EVALUATING THE CONSEQUENCES OF MARKETING CHANGE: AN APPLICATION OF SYSTEMS THEORY

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ABSTRACT

EVALUATING THE CONSEQUENCES OF MARKETING CHANGE: AN APPLICATION OF SYSTEMS THEORY

by John E Griggs

Measuring the economic consequences of a change in the marketing system of a developing country in order to evaluate the role of marketing in economic development is treated as a problem where the application of systems theory can provide both assistance and increased understanding through the development of mathematical simulation models.

A review of the literature on the role of marketing in economic development is presented and the necessity to view the economic system as a set of interrelated economic sectors is indicated. A review of existing economic models of the input-output and national income type is presented and these models are found to be inadequate for the measurement task; certain features of these models are found to be valuable however.

The methodology of systems theory is presented in qualitative terms. An understanding of the methodology is extremely important and it is discussed in terms of the

problems associated with modeling a socio-economic system; the limitations and flexibility of systems theory are explained.

Two systems models are developed from sets of assumptions concerning the behavior of and relationships between three basic sectors of the economic system; production, distribution, and consumption. Each of these sectors is defined in terms of a food and a nonfood production subsector, the distribution sector in terms of a food and nonfood distribution subsector, and the consumption sector in terms of three consumer subsectors which differ in income level and consumption behavior. The defined sectors are related by the exchange of economic goods; primarily labor and food and nonfood commodities.

Parameters used in the development of the systems models are evaluated using data from several sources about the conditions in Puerto Rico in 1963. Once the parameter values are determined and computer programs written, various simulations are conducted in which the parameter values associated primarily with the food distribution subsector are altered. Variations in parameter values result in differing values being computed for the system variables; these system variables measure such items as the level of consumption of food and nonfood items, the levels of wage and nonwage income, and food and nonfood prices to consumers. Changes in parameter values are used to reflect changes within the distribution sector and the changes recorded for the values of the systems variables are used to indicate the response of the economic system to the changes.

The methodology of systems theory is found to provide a flexible framework from which the measurement problem of evaluating the role of marketing in economic development can be addressed. The development of operationally definable measurement terms and the estimation of parameter values from existing data demonstrates that the approach is practical, although admittedly difficult.

EVALUATING THE CONSEQUENCES OF MARKETING CHANGE: AN APPLICATION OF SYSTEMS THEORY

By

John E Griggs

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CHAPTER I

INTRODUCTION

Statement of Purpose

The purpose of this dissertation is to present an approach to the development of quantitative tools to assist in the evaluation of the role of marketing in the economic growth of a developing country. An analytical framework is presented which allows for a partial analysis of the economic consequences of certain changes or reforms in the marketing system.

A mathematical modeling technique, referred to as systems theory, is used to construct mathematical models which allow for simulations of the response of the socio-economic system to certain changes in the marketing system.

Background of Problem

In recent years, growing interest in the role of marketing in economic development has become evident. A review of the literature on the role of marketing in economic development suggests many aspects of marketing which seem to warrant the attention of those concerned with economic development.[1]

A research effort undertaken by Michigan State University and funded by the United States Department of State, Agency for International Development brought the problem addressed in this thesis to clear focus.[2,3] The objective of this research effort was the evaluation of the role of marketing in the economic development of certain Latin American countries.

The central premise guiding the research effort was that,

> the creation of more effective marketing systems would contribute to self-reinforcing agricultural and industrial expansion and an acceleration in over-all rates of economic growth.[4]

The central purpose of the research effort was;

> to provide background information and analysis useful in planning marketing reforms that will more effectively coordinate the development of the rural and the urban sectors. . . .[5]

If the research was successful, it was hoped that the suggested marketing reforms;

> . . . would stimulate an expansion in agricultural output and provide consumers with more dependable supplies of higher quality food at lower prices.[6]

The first phase of the research was conducted in Puerto Rico. Puerto Rico was chosen because it offered an unusual opportunity to gain insight into an economic system which had undergone rapid and relatively well documented economic growth and change in its marketing system.[7]

One of the many problems faced by the research team was the development of analytical tools to provide estimations of the effects of changes in the food marketing system in Puerto Rico.

Attempts were made to adopt national income and input-output models for use as analytical tools. Unfortunately, none of the existing models proved adequate for the type and extent of emperical testing envisioned by the research team.[8] Recognizing that a properly conceived mathematical model would be an important aspect of the total research effort, it was decided to undertake an original modeling effort.

An evaluation of the response of a socio-economic system to a change in the marketing system entails an estimation of changes in such measures of economic activity as employment, consumption, and physical output. Relating these measures of economic activity to certain measures of performance of the marketing system such as the level of technology, gross margins received, or pricing strategy, defines, in part, the modeling task which the research team decided to undertake.

The Approach

Evaluating the economic consequences of a change or reform within the marketing system of a developing country is viewed as a problem where the application of mathematical simulation techniques can provide new insight and understanding.

Using Puerto Rico as a laboratory, two mathematical models of a socio-economic system are developed. In both models, the system is viewed as a collection of interacting economic sectors linked by exchange. The exchange involves food and nonfood commodities and labor for money.

Three sectors, production, distribution, and consumption, represent the major classifications of economic activities considered. Each of the three economic sectors is viewed as a set of subsectors. The distribution sector, for example, is defined in terms of two subsectors: a food distribution subsector and a nonfood distribution subsector. The production and consumption sectors are defined in terms of sets of subsectors also.

