8,11,10}) \]

\[ A = [a_{ij}] \text{ with } i \text{ and } j \text{ as defined in Table 12} \]

\[ b' = (b_{1,1}, b_{1,2}, \ldots, b_{11,23}) \]

\[ d_{1}' = (d_{1,0}, d_{1,1}, \ldots, d_{11,11}) \]

\[ s' = (s_{3,5}, s_{3,6}, \ldots, s_{8,11}) \]

\[ Q = [q_{1,5}, q_{1,6}, \ldots, q_{1,11}] \]

for \( i \in \Theta \)

\[ d_{2}' = (d_{3,0}, d_{3,1}, \ldots, d_{8,11}) \]

\( J \) matrices contain only elements -1, 0 and 1 in appropriate places; \[5.27\] may be substituted into \[5.26\]. The model can thus be stated in a matrix form as

To minimize \( Z = c'X \) \[5.32\]

subject to

\[
\begin{bmatrix}
A & \emptyset & \emptyset & \emptyset \\
-J_1 & -J_2 & \emptyset & \emptyset \\
\emptyset & \emptyset & J_3 & \emptyset \\
\emptyset & \emptyset & \emptyset & -J_4
\end{bmatrix}
\begin{bmatrix}
x_1 \\
x_2 \\
x_3 \\
x_4
\end{bmatrix}
\leq
\begin{bmatrix}
b \\
-d_1 \\
g \\
-d_2
\end{bmatrix}
\]

\[5.33\]

\[ J_6 x_1 - J_7 x_3 = \emptyset \]

\[5.34\]

\[ Q J_3 x_3 - J_5 x_4 = \emptyset \]

\[5.35\]

\[ x \geq \emptyset \]
where

\[ X' = (x_1, x_2, x_3, x_4) \]

\[ c' = (c_1', c_2', t_1', t_2') \]

A few problems could be present which may prevent us from obtaining a nontrivial, optimal and feasible solution. The projections of the demand requirements assume either that past consumption gives a clue to what future demand is going to be or, that as far as foreign demand is concerned, some certain, numerically specified terms of trade are likely to prevail at some future point in time. In other instances, when per capita consumption is used as a basis for projections, it is implicitly assumed that consumption is independent of income and other factors. Stock requirements are not explicitly treated but are implied in demand projections. This can be seen clearly if we let \( Y_t \) denote the amount of a commodity produced, \( C_t \) the amount consumed, \( S_t \) the stocks, and \( (X-M)_t \) the net amount exported. The subscript \( t \) refers to the time where \( t = 1, 2, \ldots, T \). It follows that \( Y_t = C_t + S_t + (X-M)_t \). The estimation procedure used to find the average per capita consumption is given by

\[
\frac{1}{T} \sum_{t=1}^{T} \frac{C_t + S_t}{P_t}
\]

where \( P \) is the size of the population. Evidently, the stocks are included. It is logical to distinguish \( C \) from \( S \) but, since \( S \) is not known, the distinction is not possible without making an explicit assumption about the relationship between the size of the stocks and production in the following period.
If anything, it is also equally difficult in evaluating the growth in industrial requirements. Certain industries are still in their initiation phase, while some others have yet to be built. This means that future demands for farm commodities by the industrial sector may be uncertain even in the short run. For this reason, the demand estimates of some commodities may be replaced by what the National Third Five Year Plan envisages to be.

So far two models have been developed, one for agricultural planning by 1976 and the other by 1980. They are labeled as Model I and Model II respectively. Model III is similar to Model I except that it contains minor changes so as to incorporate some of the Third Five Year Plan's economic goals. In particular, the Plan aims to achieve an annual production of 14.47 million tons of paddy rice, 3.5 million tons of maize, 6.26 million tons of cassava roots, 400,000 tons of kenaf, and 300,000 tons of soybeans by the end of 1976. In addition, the rate of population growth is to be reduced to 2.5%. As a result, the domestic requirements and the level of exports, \((d_1, d_2)\) in Model III are different from Model I.

Models I and II provide an answer to the recurring problem of whether the economy has sufficient capacity to meet domestic and foreign demands in 1976 and 1980. If it has, they also identify the optimal pattern of spatial resource allocation and use. They tell us how much of each commodity \(X_{ij}\) to be produced, region by region, so that the total costs incurred are minimized. From [5.25], the amount of surplus land available for other employments can be determined. In the case where land resources are insufficient, the models permit us to see how much and where they have to be increased so that our projected goals are realized. The insufficiency
can be detected by the importation of the commodities involved to satisfy final demands. In particular, if some of the $X_{i,0,k'}$'s, for $i = 1, 2, \ldots, 11$ and $k' = 1, 2, \ldots, 11$ are not zero in the optimal feasible solution, two implications can be drawn. First, the foreign demand may be too large to be met by domestic production. Secondly, commodity shortage is so serious that imports have to occur. Under these circumstances, to save or increase foreign exchange calls for an increase in domestic commodity supplies by shifting available surplus land from one activity, e.g. rice growing, to another, or by bringing unused but potentially cultivable land into use. The effects of the change in the land distribution, i.e. in the $b_{ij}$'s, can be examined from the new optimal solution when it is incorporated into the model.

In war time emergencies a situation in which a part of arable land falls outside government control can arise. Given this, regional land supplies will alter disproportionately, since different producing regions are subject to different degrees of military pressure. In any region, the population density tends to increase with the degree of pacification and stabilization achieved. As a result, the spatial distribution of commodity requirements may also be altered. With a new resource and demand structure, viz., with a change in $b$, $d_1$ and $d_2$, optimal resource allocation is unlikely to be the same as before. Contemplating that internal warfare may increase in intensity in the coming years, and technical change that takes place in agriculture may consequently be less drastic, Model I could provide a reasonable guide as to the future outlook of the economy by 1976. This comes as no surprise because it is largely based on the past in which agricultural productivity has increased little.
With all probabilities, the goals of the Third Five Year Plan on farm production are greater than what we estimate to be sufficient to meet the bill of final demands. When they are compared with the actual 1970 level, maize production has to increase by 75%, while cassava production must double. With Model III, we may investigate if these goals are attainable and, if so, how. We may also compare this situation with one under Model I and evaluate economic implications thereof. For example, land use could well be more extensive in Model III but, if this is the case, less would be available for other alternative uses. Given that most farm production goals in Model III are higher and attainable, it cannot be said a priori that farmers are actually better off with regards to their farm income position. These goals are set on the basis that there is a sufficient effective demand to be met. If the domestic requirements are held on the same level as in Model I, after the effect of the reduced rate of population growth (2.5%) has been accounted for, then most export goals \( \{d_{10}, i = 1, 2, \ldots, 11\} \) will have to increase. However, suppose that the actual level of exports falls short of these goals. The commodity surpluses will be diverted to the domestic market, barring the possibility of commodity storage. As a result, prices are likely to fall. If commodity demand is inelastic with respect to price, farm revenue will also fall.

The way by which future demands for exports are estimated in Models I and II allows us to examine how changes in export prices, agricultural policies and economic conditions of importing countries, etc. affect Thai agriculture and, more generally, the economy. For example, if the world price of wheat falls to a new level or the rate of increase in cereal
production in the ECAFE region rises from the average of about 3% per annum during the 1962-68 period to, say, 5% by 1976, then $X_{4t}$ and $X_{7t}$ in (5.21) will have to be altered to accommodate these changes. Thus the amount of the export demand for rice will change accordingly. In general, changes such as these are reflected in the pattern of export demands $(d_{i0}, i = 1, 2, \ldots, 11)$ in (5.3) and (5.8). The model represented by (5.1) through (5.8) under the new set of conditions would suggest a different optimal solution, from which the effects on agriculture, e.g. farm income, may be inferred.

The urgency in farm problems, particularly in income and employment, which arise essentially from low productivities calls for long-run planning on an interregional basis, involving use of several scarce resources that entail when new, different technologies are introduced. These resources include land, labor, water and capital, all of which must be subject to careful consideration. For instance, land is no longer fixed but can vary in qualities, depending on the amount of improvements done to it. An increase in irrigated water supply reduces the physical amount of arable land but may greatly improve it. By the same token, well financed farmers can easily invest in costly but more productive resources, e.g. better land. They can sustain greater losses in case of crop failures. All this shows the importance of, as well as the degree of interdependency among, the scarce resources. With new technologies, i.e. under a changed structure, the planning problems are thrown under a new light. No longer can we assume the link between historical past and uncertain future. They bear little or no relationship with one another, but the gap leaves us room to fill in. Given a set of specific goals, we are not so much
interested in the question of whether it can be achieved, but how we should go about in achieving it. Where (location, region, etc.) and by how much must resources be increased in order to maintain a given level of growth determinants that include employment and income? Particularly, we shall consider in detail the farm needs for water resources and decisions concerning investment in irrigation projects. Thus, the planning problems we are facing include not just spatial allocation of resources but more or less the entire spectrum of developmental needs as well.
CHAPTER VI: STOCHASTIC AND PROBABILISTIC LINEAR PROGRAMMING MODELS

An implication of the fact that the technical coefficients in the original model along with the demands are not known with complete certainty but have to be estimated is that they contain error components which tend to distort the actual optimal solution. In [5.9], $u_{ij}$ is not zero for all observations. Tentatively, we cannot expect it to be zero at a future point in time. A fundamental reason is that land is not the only input which enters productive activities. Since the production function may be generally written as

$$y = f(L, t, x_1, \ldots, x_n)$$ [6.1]

where

- $y$ = output
- $L$ = land
- $t$ = time
- $x_i$'s = other inputs, $i = 1, \ldots, n$

and if $L$ may be expressed in terms of other variables, i.e.

$$L = f(y, t, x_1, \ldots, x_n)$$ [6.2]

then $L/y$ is a function of not only $t$ alone but the $x_i$'s also. That is, if [6.2] is linear homogeneous in $y$, then

$$L/y = f(1, t, x_1, \ldots, x_n)$$ [6.3]

Therefore, [5.9] fails to take into account the effects of the $x_i$'s. If
some of the $x_i$'s change, the corresponding technical coefficients will also change and hence the optimal solution of the model. This leads us to utilize the method of stochastic linear programming in an attempt to specify a particular planning choice (55, 56, 76).

On the other hand, we may assign a priori a probability to each constraint such that the constraints are allowed to be violated some of the time. In this case, we are dealing with probabilistic programming (39, 41). Still another way of approaching the problem at hand may be found in two-stage linear programming under uncertainty (46, 55), in which a decision is first selected arbitrarily and, in the second stage, after the effects of the random elements associated with the first decision are observed, a second decision is made to compensate for the inaccuracies of the first decision. Compensation cannot take place without incurring some form of penalty costs. A two-stage linear programming problem may be stated as follows:

To minimize \( Z = c'x + f'y \)

subject to \( Ax + By = b \)

\[ x, y \geq 0 \]  \[ \text{[6.4]} \]

where

- \( c, f, x \) and \( y \) are \( nxl \)
- \( f = \) the penalty cost vector
- \( A \) and \( B \) are \( mxn \)
- \( b \) is \( mxl \)
In terms of [6.4], $x$ represents the first-stage decision, while the decision $y$ is chosen after the inaccuracies of $x$ have been assessed. This is a wait-and-see situation which does not suit our purpose of formulating planning models. The mistakes made in the first decision may cause irreparable damage to the economy and, under these circumstances, the penalty costs could be infinite. In any event, planning in its true sense has to be well anticipated and deliberately made at least with a certain degree of certainty that the objectives of the plan will be realized. In contrast with the wait-and-see situation, a here-and-now type problem is to allow the decision $x$ to take on a range of values: $X = \{x^1, x^2, \ldots, x^k\}$. Corresponding to each $x^j$, $j = 1, \ldots, k$, there may be an optimal feasible solution in $y$. The solution is obtained from solving the following transformed problem:

To minimize $V = f'y$

subject to $By = b - Ax$

$y \geq 0$

and $x$ given

[6.5]

Hence, barring the multiplicity of solutions, the maximum number of optimal feasible solutions is $k$. Let these solutions be represented by $V^1, V^2, \ldots, V^s$, each of which corresponds to one and only one $x^j$ where $x^j \in X$ and $s \leq k$. The overall optimal feasible solutions may be denoted by $Z^1, Z^2, \ldots, Z^s$. If $Z^t$ is the smallest among the $Z^i$, $i = 1, \ldots, s$, and $t \leq s$, then the $x^j$ which gives rise to $Z^t$ constitutes the optimal
first-stage decision. In this sense, the here-and-now type is much more operational than the wait-and-see counterpart. For our purposes, two-stage linear programming under uncertainty refers to the here-and-now version only.

In Model I, which is represented conveniently by [5.32] through [5.35] it is evident that $A$, $b$, $d_1$ and $d_2$ are not known constants. Neither is $c$. We, nevertheless, assume away the variations in $c$ on the grounds that little is known about it. $Q$ and $g$ are not expected to vary much and thus are treated as constants. In all, three distinct cases will be investigated. They are:

- Case (i) where only $A$ is random
- Case (ii) where $b$, $d_1$ and $d_2$ are random
- Case (iii) where all $A$, $b$, $d_1$ and $d_2$ are random

**Case (i) Where Only A is Random**

Summarily, there are three available methods of approaching this problem: stochastic linear programming, chance-constrained programming and two-stage linear programming under uncertainty. All apparently involve to varying degrees computational efforts greater than are required under Model I or Model II. The selection of these methods should not be made only from the computational viewpoint, but also on the basis of the type of problem we are faced with. Stochastic linear programming is divided into two different approaches: the active and the passive. Strictly speaking, both have no application to Case (i) in which we are currently interested. The active approach will be discussed later in Case (ii). Under the passive approach, the probability distribution of $Z$
is derived by numerical approximations based on the assumed distribution of the elements $a_{ij}$'s. In what follows, we shall describe how this is done in detail and discuss the resulting implications on the value of the $x$'s. Our method of finding a stochastic linear programming solution differs from the conventional method of the passive approach in that the former deals with only one approximated distribution of the objective function, while the latter compares two such distributions by the use of some central measures, e.g. means, medians or coefficients of variation, and thus have applications in determining the choice over alternative planning policies.

From [5.9], the $a_{ij}$'s are found from fitting the equation

$$a_{ij} = \mu_{ij} + \lambda_{ij} t + u_{ij}$$

[6.6]

where $u_{ij}$ is independently and identically distributed with mean zero and variance $\sigma^2_{ij}$.

Model I ignores the presence of $\sigma^2_{ij}$ and proceeds to employ $a_{ij} = \hat{\mu}_{ij} + \hat{\lambda}_{ij}(76)$ as an estimate of the technical coefficient for the year 1976. Intuitively, the variance of $\hat{a}_{ij}$ depends on the size of $\sigma^2_{ij}$ and, if $\sigma^2_{ij}$ is large, the optimal feasible solution to Model I may actually turn out to be nonoptimal or infeasible.

Let the estimate of $\sigma^2_{ij}$ be $s^2_{ij}$

Let the variance of $\hat{a}_{ij}$ be denoted by $V(\hat{a}_{ij})$

Thus, $V(\hat{a}_{ij}) = E[a_{ij} - (\hat{\mu}_{ij} + 76\hat{\lambda}_{ij})]^2$

$$= E[u_{ij} + (\mu_{ij} - \hat{\mu}_{ij}) + (76\lambda_{ij} - 76\hat{\lambda}_{ij})]^2$$
Assuming the normality regarding the error distribution, \( \hat{a}_{ij} \) is then distributed as the student-t with \( 6 - 2 = 4 \) degrees of freedom. The underlying reason is that the true mean and variance of \( a_{ij} \) are not known and have to be estimated. If they were known, \( \hat{a}_{ij} \) would be normal. For the same reason, two degrees of freedom are lost in the process.

The confidence interval for \( \hat{a}_{ij} \) at \((1-\alpha)100\%\) is given by

\[
\hat{a}_{ij} \pm \sqrt{\hat{V}(\hat{a}_{ij})} \left( t_{\alpha/2, 4} \right)
\]

where \( \hat{V}(\hat{a}_{ij}) \) is the same \( V(\hat{a}_{ij}) \) except that \( \sigma_{ij}^2 \) is replaced by its estimate, \( s_{ij}^2 \), and \( t_{\alpha/2, 4} \) is such that \( P[|t| \geq t_{\alpha/2, 4}] = \alpha \).

There are then two extreme values within which \( \hat{a}_{ij} \) lies with a \((1-\alpha)\) 100\% confidence level. We proceed, according to the passive approach of stochastic linear programming, to find these values for each \( a_{ij} \). There are altogether 224 sets of values and, consequently, we form \( 2^{224} \) combinations, each representing \( A \). Assuming that the \( a_{ij} \)'s are mutually
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statistically independent, the joint probability distribution is still normal but all correlation coefficients are zero. This assumption is not crucial; it merely reduces the workload that is required to complete the analysis. For each combination, an optimal feasible solution, if it exists, is found. The $2^{2^2}$ potential solutions are then used to construct the approximate distribution function of $Z$. For the method of construction, see (76).

A major setback in stochastic linear programming models lies in the amount of computational efforts needed. Potentially, there are $2^{2^2}$ probability values associated with the optimal values of the objective function. To overcome the computational problem, we may ignore some of the smaller probabilities on the basis that their inclusion does not alter the results significantly. Alternatively, we may reject the variations in certain $a_{ij}$'s as not significant if the coefficient of multiple determination, $R^2$, found on them through fitting [6.6] exceeds an arbitrarily preassigned limit, say, 0.90. The size of the workload will be further reduced when we recognize the possibilities that, for some $A$, the solution to the model is infeasible.

With the distribution $f(Z)$ approximated, we are faced then with a question: what is the final optimal feasible solution in $X$, given the results attained so far? Let the total number of different nonmultiple optimal feasible solutions found be $m$. These solutions may be denoted as $x^1, x^2, ..., x^m$, where $m \leq 2^{2^2}$. The corresponding values of $Z$ are $z^1, z^2, ..., z^m$. Let us set the tolerance limit, $\xi$, on the objective function such that $P[Z \leq z^*] = \xi$. If $z^1, z^2, ..., z^m$ are ordered in an increasing magnitude, then $x^*$ is said to be tolerable with the probability
\( \xi \), for \( Z^* \leq Z^m \). In rare circumstances where \( Z^* > Z^m \), the tolerance limit has to be lowered to a level given by \( P[Z \leq Z^m] \) so as to preserve the feasibility while maintaining the optimality of the solution.

\( X^* \) thus becomes the ultimate optimal feasible solution. The model described may be designated as Model IV. Let us now turn to a chance-constrained programming model.

The random nature of the technical coefficients has an implication that the resource constraints may at times be violated. In chance-constrained programming, we associate each constraint with a probability of occurrence such that the model given by [5.32] through [5.35] is modified to one whose objective is

To minimize \( Z = c'X \)

subject to

\[
P[Ax_1 \leq b] \geq \alpha
\]

\[
\begin{bmatrix}
-J_1 & -J_2 & 0 & 0 \\
0 & 0 & J_3 & 0 \\
0 & 0 & 0 & -J_4
\end{bmatrix}
\begin{bmatrix}
X_1 \\
\end{bmatrix}
\leq
\begin{bmatrix}
-d_1 \\
-g_1 \\
-d_2
\end{bmatrix}
\]

\( J_6x_1 - J_7x_3 = 0 \)

\( QJ_3x_3 - J_5x_4 = 0 \)

\( X \geq 0 \)

\( \alpha \) is a vector with 224 elements, each of which is preassigned a value in \([0, 1]\) so that the probability that \( Ax_1 \leq b \) is at least equal to \( \alpha \).

We call [6.10] Model V. For simplicity, we confine ourselves to a single
row of $P[\mathbf{A}_{ij} \leq \mathbf{b}] \geq \alpha$, i.e. to $P[\mathbf{a}_{ij} \mathbf{x}_{ij} \leq \mathbf{b}_{ij}] \geq \alpha_{ij}$. Just as before, $\hat{\alpha}_{ij}$ is the estimate of $\alpha_{ij}$ with the variance $V(\hat{\alpha}_{ij})$. Following [6.8], the estimated $V(\hat{\alpha}_{ij})$ is given by

$$
\hat{V}(\hat{\alpha}_{ij}) = \left[ 1 + \frac{1}{6} + \frac{(76 - 65.5)^2}{68} \sum_{t=63} \frac{(t - 65.5)^2}{2} \right] s^2_{ij}
$$

[6.11]

Assuming the normality of the $u_{ij}$, we have

$$
P \left[ \frac{\hat{\alpha}_{ij} \mathbf{x}_{ij} - \hat{\alpha}_{ij} \mathbf{x}_{ij}}{[\mathbf{x}_{ij}^2 \hat{V}(\hat{\alpha}_{ij})]^{\frac{1}{2}}} \right] \geq \frac{b_{ij} - \hat{\alpha}_{ij} \mathbf{x}_{ij}}{[\mathbf{x}_{ij}^2 \hat{V}(\hat{\alpha}_{ij})]^{\frac{1}{2}}} \geq \alpha_{ij}
$$

in which $\frac{\hat{\alpha}_{ij} \mathbf{x}_{ij} - \hat{\alpha}_{ij} \mathbf{x}_{ij}}{[\mathbf{x}_{ij}^2 \hat{V}(\hat{\alpha}_{ij})]^{\frac{1}{2}}}$ - student-t with 4 degrees of freedom