Each defined sector in the economic system is linked to the other sectors. Economic goods of various types move between them. The distribution sector is tied to the production sector by virtue of the distribution sector's purchases of economic goods. A relationship between the distribution sector and the consumption sector is established in two ways; first, the distribution sector acts as a source of supply for goods purchased and consumed by the consumption sector; second, consumers within the consumption sector serve as a source of labor input to the distribution sector.

The major flows used to characterize the interaction between the defined economic sectors are goods and labor. Variations in the magnitude of these flows are taken as measures of economic activity within the system. In the first model, the magnitude of the flows is measured in dollar value terms only. In the second model, certain flows are measured in both quantity and price terms. The flows defined in both models are designed to measure such indicies of economic activity as physical output, income, and food and nonfood consumption levels.

Assumptions concerning the relationships between the items entering and leaving a defined economic sector are used to construct a mathematical description of the behavior of that sector. The mathematical description of the behavior of a sector defines a model of that sector.

A model of the distribution sector could, for example, relate the amounts and prices of economic goods entering that sector to the amounts and prices of those goods upon exit. Parameters referring to the level of technology (production coefficients) and pricing strategy (gross margins) can be included explicitly in these relationships. The relationships actually used for the sectors differ for the two models developed. Since the output of one sector is in fact the input to another sector, the interrelatedness of the entire socio-economic system becomes evident.

Models of the socio-economic system are constructed from the models of the defined sectors. The models of the system serve as the mathematical tools for simulating the responses of the system to certain changes in the behavior of some part of the system. Changes in the relationship between input flows and output flows of the distribution sector could, for example, cause changes to occur throughout the system; the model is used to measure those changes.

To provide a more complete description of the economic system, relationships between the production and consumption sectors and government, and between the production sector and other economic systems are established. The government is treated as a purchaser of goods and labor and a supplier of both wage and nonwage income. Relationships with other economic systems are made to allow for importation and exportation.

Once a systems model is developed, the values of parameters used to construct the model are estimated from existing data, the model is computerized, and simulations are conducted on a computer.

Evaluating change throughout the economic system in response to changes in the behavior of the distribution sector is a prime objective of the simulations. A technological change within the distribution sector, for example, not only alters the relationship between output and input requirements, but might also alter prices and flows throughout the entire economic system. Using the systems models, the results of such changes as technology upon employment, consumption, physical output, or upon any specified flow between any two sectors of the system can be estimated.

The modeling technique of systems theory, used to develop the models, will be shown to be uniquely suited to the measurement problem described above. In developing the approach to the problem of evaluating the response of an economic system to a change in the marketing sector, a major effort was made to take advantage of the methodology provided by systems theory.[9]

Scope

The purpose of this dissertation is, as stated above, to present an approach to the development of quantitative tools to assist in evaluating the role of marketing in the economic growth of a developing country.

Two models are presented in this thesis; they should be viewed as part of a continuing effort. The models presented should be judged, in part, by how well they assist in evaluating the consequences of a marketing change; restricted to change within the distribution sector in this thesis. The first model developed is rejected for the simple reason that it can not assist in evaluating a potentially important response to a marketing change; the model is important, however, in that it was built, tested, and provided the basis for building the second model.

It is the process of model building, using the technique of system theory, which is of prime importance to convey. The building of a model, the evaluation of its parameters, its computerization, its testing, and its alteration are all parts of the process.

The modeling effort is an iterative process; the models presented here are first steps in that process. It is hoped that the conceptual forms of the models and the documentation of their usage will be useful to others interested in taking another step.

Order of Presentation

Chapter II is a review of literature on the role of marketing in economic development. The purpose of this chapter is to identify those factors which should be included in the mathematical models. The way in which the distribution sector is related to other sectors in the economic system is suggested.

Chapter III is a review of literature on existing economic models. The objective of the review is to determine how the distribution sector has been treated in existing models and to identify those features of existing models relevant to the evaluation problem.

Chapter IV is a description of the methodology of systems theory germain to the modeling of socio-economic systems. The objective of the chapter is to qualitatively explain the concepts of systems theory and its flexibility and limitations.

Chapter V and Chapter VI present the development and testing of two systems models. The distribution sector of the socio-economic system is explicitly defined in both models; the assumptions made about that sector's behavior and the response of other sectors to it differ. Computer programs are written for both of the models and parameter value estimations are made from existing economic data on Puerto Rico.

Summary statements and recommendations for further research are presented in Chapter VII.

CHAPTER II

MARKETING IN ECONOMIC DEVELOPMENT

This chapter provides a review of the role of marketing as a stimulator of economic development. The objective of the review is to determine what needs to be considered in constructing a model designed to assist in evaluating the economic consequences of certain changes or reforms within the marketing system.

Economic Development

Economic development is a phenomenon defined in part by reference to the rate of change in the magnitude of economic "flow" variables. Gross national product (GNP), total wage income, and physical output are examples of common economic flow variables. Both the magnitude and the rate of change in the magnitude of these and similar variables are taken as indicators of the economic development of a socio-economic system.

Identical economic measurement terms can be used for describing growth in all types of economic systems; the phenomenon of growth being measured can be quite different between those systems however.

Gardner Ackley makes a distinction between two types of growth phenomena. According to Ackley, "growth" or "development" which constitutes a shift from an "under-developed" to a "developed" economy is distinctly different from the growth phenomenon characteristic of a "developed" economy.[1]

Ackley uses the economies of Western Europe and North America as examples of the "developed" economies. The economies of Latin America are generally classed as "developing." While many economies of the world can not be placed accurately in one category or the other the distinction is still a highly useful one.

Ackley describes six aspects of the growth phenomenon in the developing economies.[2] Involved is change from;

1. non-economic to economic motivation,
2. simple to complex forms of economic organization, and
3. primitive, inefficient techniques to modern techniques of production.