Let $T(t_0) = P[t \leq t_0]$ and $s(\hat{\alpha}_{ij}) = (\hat{V}(\hat{\alpha}_{ij}))^{\frac{1}{2}}$

Then,

$$
T \left[ \frac{b_{ij} - \hat{\alpha}_{ij} \mathbf{x}_{ij}}{\mathbf{x}_{ij} s(\hat{\alpha}_{ij})} \right] \geq \alpha_{ij}
$$

i.e.,

$$
T^{-1}(\alpha_{ij}) \leq \frac{b_{ij} - \hat{\alpha}_{ij} \mathbf{x}_{ij}}{\mathbf{x}_{ij} s(\hat{\alpha}_{ij})}
$$

i.e.,

$$
[\hat{\alpha}_{ij} + T^{-1}(\alpha_{ij}) s(\hat{\alpha}_{ij})] \mathbf{x}_{ij} \leq b_{ij}
$$

[6.12]

Hence, $P[\mathbf{a}_{ij} \mathbf{x}_{ij} \leq \mathbf{b}_{ij}] \geq \alpha_{ij}$ is completely transformed into a certainty-equivalent constraint given in [6.12].
As an example, consider the time series data on sugar cane production in producing region #13. Thus, \( i = 4 \) and \( j = 13 \). In applying least squares to [6.6] we have

\[
\hat{a}_{4,13} = 0.33884476 - 0.00280857 t \quad [6.13]
\]

\[
s^2_{4,13} = 0.00005103
\]

It should be noticed that the trend factor does not appear to be significantly different from zero at the 5% level. When \( t = 76 \), \( \hat{a}_{4,13} = 0.12539344 \). From [6.11], \( \hat{v}(\hat{a}_{4,13}) = (7.466667)(0.00005103) = 0.00038102 \). Therefore, \( s(\hat{a}_{4,13}) = 0.01951973 \).

Set \( \alpha = 0.90 \). Since \( T(0.90) = 1.533 \), with \( v = 4 \), from the standard statistical tables, [6.12] becomes

\[
[0.12539344 + (1.533)(0.01951973)] x_{4,13} \leq 431,131
\]

That is,

\[
(0.15531718) x_{4,13} \leq 431,131 \quad [6.14]
\]

Hence, it has been illustrated how a probabilistic constraint

\[
P(\hat{a}_{4,13} x_{4,13} \leq 431,131) \geq 0.90 \text{ is transformed into } (0.15531718) x_{4,13} \leq 431,131.
\]

Generalizing this, we have a model which is equivalent to [6.10] but more readily operational:

To minimize \( Z = c'X \)

subject to

\[
[A + GS]x_1 \leq b
\]
where G and S are (224x224) diagonal matrices with $T^{-1}(a_{i,j})$ and $s(\hat{a}_{i,j})$ respectively for i and j as defined in Table 12.

[6.15] is still a linear programming model and all conventional methods of solving it apply. The simplicity of the chance-constrained programming version of Model I is achieved because the value of the objective function is not itself chance-constrained. Had we imposed a condition that $P(Z \geq Z_0) = \gamma$ where $0 < \gamma < 1$, the transformed objective function would be nonlinear. If, for instance, it was assumed that $Z = c'X - N(c', X'VX)$ in which case $c$ and $V$ are known constants, $P(Z \geq Z_0) = \gamma$ might be rewritten as $P[U \leq (Z_0 - c'X)(X'VX)^{1/2}] = \gamma$ where $U \sim N(0, 1)$.

Let $F(u)$ denote $P(U \leq u)$

Then $F^{-1}(1 - \gamma) = (Z_0 - c'X)(X'VX)^{1/2}$

That is,

$$Z_0 = c'X + F^{-1}(1 - \gamma)(X'VX)^{1/2}$$  \[6.16\]

Consequently, we would aim to minimize $Z_0$ subject to the constraints in [6.15]. Evidently, $Z_0$ involves the square root of a quadratic term.
in the $x$'s. If $\bar{c}$ and $V$ were not known, and had to be estimated, [6.16] would have to be modified but still retain the nonlinearity.

Undoubtedly, the variabilities in $c$ do exist but because of the lack of data and the degree of complexities already present in large size linear programming, there is little justification to introduce a chance-constrained objective function and thus nonlinearities into the planning models. For our purposes, $c$ is regarded as fixed at least for the planning years.

The two-stage linear programming under uncertainty approach to Case (1) is made difficult by the unknown nature of the penalty cost function, apart from the computational aspects of the problem. The failure to anticipate positive excess demands and thus to accordingly readjust resource use has wide ranging effects, which cannot be easily assessed in money terms.

Consider two cases of commodity shortage. The first is concerned with the situation in which foreign demand cannot be met, while there is no internal shortage. Since all commodities analyzed constitute a major source of foreign exchange earnings, the deficiency in commodity supply means a heavy blow to the export dependent economy, especially from the balance of payments point of view. The repercussive effects could be felt upon various sectors of the economy, given the severity of the situation. The second case occurs when commodity shortage affects the domestic consumers. The government may seek to meet all foreign demands and has to be content in allowing commodity shortage to fall on the domestic consumers. Such action is possible if it decides to stop the steady deterioration in the payments imbalances. On the other hand,
the government may place priorities on the sufficiency of supplies to the domestic economy. In any event, internal commodity shortage can be met by importing from the rest-of-the-world at a cost consisting of the import price and transportation expenses. If this is the case, the government may either ration the imported commodities free or allow the costs to pass directly onto the consumers. Rationing forces the government to enlarge the national budget which can increase inflationary pressures, or to cut down some public expenditures in which case the level of overall employment may be affected. It also encourages black markets. If the government decides not to interfere with commodity shortage directly, it is almost certain that prices will be higher. The distortions in the price ratios, backed up by lower per capita real income and the inequality in income distribution, are likely to alter the consumption pattern at least in the short run. This is the direct result of the interaction between income and substitution effects initiated by price changes. Even if changes in the price of certain commodities may be dismissed as economically unimportant, it is doubtful if rice belongs to this category.

Economic consequences precipitated by commodity shortage hence may be extensive and cannot be easily evaluated in numerical terms. On the basis of the difficulties in specifying the penalty cost function, two-stage linear programming under uncertainty is rejected as a method to deal with stochasticities present in Model I.

Case (ii) Where $b$, $d_1$ and $d_2$ are Random

The active approach of stochastic linear programming and chance-constrained programming are here considered. The first method, the
active approach of stochastic linear programming, however, cannot satisfactorily treat d's as random variables.

Throughout our analysis, land is assumed to be the only scarce resource. Assuming that land in any producing region is homogeneous and perfectly substitutable with regards to its uses, we may partition it into several parts in some suitable fashion and allocate them among productive activities. If \( b_j \) is the total productive land in the \( j \)-th producing region, we arbitrarily choose \( [u_j] = (u_{1j}, u_{2j}, \ldots, u_{11j}) \) such that the maximum amount of land which may be used in the production of the \( i \)-th commodity is \( b_j u_{ij} \), for \( i = 1, 2, \ldots, 11 \), where \( 0 < u_{ij} < 1 \) and \( \sum_{i} u_{ij} = 1 \). The \( [u_j] \) is called the allocation matrix.

Let us assume that the amount of land used in a producing region in any one year is the sum of the amounts used in the production of individual commodities. Since extra land can be and has been brought into cultivation, the possibility that some land is used under multiple cropping can be safely ignored. Furthermore, the total amount of land potentially available in a producing region is, as before, assumed to be the maximum amount previously used. Let the allocation matrix be \( u \) which contains vectors \( [u_j] \) along the main diagonal. \( [u_j] \) may contain up to 11 elements, depending on whether the \( j \)-th producing region produces some or all of the commodities analyzed. The choice of \( [u_j] \) should be close to what they actually are, in order to avoid a high degree of absurdities. For instance, the maximum amount of land previously used for producing region \#6 was 6.164 million rais in 1968. In that year, about 0.22% and 0.077% of it were used to produce maize and mung beans. We may take \( u_{2,6} \) to be
0.2 or 0.3 and $u_{9,6}$ to be 0.07 or 0.08. Since there are 224 real activities in the production process, $u$ is then of the size $(224 \times 23)$.

The case where commodity demands are distributed among consuming regions is extremely difficult to deal with. Logically, the distribution or allocation matrix depends on a number of factors which include tastes, relative income, etc. But, as we have seen, the demand projections for each consuming region are only crudely approximated from either the population size or past growth performance. Seen under this light, we may conclude that until the knowledge about the relative commodity distribution and its determination and, in general, about the dynamics of regional economic growth is increased, the randomness in $d_i$'s is ignored. Otherwise, assigning arbitrary values to the distribution matrix may result in socially unacceptable choices.

To sum up, what we may call Model VI can be mathematically stated as

To minimize $Z = c'X$

subject to

$$Ax_1 \leq u_l$$

$$\begin{bmatrix} -J_1 & -J_2 & \emptyset & \emptyset \\ \emptyset & \emptyset & J_3 & \emptyset \\ \emptyset & \emptyset & \emptyset & -J_4 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} \leq \begin{bmatrix} -d_1 \\ g \\ -d_2 \end{bmatrix} \quad [6.17]$$

$$J_6x_1 - J_7x_3 = \emptyset$$

$$QJ_3x_3 - J_5x_4 = \emptyset$$

$$x \geq \emptyset$$

where
\[ u = \text{Diagonal } ([u_1], [u_2], ..., [u_{23}]) \]

\[ L' = (b_1, b_2, ..., b_{23}) \]

\[ b_j = \max_{t} \sum_{i} b_{ij}(t) \text{ for } t = 1962, ..., 1968 \]

\[ [u_j]' = (u_{1j}, u_{2j}, ..., \text{ up to at most } u_{11j}) \]

\[ \sum_{i \leq 11} u_{ij} = 1 \text{ for all } j \]

\[ i = 1, 2, ..., 11 \]

\[ j = 1, 2, ..., 23 \text{ as defined in Table 12} \]

As \( u \) is allowed to vary, there is an optimal feasible solution, if the model permits, associated with each particular \( u \). With a number of optimal feasible solutions, different values of \( Z \) can be found. If these are \( Z^1, Z^2, ..., Z^m \), then there exists \( Z^s \leq \text{ any other } Z^i \) for \( 1 \leq s \leq m \) and \( i = 1, 2, ..., m \). The value of \( u \) that gives rise to \( Z^s \) is the final policy choice and the corresponding solution \( X^s \) represents the final regional production goal.

The chance-constrained programming model under Case (ii) closely follows the one presented in [6.10]. It may be expressed as

To minimize \( Z = c'X \)

subject to

\[ P[Ax \leq b] \geq a_1 \]
\[ P[J_1x_2 + J_2x_2 \geq d_1] \geq \alpha_2 \]
\[ J_3x_3 \leq g \]
\[ P[J_4x_4 \geq d_2] \geq \alpha_3 \]
\[ J_6x_1 - J_7x_3 = 0 \]
\[ QJ_3x_3 - J_5x_4 = 0 \]
\[ x \geq 0 \]  

\[
\alpha_1, \alpha_2 \text{ and } \alpha_3 \text{ are vectors whose elements take on the value within } [0, 1]. \ A \text{ is assumed to be constant. As for } d_1 \text{ and } d_2, \text{ only those demand components, mainly foreign demands, which are estimated by regression analyses are allowed to vary. Regression permits us to obtain the variances associated with the demand projections, and thus, with these variances, to transform the chance-constrained into certainty-equivalent constraints.}
\]

The transformation is similar to that described in Case (i). If \( b \sim NID [\bar{b}, V(b)] \), then the first set of constraints in [6.18] becomes

\[ AX_1 \leq \hat{b} - [\hat{V}(\hat{b})]^\frac{1}{2} T^{-1}(\alpha) \]  

[6.19]

where \( \hat{b} \) is the estimate of \( \bar{b} \), while \( \hat{V}(\hat{b}) \) is the estimate of \( V(b) \); \( \hat{V}(\hat{b}) \) is diagonal and of the size \((224\times224)\); \( T^{-1}(\alpha) \) is \((224\times1)\) and contains elements \( T^{-1}(\alpha_{13}) \) as in [6.12].

As an example, let us consider the case of rice production in producing region #8. \( \hat{b} \) is found to be 2,798,857 with the standard deviation of 196,089. Setting \( \alpha_{1,8} = 0.90 \), the probabilistic constraint
\[ P(a_{1,8}x_{1,8} \leq b_{1,8}) \geq 0.90 \] is then converted into a certainty-equivalent of the form

\[ a_{1,8}x_{1,8} \leq 2,798,857 - (196,089)(1.533) \]

or

\[ a_{1,8}x_{1,8} \leq 2,498,253 \]

This process may be repeated to other constraints and thus the model can eventually be restated as an ordinary linear programming problem. This constitutes Model VII.

**Case (iii) Where all A, b, d_1 and d_2 are Random**

Chance-constrained programming in Case (iii) apparently is undesirable. The most difficult problem it poses lies in the fact that the transformation results in nonlinear constraints. As A and b are random, the variance-covariance matrix of \((Ax_1 - b)\) can be written in the form of \((Ax_1 - b)' V (Ax_1 - b)\) for some V. It involves quadratic as well as linear terms in \(x_1\) so that, in any single constraint, the standard deviation for \((a_{ij}x_{ij} - b_{ij})\) is highly unlikely to be a simple linear function in \(x_{ij}\).

Under stochastic linear programming, Case (iii) is a generalization of the two earlier cases. When either A or b, \(d_1\) and \(d_2\) are random, only a single probability distribution of Z is derived. However, when both are random, a number of distributions have to be approximated. If, with A varying, the allocation or distribution matrix \(\nu\) is allowed to take k different sets of values, there are then k distributions for Z. Comparisons of some central measures, e.g. means or coefficients of variation,
provide a guide in selecting a particular distribution. Production planning can then be mapped out in the same manner as in Case (ii).

As we have seen, the derivation of only one approximate probability distribution requires serious computational efforts. Whereas chance-constrained programming leads to nonlinearities, the problem associated with stochastic linear programming is largely computational. Thus, that Case (iii) is really worth consideration at all is questionable.

Stochastic and Probabilistic Linear Programming in Retrospect

Random elements do exist in linear programming models, especially those designed for planning in advance. The degree of randomness may or may not be extreme but whether it can be captured and quantified depends on the availabilities of the time series data or the existence of prior information. It is true that, in recognition of risks and uncertainties, production planning goals are likely to differ with the results actually achieved. However, this cannot be taken for granted that stochastic and probabilistic linear programming are not important in short-term planning. Agriculture is subject to frequent and violent fluctuations in the weather and the like as may be witnessed from the time series data. This characteristic will not simply disappear in the short run. Only in the long run, when more and better control can be exerted on the environment affecting agriculture, will it become less important. In regional planning, the presence of uncertainties in agriculture has to be realized from another standpoint. Different regions tend to experience different kinds of weather variations and, therefore, different degrees of risks and uncertainties. For example, the Northeast has constantly experienced
far more extreme floods and drouths than other regions. If this was not recognized we would, in effect, be assuming that all producing regions are subject to the same degree of risks. Stochastic and probabilistic linear programming, on the other hand, allow us to incorporate the differences in risks among these regions. For this reason, they seem to be useful in short-term planning.

The choice between stochastic and probabilistic linear programming as a method to deal with random elements should be made in accordance with the purpose of introducing risks and uncertainties into the planning problem. Computationally, probabilistic (chance-constrained) programming would be preferred. Notwithstanding the computational aspects, it may be concluded that, whereas ordinary linear programming leads to unqualified optimal production planning choices, stochastic and probabilistic linear programming give qualified answers.

When it comes to long-term planning, the needs for stochastic and probabilistic linear programming tend to disappear. Allowing for the possibilities of drastic technological advance, the time series data do not provide a useful guide to what will prevail in the long run. This is so, particularly when we consider technological advance as being man-made and designed for countering extreme variations that exist in the production and marketing processes.
Model Formulation

We have argued that the short run and the long run bear no resemblance with regards to economic planning. Projections in the trend values are likely to be erroneous when it is considered that technological change is continuously and, at times abruptly, taking place. Moreover, the dynamic elements that propel the developmental process are not solely based on the past. By itself, economic planning draws two unique implications: that technological change will occur which results in a fundamental change in the structure of the economy, and that some sort of control has to be introduced in order to force technological change in a certain direction.

Technological change is used here to include increases in productivities, reallocation of scarce resources so that it is more efficient, and improvements in transportation facilities as well. With this in mind, we notice that technological change brings with it an important question: how will it take place? Inevitably this question involves the determination of scarce resources which are "bottlenecks" to agricultural development and, as a consequence, the evaluation of appropriate investment projects to increase their supplies.

To attack these problems we shall develop a linear program, Model VIII, which is operational and can be applied in due time. It is essentially an extension of the earlier model, as its objective is still to minimize the costs of meeting food and fiber demands, given limited resources. However, land is no longer the only factor of production whose supply is fixed.
There are labor, water supplies and capital also. Each of these resources will be discussed below.

Land constraints

Land belongs to two broad categories: irrigated and nonirrigated. The distinction is necessary because it permits us to evaluate the need to irrigate areas in different regions and even to identify the location in which investment in irrigation dams is needed. Improved technologies, particularly in water resource development, e.g. in increasing water supplies in the dry season, and in water control and management offers a real possibility of multiple cropping. At present double cropping in paddy rice is virtually unknown, mainly because of the extreme water shortages in the summer. However, dry rice farming may be more productive in terms of output per unit rai than wet rice farming, given the same varieties and other inputs such as water and fertilizers (52, p. 33). If this is the case, the technical coefficient may be different for the same crops when they are grown in different periods of the year. Allowing for multiple cropping, we have the following constraints on land use:

\[
\begin{align*}
  a_{ij}^1 x_{ij}^1 & \leq b_{ij}^1 \quad \text{for } j \in m \\
  a_{ij}^2 x_{ij}^2 & \leq b_{ij}^2 \\
  \sum_{i, j \in m} b_{ij}^1 & \leq b_{m}^1 \\
  \sum_{i, j} (b_{ij}^1 + b_{ij}^2) & \leq b
\end{align*}
\]

where
\( x_{ijs}^1 \) = the amount of the \( i^{th} \) commodity produced in the \( j^{th} \) producing region during the \( s^{th} \) season when irrigated land is used

\( x_{ijs}^2 \) = the same as \( x_{ijs}^1 \) except that nonirrigated land is used instead

\( a_{ijs}^1 \) and \( a_{ijs}^2 \) = the technical coefficients on land

\( b_{ij}^1 \) and \( b_{ij}^2 \) = the amounts of irrigable and nonirrigable land available respectively

\( b_m^1 \) = the total amount of irrigable land in the \( m^{th} \) water supplying region

\( b \) = the total amount of cropland available

\( i \) and \( j \) are defined as before. \( m \) will be defined later. \( s \) may take the values of 1, 2, 3 and 4 to cover the entire year. \( s = 1, 2 \) refers to the dry season which generally runs from November to April; \( s = 3, 4 \) refers to the wet season, starting in May and ending by October. The subdivision in the seasons lends us the flexibilities of incorporating into our model the fact that the suitable time for planting is different for different crops. For example, rice may be planted as early as May, while mung bean planting may be done in October (59, p. 116, Table 16). The subdivision is also useful when the effects of planning on seasonal labor employment are analyzed.

\[7.1\] and \[7.2\] show ordinary constraints on land use. In \[7.3\], the total amount of irrigated land in any water supplying region cannot exceed its supply. \[7.4\] states that the total land, irrigable and nonirrigable, cannot exceed its national supply.
Labor constraints

Agricultural labor is widely believed to be underemployed at least some time during the year to the extent that a withdrawal of some labor from farm activities will not reduce the total output appreciably. Even with economic planning, this characteristic may still prevail in agriculture. As a result, labor may not impose itself as a set of effective constraints on the linear programming model. Nevertheless, simple calculations reveal what situation on labor would be like at the end of the planning period. Knowing the amount of labor (in hours) that has to be put into the production of a unit commodity and the amount of the commodity planned to be produced, direct multiplication yields the amount of labor requirements and thus employment created.

Even though labor availabilities are more or less constant throughout the year, labor requirements for farm commodity production do differ between planting and harvesting. This is particularly true for rice. In rice farming, planting draws less labor if it is carried out by the method of broadcasting and less so than harvesting. For this reason as well as for policy purposes, the labor constraints are subdivided to express the differences in labor requirements during different seasons of the year. It is also contemplated that labor use differs between the types of land employed. Thus we have

\[ \sum_{\text{all } i,j,s} a_{ijs} x_{ijs}^1 \leq \lambda_{js} \] for \( j \in m \) \[7.5\]

\[ \sum_{\text{all } i,j,s} a_{ijs} x_{ijs}^2 \leq \lambda_{js} \] \[7.6\]

\[ \sum_{\text{all } j} (\lambda_{js}^1 + \lambda_{js}^2) \leq \lambda \] \[7.7\]
where

\[ a_{ijs}^3 = \text{the technical coefficient on labor when land is irrigated during the } s^{th} \text{ period} \]

\[ a_{ijs}^4 = \text{the technical coefficient on labor when land is unirrigated during the } s^{th} \text{ period} \]

\[ \ell_{js}^1 = \text{the amount of labor available when land used is irrigated during the } s^{th} \text{ period} \]

\[ \ell_{js}^2 = \text{the amount of labor available when land used is unirrigated during the } s^{th} \text{ period} \]

\[ \ell = \text{the size of the farm labor force} \]

[7.5] and [7.6] insure that the amount of labor applied cannot exceed its availabilities. [7.7] states that the sum of labor available for use in irrigated and nonirrigated land in all producing regions must be less than the national potential farm labor force.