Needed to permit such changes are;

4. investment in "social capital" or roads, communication facilities, and public works,
5. acquisition of new skills - production, organization, communication, and management, and
6. relocation of population from the rural to the urban areas.

These and other changes are required for economic growth to occur in developing economies and they take place "along with the capital accumulation, population growth and technological change which are the earmarks of the further growth of an already developed economy."[3]

Ackley, while reviewing several simple economic growth models, states that most current theories of growth are designed to study the growth of a developed economy; modern productive techniques, highly developed economic institutions, and an essentially free-market, free-enterprise system of organization are assumed to exist.[4]

The factors which influence growth and the relative importance of those factors may well be different in a "developing" economy than in a "developed" economy. If this is the case, it may be necessary to consider factors when discussing growth in a developing economy which are not normally included in growth theories of developed economies.

Ackley states that for the developed countries, "it is at least plausable to assume that it (growth) can be analyzed by purely economic tools." In the case of growth in the developing countries, however, Ackley states that the "concepts, theories, and insights of sociologist, political scientist, anthropologist, psychologist, engineer, and educator," are required.[5]

Bruton, in a review of contemporary economic growth theory states that:

> . . . there has been a healthy emphasis on non-economic aspects of growth in much of recent literature . . . a strong argument can be made that the problem of underdevelopment will not be solved until economics has achieved a more compatible marriage than now prevails with other social sciences.[6]

Abromvitz maintains that "The economics of growth is . . . the field of work in which the dependance of economics upon its sister social sciences appears in a supreme degree."[7]

The search for those factors which influence growth in the developing countries has led some to the study of marketing. While ignored or assumed away in discussions of growth in developed countries, marketing appears to be a more difficult factor to ignore in a developing country.

Moyer summarized what he felt was the assumption which led economists to neglect marketing in development theory:

> The argument is that marketing is a self-adjusting mechanism that alters itself in response to changes in the rest of the economic system. Being both a passive and automatically adjusting mechanism, marketing, it is argued, can be ignored.[8]

Moyer proceeds to give a most practical reason why he feels marketing can not be ignored so easily in developing countries;

> Out of the limited research into marketing's place in development, one fact emerges; it is fruitless to induce development in the productive sector without insuring that complimentary advances are made in the distributive sector.[9]

Kindleberger also calls for attention to be paid to the marketing problems of development:

> Whether markets pull development or lag behind it, it is evident that much planning in this area of economic development today neglects distribution. . . . Distribution is inescapable. The Western economists have always been fascinated with how little direction free markets can perform this function. Whether the linkage of local into larger markets be encouraged for its transforming function or the movement of goods and services into consumption and investment be tackled directly according to plan, distribution takes resources. It can not be overlooked.[10]

Just as Ackley distinguishes between two phenomena both called economic development, it is necessary to distinguish between types of marketing.

The profession of marketing in the United States uses as a definition of marketing;

> The performance of business activities directed toward, and incident to, the flow of goods and services from producer to consumer or user.[11]

The performance of business activities can be accomplished by the producer of a good or service and/or by the "middleman" operating between the producer and consumer. Marketing, as conducted by a firm or middleman may include aspects of advertising, promotion, product development, and physical distribution.

Kindleberger, as reflected in his statement, refers primarily to the activities of middlemen. Marketing, as the term is used by Kindleberger is best termed distribution.

Moyer is satisfied with neither the traditional definition of marketing or with Kindleberger's use of distribution and marketing as similar terms. According to Moyer, marketing implies more than the simple linking of producers and consumers;

> there is abundant evidence throughout economic history that marketing has played a key organizing role; hence, it has been an indispensible partner in economic progress.[12]

The literature on "marketing" and "economic development" is extensive and not all is relevant to the problem at hand. Before continuing, it would be profitable to clearly define what will be considered in this thesis.

For the purposes of this thesis, attention is focused on the role of the distribution sector in the economic growth of a developing country. The distribution sector is defined to include those economic units engaged in the distribution of economic goods.

A "sector" of an economic system is defined in this thesis as a grouping of economic activities. The use of resources to produce an output of value is taken as a definition of an economic activity.

The "industrial sector" defines such production activities as agriculture, manufacturing, and mining. Each of these sectors employs resources such as material and labor to produce an output of value. The "consumption sector" defines households which consume goods and services and produce labor as an output. The "distribution sector" defines economic units engaged in the distribution or marketing of food and nonfood items.

That aspect of the role of marketing in development being considered in this thesis relates primarily to the role of members of the distribution sector; not all aspects of the role of marketing in economic development are thus considered.

The analysis of the distribution sector and its relationship to economic development is conducted in terms of its effect on other sectors of the economic system. It is the effect of a change or reform within the distribution sector on the economic system which is of concern. The effects of a change are measurable in terms which are adaptable to mathematical modeling. Economic flow variables such as employment and physical output provide such measurement terms and are used to record the effects of change.

The factors that need to be considered in estimating the economic consequences of a change or reform in distribution practices may be clarified by reviewing what has been written concerning the role of marketing in economic development with emphasis on the role of the distribution sector.

Marketing and Economic Development

Those concerned with the role of marketing in economic development have isolated certain functions performed by marketing which aid development. Moyer enumerated six specific functions as follows:[13]

1. An organizational and informational function. "Organizing the information network and providing the physical facilities to handle the product system's output . . ."