A major advantage of including [7.5], [7.6] and [7.7] in the model, apart from employment determination, is that we would be able to evaluate the farm income situation -- in particular, the extent of growth in per capita income as a result of regional planning. Obviously, the total farm income is given by the difference between the total farm receipts and the total nonlabor costs at the farm gate. From this, per capita farm income can be readily found. The model, as it will be clear later, permits us to see why some regions are noted for widespread poverty, e.g. the Northeast, and to develop means to relieve them.
Water supply constraints

All producing and consuming regions are the same as in the earlier model. The additional water supplying regions are needed, for the distribution for farm use is not uniform throughout the economy. A water supplying region is here considered to be an area in which water for farm use can be drawn largely from a number of irrigation projects located within it. Each water supplying region is defined to consist of contiguous producing regions (at least one) and no producing region belongs to more than one water supplying region.

Figure 8 shows Thailand’s principal rivers including the Mekong. Table 14 indicates their names and, in addition, contains the number and location (by producing regions) of state irrigation projects due to be completed by 1972. These projects vary in size, e.g., in the Mekong river basin the Nam Marn Project irrigates only 5,500 rals of land whereas in the Mae Klong river basin the Greater Mae Klong Project can irrigate up to a million rals. Apart from these irrigation projects, there are people irrigation projects, tank irrigation projects, reservoir projects, and dike and field ditch projects around the country. Considering the location of the principal rivers and these projects, we delineate Thailand into 12 water supplying regions and these are illustrated in Figure 9. Producing regions and principal rivers contained in each of the water supplying regions are shown in Table 15.

The amount of water supplied by each region can be determined only approximately. Water for irrigated land is derived from two major sources. One is the direct precipitation; the other is through irrigation dams. Water from surface runoff, lateral seepage and groundwater
Figure 8. Principal Thai rivers
<table>
<thead>
<tr>
<th>No.</th>
<th>River</th>
<th>No. of state irrigation projects</th>
<th>Beneficiary producing regions #</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mae Ping</td>
<td>4</td>
<td>1 and 3</td>
</tr>
<tr>
<td>2</td>
<td>Mae Wang</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Mae Yom</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Mae Kok</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Chao Phraya</td>
<td>21</td>
<td>6,7,8,10,11 and 12</td>
</tr>
<tr>
<td>6</td>
<td>Bang Pakong</td>
<td>3</td>
<td>10 and 11</td>
</tr>
<tr>
<td>7</td>
<td>Mae Klong</td>
<td>1</td>
<td>8,9 and 12</td>
</tr>
<tr>
<td>8</td>
<td>Phetchaburi</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>9</td>
<td>Tapi</td>
<td>-</td>
<td>16</td>
</tr>
<tr>
<td>10</td>
<td>Phathalung</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>11</td>
<td>Pattani</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>12</td>
<td>Mekong tributaries</td>
<td>5</td>
<td>18 and 19</td>
</tr>
<tr>
<td>13</td>
<td>Chee</td>
<td>5</td>
<td>18 and 20</td>
</tr>
<tr>
<td>14</td>
<td>Mune</td>
<td>4</td>
<td>22 and 23</td>
</tr>
</tbody>
</table>

*aSource: (63, pp. 160-167).*
Figure 9. The 12 water supplying regions
Table 15. Producing regions contained in the 12 water supplying regions

<table>
<thead>
<tr>
<th>Water supplying region no.</th>
<th>Producing regions contained</th>
<th>Principal rivers contained</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1, 3</td>
<td>Ping and Wang</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Yom, Nan and Kok</td>
</tr>
<tr>
<td>3</td>
<td>4, 5</td>
<td>Ping, Yom and Nan</td>
</tr>
<tr>
<td>4</td>
<td>6, 7, 10</td>
<td>Chao Phraya and Pasak</td>
</tr>
<tr>
<td>5</td>
<td>8, 9, 12</td>
<td>Mae Klong</td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>Bang Pakong</td>
</tr>
<tr>
<td>7</td>
<td>14</td>
<td>Phetchaburi</td>
</tr>
<tr>
<td>8</td>
<td>16</td>
<td>Tapi and Phathalung</td>
</tr>
<tr>
<td>9</td>
<td>17</td>
<td>Pattani</td>
</tr>
<tr>
<td>10</td>
<td>18, 19</td>
<td>Mekong tributaries</td>
</tr>
<tr>
<td>11</td>
<td>20, 21</td>
<td>Chee</td>
</tr>
<tr>
<td>12</td>
<td>22, 23</td>
<td>Mune</td>
</tr>
</tbody>
</table>

sources enters the dams via streams and becomes stored. The dams can be used to regulate the flow of irrigation water and it is evident that the size of the flow is dependent to a great extent on the size of the water storage. According to Löl and Hardison (45), the net amount of water supply can be calculated, given the size of the water storage and mean annual runoff. In their study, explicit recognition is given to year-to-year and seasonal variations in the amount of water stored and also to the rate of evaporation that takes place, while water remains in the reservoir.
Following Heady et al. (29, pp. (III-14)-(III-15)), the technical coefficient on water use may be estimated by

\[ a^5_{ij} = g_{ij} - (f_{ij})[g_{ij} - (w_{tij} - w_{p_{ij}})] \]  

where

- \( a^5_{ij} \) = the amount of irrigation water required for production of a unit of the \( i \)th commodity in the \( j \)th producing region
- \( g_{ij} \) = the amount of irrigation water required to be delivered
- \( f_{ij} \) = the fraction of the amount of irrigation water not used by plant which is returned for reuse
- \( w_{tij} \) = the amount of water required by plant for consumptive uses
- \( w_{p_{ij}} \) = the amount of water supplied by precipitation, condensation, adsorption less evaporation and deep percolation

\( (w_{tij} - w_{p_{ij}}) \) is the amount of water used that has to be supplied by irrigation and, by definition, \( g_{ij} \) should vary in proportion with \( (w_{tij} - w_{p_{ij}}) \). The constant factor is regarded as the efficiency index which shows how efficiently irrigation water is used by plant. This index depends on two factors: the conditions of the delivery system and the characteristics of the soil, e.g. water holding capacities. \( w_{tij} \) and \( w_{p_{ij}} \) are not constant but vary with the seasons of the year. This is due to two reasons: 1) water requirements are different over the various stages of plant growth, and 2) the natural water supply depends to a large extent on the amount of rainfall. Hence \( a^5_{ij} \) and the amount of irrigation water supply vary with the seasons of the year. The water supply constraints may now be stated as
\[ \sum_{i} \sum_{j} a_{ijs} X_{ij} = \hat{W}_{ms} \]  

[7.9]

\[ W_{ms} \leq TW_{ms} + (W_{ms} - W_{mm's}) \]  

[7.10]

where

- \( W_{ms} \) = the amount of water consumed in producing \( X_{ij} \) during the \( sth \) season for all \( i \) and \( j \).
- \( TW_{ms} \) = the net water supply available for agricultural and non-agricultural (industrial, municipal, onsite, etc.) uses.
- \( W_{mm's} \) = the amount of water that has to be transferred from the \( mth \) to \( m'th \) water supplying region in order for [7.10] to hold.

[7.9] is merely a definition. [7.10] insures that water consumption by agricultural activities cannot exceed its supply plus net transfer.

**Capital constraints**

A number of factors may be grouped under a heading of "capital". Use of machinery, animal power, seeds or storage facilities involves capital of one form or another. No attempt is made to treat different forms of capital as separate constraints. Instead, we focus our interest entirely on monetary capital which circumscribes capital in general, regardless of its forms. The importance of money in economic development has been emphasized elsewhere (7, pp. 79-145). As a medium of exchange, money can be conveniently used to acquire farm inputs needed for production. As a store of value, it can delay or extend resource use to a point in time deemed most suitable. The latter point is important from an agricultural credit point of view; that is, by obtaining credit,
resources not owned can be acquired well before the actual earning power
develops or becomes adequate. These resources include land, hired labor,
irrigation facilities, etc. Since in due course agriculture will be
commercialized, farm credit has to be one of the major determinants of
the pace at which it is moving, just as it seems to be in the development
of U.S. agriculture. Without sufficient provision for farm credit,
production will fall short of the planning goals.

Like labor and water requirements, the question of seasonality also
arises in the case of capital. As plant growth is crucial during planting
and growing seasons, growth stimulants such as fertilizers have to be
applied, while control on resources and plant diseases must be exercised
so as to insure optimal plant growth. Thus it is during these seasons
when farm credit needs are likely to be greater. As a result, the
following set of constraints on monetary capital is introduced.

\[
\sum_{i} a_{ijs}^{6} x_{ijs}^{1} \leq p_{js}^{1} \quad \text{for } j \in m
\]

\[
\sum_{i} a_{ijs}^{7} x_{ijs}^{2} \leq p_{js}^{2}
\]

where

\[a_{ijs}^{6} = \text{the amount of cash required for farm operations in production of a unit of the } i^{\text{th}} \text{ commodity when irrigated land is used in the } j^{\text{th}} \text{ producing region during the } s^{\text{th}} \text{ season}
\]

\[a_{ijs}^{7} = \text{the same as } a_{ijs}^{6} \text{ except that nonirrigated land is used instead}
\]
\[ p_{js}^1 = \text{the total monetary capital available in the } j^{th} \text{ producing region to cover operating expenses when irrigated land is used during the } s^{th} \text{ season} \]

\[ p_{js}^2 = \text{the same as } p_{js}^1 \text{ except that nonirrigated land is used instead} \]

The constraints recognize the fact that capital requirements are different for different types of land. Presumably, capital requirements for production of a unit commodity would be greater when land used is not irrigated, as capital may be substituted to some degree for irrigation water. In other words, by incorporating [7.11] and [7.12] into the model, we are allowing for the possibility of factor substitution that is always present.

Both \( p_{js}^1 \) and \( p_{js}^2 \) consist of, firstly, the total amount of wealth owned by farmers which can be used to finance farm operations and, secondly, the amount of farm credit granted under the direction of some governmental machinery. Owned wealth is largely in the form of land holdings. The rest is made up generally of farm buildings and inventories, e.g. seeds and livestocks. In a 1962-63 study report on family farms in the three Northeastern provinces (66, p. 35), land accounted for about 56% of all farm assets per family. Clearly, the percentage would be higher if only those assets devoted to farm operations were considered. As a result, it is assumed that farm credit is provided mainly on the basis of land values.