2. An equalizing and distribution function. "The job of matching and equalizing diverse supplies and demands . . ."

3. A connective function. This is the spacial connection of geographically separated entities.

4. A capitalistic function. "The middlemen assume risks supportable only on a base of capital."

5. A source of entrepreneurial talent.

6. A source of capital.

Drucker has asserted that marketing is the most effective engine of economic development. The training and developing of entrepreneurs and managers, so important in economic development, is one of its many contributions.

> My thesis is very briefly as follows: Marketing occupies a critical role in respect to the development of growth areas. Indeed, marketing, is the most important 'multiplier' of such development. It is in itself . . . the least developed. Its development . . . makes possible economic integration and the fullest utilization of whatever assets and productive capacities an economy already poses.[14]

The role of marketing as a "coordinating" factor which can stimulate growth is reviewed in a doctoral thesis on the role of food marketing in the development of Puerto

Rico. Kelly Harrison concluded that government and private efforts to improve market coordination resulted in rapid agricultural productivity improvements. The "structure and performance of the marketing systems may have significant effects on the total production of a given commodity, on consumer prices, and on the adoption of improved production methods."[15]

Special attention to the problems of food marketing have led both George Mehren and J. C. Abbott to conclude that improved marketing systems could lead to significant improvements in agricultural production.[16,17] Harrison provides a comprehensive review of the coordinating role or marketing in agricultural production and distribution.[18]

In a study conducted in Puerto Rico, Holton and Galbraith found that the marketing of food was performed by highly inefficient methods and institutions. It was estimated by these men that the cost of food to consumers could have been reduced by more than $15 million in 1950 if a reasonably efficient system of food distribution had existed instead of the actual system of distribution.[19]

It is the multiple influences of marketing which are extremely interesting. As Mehren, Abbott, and Harrison propose, marketing practices may influence the levels of agricultural production; this could result from altered techniques of production or higher physical output employing the same techniques of production. As Holton and

Galbraith propose, more effective marketing could lower food costs to the consumer; reductions in food cost could cause shifts in demand for both food and nonfood items thus effecting physical output requirements.

Attempting to combine all of the possible responses to marketing change is a most difficult task. Shifts in consumer demand caused by altered food prices resulting from some marketing change could, for example, have an effect on production requirements within the economic system. Changes in techniques of productions could, for example, effect labor requirements and thus employment and thus consumer demand.

An interesting and integrating concept has been proposed by Rostow. The national market concept has particular significance to marketing and its role in development.

The National Market Concept

Rostow's concept of a national market is part of a more general thesis concerning the stages of economic growth. The particular significance of a "national market" to marketing in development can be isolated, however.

Rostow contends that the developing countries began the process of modernization, or economic development, in two basic areas; the production of manufactured goods; and a build-up in basic infrastructure. According to Rostow, this led to a neglect of the agricultural sector and a concentration of developmental activity in a few of the large cities of those developing countries.

As a basic economic development task, Rostow sees the need for these countries to

> . . . convert their somewhat isolated urban industrial concentrations into active, dynamic centers which purposefully diffuse the process of modernization out across the nation while they generate the capacity, on this wider market foundation, to pay their way as they move to full industrialization of their societies.[20]

The "wider market foundation" is the internal national market. What Rostow is suggesting is the building of an integrated economy where the rural sector provides markets for the goods produced in the urban sector and also provides sufficient amounts of food stuffs, at stable and lower prices, to the urban sector. In *View from the Seventh Floor* Rostow summarized his notions on how national markets are built,

> Now, how do you do it? How do you make a national market, starting from the kind of distorted situation that can be observed in the world around us?
>
> I suggest that there are four major jobs that must be done, and they should be done simultaneously as part of a national strategy, shared by the public and private authorities.
>
> The four elements are these: a build-up of agricultural productivity; a revolution in the marketing of agricultural equipment and consumers' goods for the mass market; and a revolution in the marketing methods for such cheap manufactured goods, especially in rural areas.[21]

According to Rostow, the modernization of the rural area, a necessary step in the building of a national market, requires that four necessary and sufficient conditions be met:

> First, the farmer must receive a reliable and fair price for his product.
>
> Second, credit must be available at reasonable rates for him to make the change in character of his output or the shift in productivity desired.
>
> Third, there must be available on the spot technical assistance that is relevant to his soil, his weather conditions, and his change in either output or the shift in productivity.
>
> Finally, there must be available at reasonable rates two types of industrial products; inputs such as chemical fertilizers, insecticides, and farm tools; and incentive goods--that is, the consumer goods of good quality he and his family would purchase in greater quantity or work harder to get if they were cheaper or if his income were higher.[22]

Marketing is a vital part of the process of building an internal national market because it enters the process of modernization in two ways. First, insuring that the farmer receives a stable and fair price for his output may require changes in marketing practices associated with the movement of product from the country to the city. Second, changes in marketing practices associated with the movement of both basic agricultural inputs (fertilizers, tools, pesticides) and low priced manufactured goods from the cities to rural areas may also be required. The coordination of rural and urban areas by improving both the flow of agricultural products from rural to urban areas and the counter flow of agricultural inputs and manufactured goods from urban to rural areas is a required part of internal national market development.

By combining Rostow's ideas with those presented above, one begins to see the economic system as a highly interrelated system where the connective distributive processes may play a key role in development.