Following this, we have

\[ p_{js}^1 = p_{js}^{11} + p_{js}^{12} \]  \[7.13\]
\[ p_j^2 = p_j^{21} + p_j^{22} \]

where:

- \( p_j^{m1} \) is monetized into value terms (in bahts), while \( p_j^{m2} \) may be set arbitrarily as being some fraction, \( k_j^m (> 0 \text{ but } < 1) \), of the total monetary value of farmland in the \( j^{th} \) region.

Land value may be appraised by three methods: the sale (or market) value approach, the income approach and the cost approach. Of these, the second is chosen because it is simplest and appears to utilize least information. It assumes that the value of the land depends on the ability to produce. If the land generates an income of, say, \( P_Y \) per annum for an indefinite period, and if the rate of capitalization (or the long-term rate of interest) is \( r \), then its value is approximated by \( P_Y/r \). In our analysis, since \( P_Y \) is not known but depends on the outcome of the economic planning, the anticipated increase in land productivities as a result of technical advance, together with the past data on the value of farm production among producing regions, would provide some indication as to the actual value of the land.

**The objective function**

The constraints on the demand supply relationships are essentially the same as those in [5.2] through [5.7]. However, \( \theta \) (hence \( \gamma \)) and \( k'' \)
are allowed to change. For instance, \( \theta \) may contain commodities such as castor beans and groundnuts. Instead of exporting castor beans in a raw and perishable form as in the past, oil extracting plants may be set up to process them first. Their location is left to be determined by the model. Under these circumstances, the objective function is

\[
\text{To minimize } Z = \sum_{i,j,s} c_{ijs}^1 x_{ijs}^1 + \sum_{i,j,s} c_{ijs}^2 x_{ijs}^2 \\
+ \sum_{k,k',\gamma} t_{ikk'} x_{ikk'} + \sum_{k,k'',\gamma} (t_{ikk''} + p_{ik''}) x_{ikk''} \\
+ \sum_{k,k'',\gamma} t_{ikk''} x_{ik''k} + \sum_{m,s} p_{ms} w_{ms} \\
+ \sum_{m,m',s} p_{mm'} w_{mm'}
\]  

[7.15]

\( p_{ms} \) is the price of water for irrigation purposes in the \( m^{th} \) water supplying region, whereas \( p_{mm'} \) is the cost of water transfer from the \( m^{th} \) to \( m'^{th} \) water supplying region during the \( s^{th} \) season. All other variables carry the same meanings as before. In [7.15], water is made an explicit variable to be minimized in its use. Stated in words, the objective function is to minimize the costs of production and transportation as well as the costs incurred from water use and transfer.

\( c_{ijs}^1 \) and \( c_{ijs}^2 \) are production costs which exclude the fixed costs and the costs of using resources incorporated in the model. These may be determined similarly as in Chapter V. As for the price of water use for
a water supplying region, if the cost of applying irrigation water differs among irrigation projects, then an adjustment has to be made. The price of water use would be an average of these costs, weighted by the size of the projects in terms of irrigated land.

Water transfer may occur between upstream and downstream regions, e.g. between water supplying regions #3 and #4. The price of transferring water is such that it is greater than the excess in price of water in the downstream over the upstream region. This prevents water movement if the downstream region still has surplus water. If water in the downstream region is priced lower, the price of water transfer is set at zero. Another way in which water may be transferred is between river basins. Interbasin transfer may be priced at a zero level if transfer facilities are fixed. On the other hand, if they have to be constructed, positive costs will inevitably be incurred. No water transfer is allowed to take place between water supplying regions #8 and #9, and the remainder, since the two are geographically separated (see Figure 9).

In view of the variable nature of water and water transfer prices, it seems appropriate to impose lower bounds on water uses in each water supplying region and also upper bounds on water transfer. The variable nature as indicated stems from two important reasons. First, the per unit cost of water is unlikely to be constant for any volume applied. By imposing bounds on water uses, we are, in fact, allowing water costs to be stable within a limited range. Secondly, the existence of the water cycle implies that water is continuously being lost and gained. When water is transferred from one place to another through a canal system, greater water surface is exposed to the atmosphere, thereby increasing the chances
of more rapid evaporation. Deep percolation as well as the inefficiency in the delivery system itself means that not all water transferred will be available in the receiving region. This rationalizes the imposition of the upper bounds on water transfer. The bounds may be set at a fraction (< 1 but > 0) of the net water supply in the surplus region.

The Statement of the Model

In summary, the model may be mathematically expressed as follows:

To minimize $Z = \sum_{i,j,m,s} c_{ijs}^1 x_{ijs}^1 + \sum_{i,j,s} c_{ijs}^2 x_{ijs}^2$

\[ + \sum_{k,k',k''} t_{ikk'} X_{ikk'} + \sum_{k,k''} (t_{ikk''} + p_{ik''}) X_{ikk''} \]

\[ + \sum_{k,k''} \sum_{m,s} t_{ikk''} y_{ikk''} + \sum_{k''} \sum_{m,s} p_{ms} W_{ms} \]

\[ + \sum_{m,m',s} p_{ms} W_{mm'} \]  \[ \text{subject to} \]

\[ a_{ijs}^1 x_{ijs}^1 \leq b_{ijs}^1 \text{ for all } i, j \text{ and } s \]  \[ \text{[7.17]} \]

\[ a_{ijs}^2 x_{ijs}^2 \leq b_{ijs}^2 \text{ for all } i, j \text{ and } s \]  \[ \text{[7.18]} \]

\[ \sum_{i,j} b_{ij} \leq b_{ij} \text{ for all } m \]  \[ \text{[7.19]} \]
\[ \sum_{i,j} (b^1_{ij} + b^2_{ij}) \leq b \]  
[7.20]

\[ \sum_{i} a^3_{ijs} x^1_{ijs} \leq \ell^1_{js} \text{ for all } j \in m \text{ and } s \]  
[7.21]

\[ \sum_{i} a^4_{ijs} x^2_{ijs} \leq \ell^2_{js} \text{ for all } j \text{ and } s \]  
[7.22]

\[ \sum_{j} (\ell^1_{js} + \ell^2_{js}) \leq \ell \text{ for all } s \]  
[7.23]

\[ \sum_{i,j} a^5_{ijs} x^1_{ijs} = W_{ms} \text{ for all } m \text{ and } s \]  
[7.24]

\[ \alpha W_{ms} \leq W_{ms} \leq W_{ms} + (W_{m'm's} - W_{mm's}) \text{ for } 0 < \alpha < 1, \text{ all } m \text{ and } s \]  
[7.25]

\[ \sum_{m} W_{mm's} \leq \delta W_{ms} \text{ for } 0 < \delta < 1, \text{ all } m \text{ and } s \]  
[7.26]

\[ \sum_{i} a^6_{ijs} x^1_{ijs} \leq p^1_{js} \text{ for all } j \in m \text{ and } s \]  
[7.27]

\[ \sum_{i} a^7_{ijs} x^2_{ijs} \leq p^2_{js} \text{ for all } j \text{ and } s \]  
[7.28]

\[ \sum_{s} x^1_{ijs} + x^2_{ijs} = X_{ij} \text{ for all } i \text{ and } j \]  
[7.29]

\[ X_{ik} \geq d_{ik} + \sum_{k'} (X_{ikk'} - X_{ik'k}) \text{ for all } i \in \gamma \text{ and } k \neq k' \]  
[7.30]

\[ \sum_{j,k} X_{ij} = X_{ik} \text{ for } i \in \gamma \text{ and all } k \]  
[7.31]

\[ \sum_{j,k} X_{ij} = \sum_{k'} X_{ikk'} \text{ for } i \in \Theta \text{ and all } k \]  
[7.32]
\[ \sum_{k} X_{ikn} \leq g_{ik} \text{ for } i \in \Theta \text{ and all } k \] 

[7.33]

\[ \sum_{k} d_{ik} X_{ikn} = \sum_{k} Y_{ikn} \text{ for } i \in \Theta \text{ and all } k \] 

[7.34]

\[ \sum_{k} Y_{ikn} \geq d_{ik} \text{ for } i \in \Theta \text{ and all } k \] 

[7.35]

All X's, Y's and W's \( \geq 0 \)

\[ i = 1, 2, \ldots, 11 \] 

\[ j = 1, 2, \ldots, 23 \] 

\[ k, k' = 0, 1, 2, \ldots, 11 \] 

\[ m = 1, 2, \ldots, 12 \] 

\[ s = 1, 2, 3, 4 \]

[7.16] is the objective function which is to minimize the sum of the costs of commodity production, processing and transportation, and the costs of water use and transfer. [7.17] through [7.20] are land resource constraints. [7.21] through [7.23] are labor resource constraints, while [7.24] through [7.26] are water supply constraints. In [7.25], \( \alpha \) represents the fraction of the net water supply available in the \( m^{th} \) region during the \( s^{th} \) season that must at least be used by farms. In [7.26], \( \beta \) is the fraction of the net water supply available in the \( m^{th} \) region during the \( s^{th} \) season that can at most be transferred to other regions. Capital constraints are given by [7.27] and [7.28]. [7.29] is an identity, stating that the sum of the crop produced at different times during the year is equal to the total amount produced in that particular year. The rest of the constraints are the same as [5.3] through [5.8].
The model as presented above is apparently large and complex. If we assume that \( \gamma \) contains 4 commodities, \( \delta \) the other 7 commodities, and \( k'' \) can take 5 values, then the model potentially has 3,845 variables and 2,952 constraints. The size of the actual model would be considerably smaller, although it is recognized that the inclusion of many variables leaves open more options for the model to determine the most profitable crops to produce in each region.

Policy Implications of the Long-term Planning Model

By incorporating several resources into the long-term planning model, we make explicit recognition of the possibilities of having more than one bottleneck that may prevent planning goals from being achieved and, in general, may suppress the rate of economic growth deemed to be potentially attainable otherwise. Of course, the model is greatly enlarged but this is offset by the flexibilities it allows which can be used to formulate and recommend policies in accordance with the national interests.

The long-term planning model suggests how to get an optimal solution under a set of conditions. When these conditions change, the optimal feasible solution is likely to change. Thus, by changing the conditions we impose on the model, we would be able to answer different questions relating to economic policies and developmental investment. Policies in which we are interested include export expansion, diversification of agriculture, rural employment, water pricing and farm credit. Some of the developmental investment projects are irrigation dam construction, expansion in water storage facilities and in the delivery system between
the diversion point and the farm gate, and establishment of industrial complexes in rural areas.

The idea of formulating and testing policies and investment or development plans follows closely from the short-term planning model. Nevertheless, it has a much wider scope of application here. For example, when the rate of population growth falls to 2.0%, not only the domestic demand for commodities in each consuming region would change, but we could also infer from the optimal feasible solution of the long-term planning model about other consequences, e.g. on the size of seasonal farm employment, on farm water needs, and on national water sufficiency. By altering the rate of population growth the domestic demand, $d_{ik}$ for $k \neq 0$, and the size of the labor force, $l$, would eventually be affected. But, more importantly, the differences in the optimal feasible solution that may arise form a basis for different population policies. With other appropriate factors, e.g. the degree of social acceptance, taken into consideration a final policy choice can then be made.

The distinct treatment of the two components of the final demand allows us to "parametrize" the level of exports in order to examine production and external trade policies. The level of exports may be denoted by $d_0 = (d_{1,0}, d_{2,0}, \ldots, d_{11,0})$. A change in $d_0$, say, through setting the level of rice exports $d_{1,0} = 0$, would result in a new optimal pattern of agricultural production among regions. The change may be so drastic that resource movement must be effected at high costs or that the accompanied fall in exchange earnings is unacceptable. In this case a rise in the export level of other commodities has to be considered.
From the model, the optimal feasible solution would indicate a geographical pattern of efficient land use. The location and the types of commodities most profitable to be produced within it are pinpointed. Not only this, but we would also be able to specify quantitatively how much of each commodity should be produced so that it is adequate to meet the total demand. The problem of surplus rice that has plagued the economy during the last four years would then be minimized. Land that has historically been used to grow rice might have to be withdrawn and given new assignments. Withdrawn land could be used to produce more profitable crops, say, soybeans or left idle. Whichever is the case would, however, be implied by the model. In so doing, a pattern of agricultural diversification would be mapped and would subsequently provide a guide as to what sort of structure the agricultural sector should be by the end of the planning period. Moreover, it would shed some light on the question of relative sectorial growth. With well-conceived and effective planning, a diversified agriculture would certainly narrow the gap that exists between the agricultural and industrial sectors — the gap that is repeatedly exhibited by the amount of contributions of the two sectors to the GNP.

Agricultural diversification consistent with the optimality of the linear programming solution leads to a situation in which the spatial allocation of resources is competitively efficient in the sense of least costs. Returns to farmland would tend to be more equitable than the status quo on the basis that farmland is being brought into its most productive uses. For example, if the linear programming results indicate that, with new technologies, the traditionally rice growing area in
producing region #11 should produce soybeans instead, then the marginal revenue from soybean production is greater and consequently the returns to the land itself are higher.

The distinction made between irrigated and nonirrigated land enables us to deduce the extent of the need for irrigation. Irrigated land, as we have defined to be an area which receives irrigation from a water supplying region, presumably is more productive than nonirrigated land, i.e. \( a_{ij}^{1} < a_{ij}^{2} \). If the costs of production are comparable, then irrigated land is expected to be exhausted first. Suppose that it is exhausted, it may be of some interest to evaluate the effects of irrigating more land in certain regions on the optimal feasible solution and the value of the objective function. In particular, we may wish to explore the possibilities of shifting land in the Northeast to other alternative uses when its supply of irrigated land is increased. This can be done by conducting a sensitivity analysis on changes in \( b_{ij}^{1} \). Thus we are able not only to identify where and by how much irrigated land is in shortage, but also to investigate the extent of agricultural diversification as more land is being irrigated.

The sensitivity analysis on changes in the regional pattern of land availabilities has another important policy implication. In cases of internal insurgency or external aggression where some areas become partly outside effective government control, the distribution of land resources among producing regions is altered and consequently may have a profound change in the optimal allocation of all resources considered. As long as only noncultivable land is affected, the results are not expected to change significantly except in the unlikely event that forced mass migration
results in a different regional distribution of the labor force and thus final demands. With the use of the model, economically strategic areas can be located which may warrant some sort of protection. These areas are highly productive and usually irrigated. Densely populated areas also belong to this category. However, whether they indeed need protection depends on other considerations as well. At any rate, the model can be used to formulate regional planning policies in cases where national or regional security is threatened.

From the national point of view, actual changes in the size of irrigated and nonirrigated land should be effected only after the benefits and costs are fully evaluated. They are thus a result of investment decisions. Within this framework, we may consider two distinct types of investment: public and private. In public investment, the total benefits and costs have to be carefully weighed. Some of these are of the social nature in which case they have to be assessed into money terms. An example of this is the construction of a dam which serves as a wildlife habitat. The amount of fish available for human consumption represents a part of the social benefits that has to be taken into consideration in the investment decision making process. Obviously, the benefits of irrigating extra land can be found in better water control and management and, generally, in the increase in farm productivities. These are reflected partly in our model. First, the technical coefficient of production is smaller, that is to say, less land is required to produce the same amount of a commodity when it is irrigated. Second, apart from increasing the amount of water supply, better water control and management enhance the possibilities of multiple cropping. Third, as a result of these changes, the solution and the
corresponding value of the objective function will be different. Comparison with the status quo situation gives some rough indications on the amount of benefits received. It is evident, however, that the model generally fails to provide adequate information needed for evaluation of large investment projects, especially irrigation dams.

Private investment in irrigation may be conceived of largely as involving construction of a delivery system from the diversion point to the farm gate. Irrigation dams and the like belong to the domain of "public goods", the price for the use of which, if marketed, would be too high to be born by individual farmers. However, in private investment, charges can be visualized on water uses via renting of pumps and other facilities. Given this, two particular planning policies may be undertaken. First, the government may encourage private firms to invest in water delivery systems in the regions where irrigation is needed for optimal resource use. A water charge is allowed and, if necessary, subsidized. This can hasten the process of commercialization of agriculture, provided that other relevant policies are also effective. Secondly, such investment may be carried out through community development programs with or without government assistance. A sense of cooperation and responsibility that follows may propel dynamic forces favorable to agricultural growth. For instance, development in different but complementary investment projects by farm communities increases mutual cooperation and coordination through intercommunity loans which, in turn, may generate flow of agricultural and general knowledge. In recognition of the fact that the problem of economic development is not really a problem in economics alone, but one of breaking the political, institutional and
social barriers that are detrimental to the development process, the importance of community development programs cannot be undermined. These programs exist in Thailand but only on a small scale. Thus, as far as irrigation is concerned, it is recommended that emphasis be laid on controlling and delivering water whose supply already exists to the farm gate so that it becomes available for farm use.

The advantages that arise from the increased productivities of irrigated land and the fact that charges made directly on water devoted for farm use are almost nonexistent (82, p. 111) are capitalized into increases in the value of irrigated land. The respective owners thus gain from both increases in farm production and increases in land value, while paying little property taxes. At present, land taxes average only about 4-5 bahts per rai (10, p. 21). On rice growing areas alone they amounted to 2.52 bahts per rai in the 1971/72 crop year (70, p. 3). As the existing land tax measures make no distinction between irrigated and nonirrigated land, the pricing mechanism tends to be distorted in favor of irrigated land. Water charges, explicit in the objective function of the model, have to be paid for by the government, partly at the expense of the owners of nonirrigated land. To recoup some of the expenditures on irrigation projects which cost, by the end of 1967, approximately B 7 billions to irrigate 11.4 million rai, and to reduce the extent of factor price distortions, a policy recommendation is to levy appropriate charges on irrigation water consumed by farms and, if possible, to introduce an efficient and discriminatory taxation system that recognizes land differentials. Higher and progressive taxes should be considered also. An indication as to how much water should be charged and land taxed
is provided by the shadow prices or marginal value products which are incidental to the solution of the model.

The water pricing policy has another related implication that involves the questions of the distribution of water among its alternative uses and, more importantly, of water sufficiency. If irrigation water is free of charge, more is demanded for farm uses than would otherwise be the case. As a result, the amount of water supply available for industrial, municipal and other uses diminishes. Because only a part of irrigation water is returned for reuse, it is conceivable that national health and welfare may be ultimately impaired. For example, flow of water for waste dilution may be below a level required to maintain the desired quality of water. Furthermore, since the ability to acquire irrigation facilities depends on farm income, the Northeastern farmers generally are faced with more serious problems on water supply than those in the rest of the economy. A sample survey conducted by the National Statistical Office shows that in 1963 the Northeastern farm income per agricultural holding was the lowest (73, p. 192). On a per capita basis, the extent of poverty is further revealed as the Northeast has more farmers relative to the total regional population than any other region. This is part of the reasons why, by the end of 1967, less than one-half of the total irrigable land was irrigated (63, p. 174). An appropriate water pricing policy is to divert the revenues from irrigation water charges in other regions to finance the development and extension of irrigation facilities for the Northeast so that water shortages, especially in the summer months, are eliminated. It is expected that policies such as this are implied from investigating the shadow prices obtainable from the model.
As the model indicates the optimal amount of water for agricultural purposes needed to satisfy the constraints imposed, a number of conclusions about national water sufficiency can be drawn, given that water requirements for industrial, municipal and other uses are known (they may be projected on a per capita basis). If the total national demand for water exceeds the total supply, water shortages exist and, of all likelihoods, some regions may be relatively well off regarding their water supply-demand situation. In the event that water supply is in shortage, we may be confronted with questions such as to what extent water deficiency exists; in what water supplying regions it appears to be most critical; and by how much water has to be increased in supply to satisfy national demand. These questions are particularly of two-fold importance. They are related to the types of investment problems that already have been dealt with. The failure to have sufficient water supply is a part of the costs that must be considered in the evaluation of specific irrigation projects. In addition, they have to be studied concurrently with the implications arising from extreme variations in the weather in some regions. For example, the Northeast, generally speaking, experiences sporadic occurrence of rainfall and wide differences in rainfall intensity over a period of any one year. Almost no precipitation was registered in Udon Thani and Nakhon Ratchasima during December through February from 1964 to 1967 (72, pp. 22-23 and 73, pp. 20-21) while in the same years the minimum air temperature recorded was high during April through August (72, pp. 19-20 and 73, pp. 17-18). This suggests that water might be in shortage and, if it was, it would occur during parts of the year only. Empirical applications of the model could provide answers to these questions. They might indicate
whether a particular reservoir, e.g. the Mekong project in Nong Khai, has sufficient storage capacity to regulate the flow of water supply to meet all uses in the affected areas throughout the year. If an extension or construction of another dam is needed, a cost–benefit analysis may be conducted to determine the profitability of the investment. National priorities may have to be revised if water shortage reaches a critical stage. For instance, water shortage may be eliminated at the expense of lower commodity supplies, that is, by diverting water from farm to municipal uses. Under these circumstances, the model can be modified to allow for different water supplies during different periods of the year. To insure the feasibility of the solution, farm production goals may be reduced. Assuming that the domestic demand is to be satisfied first, this would mean a decline in exports and, given the same export prices, a decline in export earnings as well.