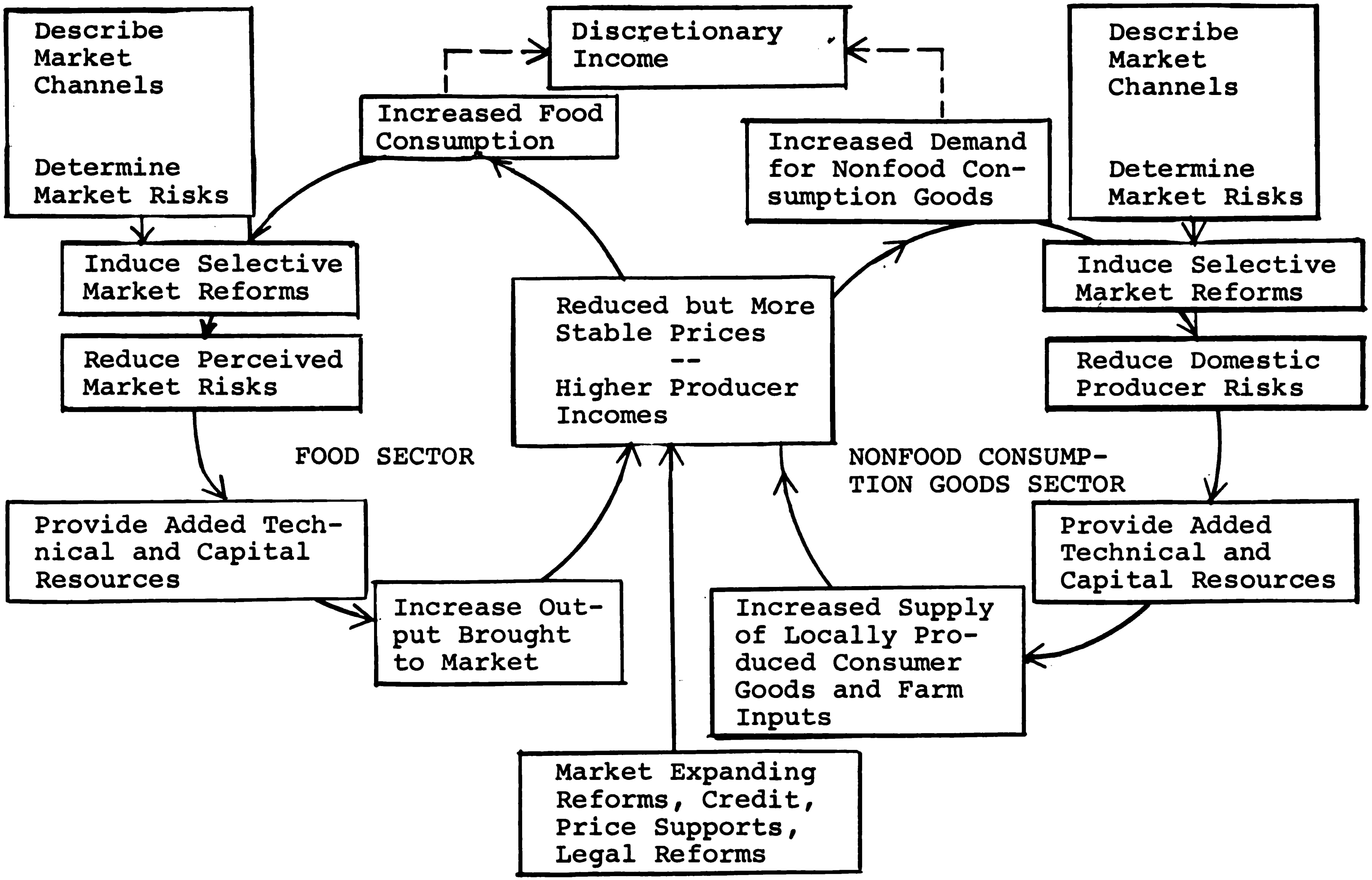
Inducing Marketing Reforms

As mentioned in the previous chapter, it was a research effort conducted by an interdisciplinary research team from Michigan State University which brought into clear focus the problems of measurement addressed in this thesis.

Measuring the impact of changes in the marketing system is a critical aspect of analysis. The impact of marketing changes upon employment, income distribution, and demand, resulting from change within the marketing system are obviously not easy to measure.

Slater, Director of the Latin American Market Planning Center, has described the approach he thinks should be followed in inducing internal national market development.[23] The approach is described schematically in Figure 2.1.

Paraphrasing from an article by Slater,[24] it is first necessary to obtain as precise a description as possible of the existing marketing channels used for moving domestically produced food products to the urban markets. With this description, the major channel members can be identified.



Inducing Internal National Market Development
Figure 2.1

The identified channel members are studied in an attempt to determine what they perceive to be the limiting factors which inhibit their accepting responsibility for more products being brought through the market channel. These factors could include uncertainty about future prices or the level of demand at some future time.

Only after an understanding of the marketing channel members attitudes toward risk and undertainty are ascertained is it generally effective to take the second step: the inducement of selected marketing reforms. These marketing reforms are designed to reduce or spread marketing risks in order to induce an expansion in marketing participation.

When marketing reforms have been made, and when capital and technical assistance is available, expansion in marketing operations will likely occur. The third step in this process is to insure that credit, storage and handling facilities, and legal reforms are available to support any expansion in the food marketing sector.

If the marketing reforms are properly designed and supported, a series of reaction in the socio-economic system are anticipated:

1. Given lower and/or more stable food prices, the final consumer may expand his consumption of food items and/or nonfood items.

2. Increased demand for agricultural output could result in higher rural incomes leading to a higher demand for manufactured items for rural personal consumption.

3. Increased agricultural output may require additional inputs to the rural sector of such items as fertilizer and machinery.

4. Any combination of increased demand for agricultural output, agricultural inputs, and manufactured items could lead to further increases in total physical output, income and final demand.

Where marketing reforms result in reduced labor requirements by the marketing sector, unemployment of a portion of the labor force could result. Such a reaction might occur where marketing efficiency is increased by a marketing reform. Both the potential "benefits" and "costs" of any marketing reform need to be studied.

Conclusions

It is the economic consequences of marketing reforms within the distribution sector of a developing economy which need to be measured.

The review has clarified one major point concerning the measurement problem; the economic system needs to be viewed as a collection of interrelated economic sectors. The consequences of a reform or change from within the distribution sector needs to be measured in terms of the effects a reform has upon the other sectors in the system; the potential impact of reforms upon both the users or consumers of economic goods and services and the producers of goods have been mentioned above.

A change within the distribution sector may alter the consumer prices of commodities; changes which alter food prices may have the effect of altering the amounts and mix of both food and nonfood purchases by consumers.

A change within the distribution sector may alter the amounts and/or techniques of production; changes in production may alter the flows of economic goods between different industrial sectors as well as labor requirements.

The problems of interrelationship are extremely important from a measurement viewpoint. The result of a marketing change can not be considered only in terms of its effect on one sector, such as consumption, without consideration of the subsequent reaction of other economic sectors, such as production. The interrelationship between the distribution sector and both the consumption and production sectors was noted; the relationship between the consumption and production sectors via such ties as labor must also be considered.

Changes in production may alter labor requirements. The effects of changing labor requirements upon consumption via changes in wage income represents a facet of the potential economic consequences of a marketing reform. Changes in demand which could result from a market reform may alter production and, therefore, effect both the flow of goods between industrial sectors (intermediate demand) and labor requirements.

The issues raised by such authors as Holton and Galbraith, and Abbott and Mehren point up important consequences to the consumption and production sectors respectively. The issues raised by such authors as Slater and Rostow point to those concerns but, in addition, reflect upon the problems of what happens once one sector is influenced.

The measurement problem is complex; the concerns include the more or less direct effects of a marketing reform upon consumption and production and, in addition, the secondary effects of consumption on production and production on consumption.

The specific approach to measuring the multiple impacts of a reform in the distribution sector will be presented in a later chapter. Another realm of concerns need to be raised at this point to lay the groundwork more fully.

A great deal of effort has been expended on the development of mathematical models of economic systems. Each of these models has the potential of offering a technique or clue of value to measuring the economic impact of a marketing reform. The following chapter reviews some of the existing economic models.

CHAPTER III

ECONOMIC MODELS AND THE DISTRIBUTION SECTOR

Introduction

Reference to a "distribution sector" is contained in few macro-economic models. This chapter reviews two major classes of economic models; input-output and national income. The objective of this review is to determine the manner in which marketing related problems can be treated using features of existing economic models.

Certain features of existing models have relevance to the problem of measuring the economic impact of changes in marketing. The models developed in this thesis incorporate certain features of both input-output and national income models. A discussion of both the conceptual frameworks of existing models and the methodological aspects of constructing these models are thus relevant to the objectives of this thesis.

Input-Output Models

The Leontief Model

Input-output analysis was developed in the early 1930's by Wassily Leontief. Since its introduction, a number of input-output model forms have been developed increasing both the complexity and usefulness of input-output analysis. Input-output ranks today as one of the most important types of economic models.[1]

In the input-output framework an economy is viewed as a set of interacting industrial sectors. Each industrial sector produces a single output which is used by other industrial sectors as a factor of production and sold to final demand. To produce its output, each industrial sector uses the output of other industrial sectors in combination with labor and, possibly, imports from other economic systems.

Final demand for the output of an industrial sector equals the amount demanded by households, government, other economic systems (exports), and usually the net change in stock. Intermediate demand for the output of an industrial sector equals the amounts demanded by all other industrial sectors in the system.

The total output of an industrial sector equals, by definition, the sum of intermediate and final demand. In the basic input-output model, final demand is treated as an exogeneous variable and therefore presents no computational problem. It is the computation of intermediate demand which presents the problems and which required Leontief to develop a set of simultaneous equations in order to obtain a solution.

The use of simultaneous equations is required because Leontief chose to view the economic system as a set of interacting industrial sectors; the total output of an industry, i, is functionally related to the input requirements of other industries which, in turn, are functionally related to the total output of industry i.

If the industries are related in a sequential manner, it is easy to see that a simultaneous solution is not required. A sequential arrangement implies that the flow of output is from a "lower" industry to a "higher" industry with no output going from a "higher" to a "lower" industry. Given values for the total outputs of the "highest" order industries and an assumption on production relationships, the input requirements and thus the total output requirements of "lower" industries can be computed. This method can be repeated until the outputs of the "lowest" industries are computed.

Leontief chose to recognize the reality of industry interrelation and, with the aid of a simplifying assumption on production functions, developed the basic input-output model. The clearest method of describing a basic input-output is to use as an example a hypothetical economy with n industrial sectors.

Let the amount of output of one industrial sector, i, which is used as an input by another sector, j, be defined as Y_{ij}. Let the final demand for the output of sector i equal F_i, and the total output of sector i equal Y_i.

The total output of sector i equals the sum of intermediate demand and final demand. Expressed in mathematical terms,

$$Y_i = \sum_{j=1}^{n} Y_{ij} + F_i \quad . \tag{3.1}$$

There are n equations of the type shown above, one equation for each of the n industries.