The inclusion of labor use in the model was done for the main purpose of determining the level of employment that can be attained through long-term economic planning. If \( x^* = (x_1^*, x_2^*) \) is the optimal feasible solution to the model, the amount of labor input required is given by

\[
\sum_{i,j} (a_{ijs}^1 x_{ijs}^1 + a_{ijs}^2 x_{ijs}^2) \quad \text{in the } s^{th} \text{ period. This follows from [7.21] and [7.22].}
\]

For the \( j^{th} \) producing region, the amount of labor input required is

\[
\sum_{i} (a_{ijs}^3 x_{ijs}^{3*} + a_{ijs}^4 x_{ijs}^{4*}) \quad \text{in the } s^{th} \text{ period. By assuming that each person works a certain number of hours a day, the level of seasonal farm employment in terms of persons can be calculated. Allowing for the natural rate of population growth, we may deduce the net effect of economic planning on farm employment.}\
\]
An increase in labor mobility would certainly reduce the size of the rural work force that remains on the farm in the nonharvesting season. But it is doubtful if this can be carried out on a large scale as the extent of the availability of the off-farm jobs to be occupied only a part of the year is limited. It is thus desirable to introduce new or improved technologies that are inclined toward replacing labor required in the harvesting season.

However, with improvements in technologies, less labor input is required to produce a unit commodity and, unless the growth of commodity demand is backed up sufficiently by increases in income (i.e. the purchasing power) of the average consumer, the labor problem that characterizes traditional agriculture will remain. In addition, because growth in per capita income depends obviously on the rate of population growth which, in turn, determines the size of labor force, it appears that new technologies, e.g. mechanization, may not only fail to solve the labor problem but aggravate it also.

In spite of this, the introduction of new technologies is needed as an instrument of commercializing agriculture and improving the farm income situation through increased productivities. It is difficult to visualize agricultural diversification as a process that can occur without improved or new technologies. In view of the employment effects, it is imperative that concerted efforts be made to reduce the increase in the size of the labor force and to create job opportunities elsewhere for displaced or unemployed (and underemployed) farm labor. An effective family planning program can reduce the net addition to the labor force, whereas economically sound policies aiming at promoting industrial growth can conceivably
increase industrial capacities to absorb surplus labor. Vocational training is likely to improve labor mobility among sectors. How far these efforts should be made is suggested by the model, since the difference between the projected size of farm labor under traditional technologies as determined from the model indicates the amount of labor that will be available for nonfarm employment.

We can also infer from the model about the extent of regional employment and thus the urgency of the labor problem each region is faced with. Given this, it is recommended that efforts be concentrated on increasing labor mobility and easing labor transfer in those regions with relatively large surplus farm labor. Possibilities of setting up an industrial complex in or near these regions should be explored. Such a complex would tend to create jobs for unskilled farm labor if it produces relatively labor-intensive goods. Its presence might improve transport facilities which benefit local business activities as well as the nation, e.g. for security reasons. The multiplier effects it generates would thus raise income of those not directly involved. The impact in the form of increased and more stable regional income would clearly reduce or minimize public discontent that might have been widespread if no action was taken in the first place.

For those remaining in agriculture, the total farm income is given by the excess of the total revenue over the total costs. If $p_{ijs}$ is the price of the $i^{th}$ commodity received by farmers in the $j^{th}$ producing region in the $s^{th}$ season, then the total farm income is

$$
\sum_{i,j,m,s} (p_{ijs} - c_{ijs}^1) x_{ijs}^1 + \sum_{i,j,s} (p_{ijs} - c_{ijs}^2) x_{ijs}^2
$$
less the total fixed costs. It is also evident that the total regional farm income for the \( j \)th region is equal to

\[
\sum_{\text{all } i,s} \left[ (p_{1js} - c_{1js})x_{1js}^1 + (p_{2js} - c_{2js})x_{2js}^2 \right]
\]

less the total fixed costs incurred in that region. Comparison among producing regions in regional income and farm income per head is one of the ways by which the results of planning under new technologies can be assessed. If the differences are noticeable, two lines of farm policies may be drawn. One is to alter some of the assumptions of the model on the resource constraints. Limiting resources may be increased in supply so that more becomes available for productive uses. Another is to alter the value of some coefficients inherent in the objective function. For example, the costs of production in specific regions may be reduced so as to bring about relative production advantage over others. In the first, we are concerned with investment policies of increasing farm income while, in the second, we are more interested in compensation policies and subsidy programs. Policy choice over the two cannot be made until the costs that would incur to the economy as a whole are fully accounted for and compared. Although the idea of compensation and price subsidy is less appealing from the allocative efficiency of resources viewpoint, it is possible that the two sets of policies are not exclusive but complementary. To raise farm income of the Northeast (producing regions \#18 to \#23), we may thus support commodity prices paid to farmers in the short run, and raise the supply of scarce resources, e.g. irrigation water, credit availabilities, etc. in the longer run.

The importance of credit availabilities in peasant agriculture as is
recognized by our model leads us to formulate two distinct policies. Since our model deals with annual production, the amount of credit would be much of the short-run nature. It would be granted only for covering operating expenses but, nonetheless, it certainly plays a role of increasing the rate of monetization in agriculture. Sufficient production credit is one of the decisive factors which insures the smooth functioning of the farm production system that serves as an instrument to successful planning. Moreover, the repayment records of the loans made can be used to discriminate the borrowers at a second stage of planning when it comes to long-term loans in financing investment capital, e.g. heavy machinery. The need for discrimination arises from the fact that funds are limited and that delinquencies usually are extensive if loans are made on the basis of the ability to pay only (as vs. the ability to honor debt).

Although production or short-term credit seems advantageous from many points of view, caution has to be exercised on the amount of credit made available. Excessive credit would be inflationary and is likely to do more harm to the economy as a whole. As inflation apparently is self-activating and is typical in a number of developing economies rightly or wrongly because of financial mismanagement, it is best not to take too liberal a stance on credit expansion. On the other hand, insufficient credit would fail to break the forces of inertia that exist in traditional agriculture. The amount of credit actually needed is suggested by the model when it is optimized. But whether this should be advanced to farmers has to be left at the discretion of the responsible authorities, e.g. the Bank of Thailand, that must assess fully the impact of such action before making any final decision.
The model also suggests where credit should be directed. It is intuitive that it is most needed in areas where poverty is widespread since the scarcity of productive resources, one of which is credit, is a major factor that reduces the ability of the farmers in those areas to withstand extreme conditions. If these extreme conditions are grouped and assigned an index, which may be called the weather index, then it is the change in this index that would indicate the risks involved in farm production. Since risks are associated with the determination of the market rate of interest, a production credit policy would be somewhat incomplete without an explicit interest rate policy. As the degree of riskiness differs among regions, the rate of interest charged should not be made uniform but allowed to fluctuate within limits in some appropriate manner with risks involved. This also argues for an abolition of, or a raise in, the legal ceiling on interest rates which is low at present (15% per annum). Again, the shadow price of capital would give a rough indication as to the differences in the rate of interest that might be charged among regions.

By the same token, the rate of interest paid on savings deposits should be allowed to follow more closely with the market conditions, instead of being around 3% as in the last decade. Higher rates would encourage savings which can then be channeled to those farmers who need loans.

Long-term credit policies may be visualized as a follow-up of the policies on production credit and interest rates. They, unlike their predecessors, are not immediate from the model. Their main objective would be concerned ultimately with the redistribution of resource ownership. One of the resources is land. To implement these policies,
a financial institution specializing in agriculture such as land banks may be developed. It should primarily aim at financing purchases of land and heavy machinery. In so doing, it can become a major instrument of the government in carrying out land reforms so needed to make the distribution more equitable.
CHAPTER VIII: SUMMARY AND CONCLUSIONS

As a primary export dependent economy, Thailand is faced with numerous problems, many of which are so common among the less developed nations. As these problems are vast and complex, an attack on all fronts would not be economical, or effectively controlled. Even in agriculture alone this would be futile, since agriculture itself is relatively large as an economic sector in terms of resources and manpower involved. Agricultural growth is less noticeable in terms of the rise in the GNP than industrial growth at least in the short run, if equal efforts are given. This stems from the fact that agriculture contributes only one-third of the GNP.

In spite of this, agricultural problems have to be solved if economic growth and development are to take place. The traditional agriculture is concentrated upon production of the subsistence crop which, in the past few years, has proved to surpass the total demand for it. As a result, prices are depressed and hence are farm income and employment. The process of agricultural diversification has a major stumbling block: resource scarcity. With insufficient resources, farmers could not at times cope with the impact that risks and uncertainties have on agriculture and would eventually fall back to the subsistence crop which does at least guarantee human survival. However, resource availabilities can be sufficiently increased only in the long run. As land is physically limited, greater output must in the final analysis come from increases in its productivities. New seed varieties, more fertilizers, farm machinery, etc. would be needed. Because of interdependencies among
factors of production, other scarce resources would also have to be increased, e.g. water and capital.

The need for greater output arises from two sources: domestic and foreign. To meet this need, as well as other associated farm problems, economic planning of agriculture is called for. Using the linear programming technique, the following mathematical but operational models are formulated:

Model I - incorporates interregional competition and aims to meet food and fiber demands by the end of 1976 on the basis of past performance.

Model II - is the same as Model I but applies for 1980.

Model III - investigates the feasibility of some of the goals contemplated by the Third Five Year Economic and Social Development Plan.

Model IV - investigates Model I under stochastic linear programming when the technical coefficients are random.

Model V - investigates Model I under chance-constrained programming when the technical coefficients are random.

Model VI - is the same as Model IV except that the demands are also random.

Model VII - is the same as Model V except that the demands are also random.

Model VIII - is designed for long-term economic planning of agriculture in which several scarce resources are recognized and new technologies are incorporated.
Models I through VII are short-term planning models and, as they are based upon the economic performance in the past, their planning results are conservative and thus are likely to be attainable. But planning in the true sense of the word cannot preclude the efforts made to alter resource supplies which bring about changes in technologies. Preconditions have to be arbitrarily stated, instead of drawing implications solely from past data. This, despite the degree of arbitrariness, is advantageous from the point of view that different planning policy choices regarding investment projects, resource needs, etc. can be formulated. Investment projects include construction and extension of irrigation dams, labor training, information investment as well as creation of effective nationwide agricultural financial institutions. All these problems are encountered in Model VIII.

An important implication of these planning models is that, since regions are different economically, an all-out attack would be more impressive and feasible if it is directed on only a few regions where farm problems are most critical, e.g. the Northeast. Nonetheless, it has to be kept in mind that such attack, viz., the regional development program, is important not in itself but insofar as it affects other regions and nonagricultural sectors of the economy as well.


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