Assume that the input required from sector i by sector j is related to the total output of sector j in fixed proportion, a_{ij}. The fixed proportion, a_{ij}, is usually referred to as a technical coefficient. Expressed mathematically,

$$Y_{ij} = a_{ij}Y_j \quad . \tag{3.2}$$

It can be shown that the relationship between the total outputs of the n industrial sectors and the final demands for the outputs of the n industrial sectors is,[2]

$$\overline{Y} = [U-A]^{-1} \ \overline{F} \tag{3.3}$$

Where,

$$\overline{Y} = \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_j \\ \vdots \\ Y_n \end{bmatrix} ,$$

$$\overline{F} = \begin{bmatrix} F_1 \\ F_2 \\ \vdots \\ F_j \\ \vdots \\ F_n \end{bmatrix} ,$$

U = an (n x n) unit matrix, and

A = an (n x n) matrix with entries of a_{ij}.

There are certain assumptions made, in addition to the assumption of fixed proportions, to develop the input-output model. First, is the assumption that each industry produces its own specific output and no other. Second, it is assumed that there is product homogeneity; each product is uniform.

There is no assumption made that the technical coefficients are fixed over time. It should also be noted that the assumption of proportionality in production disallows substitution effects, or economies or diseconomies of scale.

The basic assumptions are, of course, simplifications of reality. In attempting to justify the use of input-output in light of its obvious simplification Stone stated:

> . . . if assumptions are so misleading why, it may be asked, bring them in at all? The answer is that without them we could never make a start. They enable us to introduce some sort of order into the bewildering variety of the real world and reduce it to measurable proportion.[3]

Uses of a simple input-output model are rather obvious. First, the model allows the computation of total output requirements for a set of final demand estimations. Second, using supplemental information and assumptions about total output and labor, import, or capital relationships, estimates of labor, import and capital requirements for sets of final demand estimates can be made. The model allows a simulation of the behavior of the economic system for research or economic development planning.[4,5,6]

Final demand in an input-output model is essentially equal to gross national product. Given a projection for GNP, disaggregated to describe final demands for the output of each defined industrial sector, the total output of each sector can be estimated. Using these total output values, estimates of labor, imports and capital can be made.

Price Consideration

Prices of outputs have been introduced into the input-output model. Let X_j be the price per unit of good j. If a_{ij} is defined in physical unit per physical unit terms, a_{ij} times X_i is the cost of a_{ij} units of good i required to produce one unit of j. The cost of all industrial inputs to industry j required for one unit of good j is $\sum_{i=1}^{n} a_{ij} X_i$. Defining "value added" by industry j in producing one unit of good j as v_j, then;

$$v_j = X_j - \sum_{i=1}^{n} a_{ij} X_i \tag{3.4}$$

Value added can be broken down into labor cost and profit. Hadley demonstrates how the price and value added concepts are incorporated mathematically into the model.[7] The effect of wage rate changes upon prices throughout the economic system can be studied with this feature of an input-output model.

A "Closed" Leontief Model

The "closing" of an input-output model refers to the relationship which exists between labor input (income) and the level of final demand. One portion of final demand is export and government demand. Increasing the level of government demand for industrial output increases the total output of industrial sectors and thus labor requirements. Increased labor requirements increases consumer demands given that they have more income.

To close the Leontief model requires the addition of a consumption function which relates demand for goods to the amount of income (labor requirements). Referring again to Hadley, one possible way of including the consumer sector is to treat it as another industry.[8,9]

Dynamic Input-Output Models

Attempts have been made to introduce dynamic behavior into the input-output model.[10,11,12] One of the most extensive input-output modeling efforts, outside the Office of Business Economics in the United States, has been conducted at Cambridge University. The Cambridge Model, designed for long range economic predictions, has two characteristics which should be discussed.

It was stated above that one assumption of a Leontief model was an identity between industry and product. This means that a product is produced only in one industry. In the Cambridge model a double classification is used which distinguishes between industries and commodities. This double classification is used to reduce errors in the technological relationships established between industries by assigning product demand to the correct industry regardless of which industry, in reality, produces the product.[13] In effect, technology is described on a commodity basis rather than an industrial basis.

The second characteristic of the Cambridge model is the method of projecting technical coefficient values into the future. Due to data shortages a combination of extrapolation and direct observation is used.[14] The disaggregation of the model is fine enough that industrial experts can criticize and improve technical coefficient estimates. The model is designed to consider changes in technical coefficients since its function is to serve long range economic prediction needs.

The Distribution Sector

The Statistical Office of the United Nations has developed a list of industrial divisions referred to as the International Standard Industrial Classification (ISIC).[15] In this list, commerce, trade, finance, insurance, and real estate are grouped in one major classification. Other classifications include agricultural, mining, manufacturing, construction, public utilities, transport, storage and communication, and services.

These industrial classifications are used in most input-output models of economic systems. In a review of the development plans of thirteen countries, the trade sector is explicitly defined in only four.[16] While country development plans are not always directly related to the sectors defined in an input-output model the exception of trade in nine country plans is indicative of its neglect.

In those cases where a trade or distribution sector is treated as an industrial sector in an input-output model the inputs and outputs must be clearly understood. The inputs to the distribution sector include only such items as refrigeration units, cash registers, and wrapping paper. These inputs are for use in the commercial sector as "factors of production." The output of the distribution sector includes sales to other industrial sectors and only a portion of its actual sales to final demand.

In an input-output model the portion of industrial output going to final demand which is sold by a wholesale or retail establishment is recorded as final demand for the industry and not the commercial sector actually selling the output. While the total output value for an industry such as mining approximates the value of mining's output, the total output value for the distribution sector represents only a fraction of its actual throughput.

Physical flow patterns of goods are described in an input-output model only in the sense of origin and ultimate destination. An input-output table records only the value of goods sold by industry i to industry j. The number of intermediaries involved is not known nor is value added by the distribution sector known.

The channel of distribution describing the flow pattern for the output of any industry is not defined within the input-output framework.

Evaluation

An input-output model, without a basic alteration in the manner in which the distribution sector is treated, is not applicable to analyzing that sector's relationship to the rest of the economic system. The reason for this is the manner in which the distribution sector must be treated if it is to be defined as an industrial sector within the model.

To explicitly include a distribution sector in a model of an economic system requires that, at minimum, the actual amount of inputs to that sector and its actual output be recorded. To record this data in an input-output model would involve double counting or the altering of the values of technical coefficients and value added for all other industrial sectors by changing their values for final demand.

Although direct use of an input-output model is not possible, aspects of the model are vitally important and useful in the context of measuring the impact of certain marketing reforms or changes.

The interdependency of industrial sectors points to an important factor which must be considered in measuring the impact of a marketing change. If a marketing reform within the distribution sector alters the level of demand for the output of any industrial sector, the total output of all related industries will be effected. To simply record the demand change for the effected good would understate the impact of the reform. Properly used, the theoretical relationships of the input-output model can be used to record secondary effects of a marketing reform within the production sector.

The "closed" Leontief model provides another clue for tracing the effect of a marketing reform. Consider a marketing reform which increases the demand for the output of an industry, agriculture, for example. Industry interdependency, as described in an input-output model, indicates that the total output of other industries, manufacturing, for example, may increase. Increases in total output increase labor requirements and thus total income and consumer demand. Increased consumer demand has an additive effect upon total output requirements. The closed Leontief model describes an approach to measuring this effect.

The inclusion of price in an input-output model provides a suggested approach for dealing with price effects throughout an economic system caused, perhaps, by a marketing reform. Alterations in price at the consumer level may effect demand, total output and wage income.

Thus, while an input-output model treats the distribution sector in a manner not satisfactory for the purposes of this thesis, it does provide basic concepts which can be used to build a useful model.

National Income Models

Domar and Harrod

The original models of Harrod and Domar are the prototypes of the national income models. In these original models, the economic system was viewed in simple aggregate terms.

Evsey Domar's original model was designed to define the rate which demand must increase in order to fully utilize increasing productivity caused by capital accumulation. This model was not presented as a theory of growth but as a means of studying an aspect of the growth problem.[17]

The basic relationship in the model defines the equilibrium growth path. The equilibrium growth path is defined by the condition that no capital shortage exists yet all capital provided by previous investment is fully utilized. Expressed mathematically,

$$\frac{\Delta i}{i_t} = \alpha\sigma \quad . \qquad (3.5)$$

where

Δi = change in investment,

i_t = investment in time t,

α = marginal propensity to save, and

σ = ratio of added capacity to added capital stock.

The development of this equation rests upon fairly simple economic relationships. The amount of capacity added during any period, t, is equal to σ times i_t. For equilibrium, additional aggregate demand must also equal σi_t. Consumption can account for only $(1-\alpha)\sigma i_t$ and, therefore, additional investment, σi, must account for the rest, $\alpha\sigma i_t$. Equation 3.5 is a rearrangement of the statement $\Delta i = \alpha\sigma i_t$.[18]

Harrod attempted, in his original model, to provide a theory explaining how steady growth occurs. The "acceleration principle" is used to develop a theory of investment. A number of interpretations of Harrod's model have been made. The following is by Ackley.[19]

The model is expressible in the form;

$$\frac{Y_t}{Y_{t-1}} = (\alpha+\rho)\ \frac{Y_{t-1}}{Y_{t-2}}\ \rho \qquad (3.6)$$

where Y = aggregate demand,
α = marginal propensity to consume, and
ρ = marginal propensity to invest.

The derivation is based upon four assumptions.[20] These assumptions concern the determination of consumer demand, C_t, investment demand, i_t, the rate of output growth, $\frac{Y_t}{Y_{t-1}}$, and sales S_t. Respectively these assumptions are;

$$C_t = \alpha Y_t \qquad (3.7)$$

$$i_t = \rho(Y_t - Y_{t-1}) \qquad (3.8)$$

$$\frac{Y_t}{Y_{t-1}} = \frac{Y_{t-1}}{Y_{t-2}},\ \frac{S_t}{Y_{t-1}} \qquad (3.9)$$

$$S_t = C_t + i_t \qquad (3.10)$$

Ackley states that the Harrod model, and a similar but more sophisticated model by Duesenberry, operates on the same principle:

> Growth occurs because the actual capital-to-output ratio remains sufficiently far below the optimum ratio to induce sufficient investment to keep income growing as fast (or faster) than capital accumulates.[21]

Ackley qualifies the usefulness of these and other growth models.[22] First, he states that these growth models are concerned with the study of growth in highly developed countries which have essentially the free-market, free-enterprise system of organization. Second, he notes that they concentrated only on the accumulation of capital and claims. Even population and technological trends are not considered.

Sector Disaggregation

Recent models of the national income type are more sophisticated and treat the economic system in a more disaggregated manner. A model developed by Ichimura is an example of a national income model with two defined sectors.[23]

In the Ichimura model, a distinction is made between the private and public sectors of the economy. Private investment and consumption are treated separate from public consumption and investment.

Three definitional, seven behavioral, and one technical equations are used in the model. The definitional equations pertain to national income definitions. The behavioral equations cover private savings, taxes, imports, government expenditures, borrowing, and investment. A capital-output relationship is the technical equation.

All eleven equations need not be listed. The equation below, concerning private savings, is illustrative of the model's form.

$$(Y^P - C^P) = sY^P$$

Private savings $(Y^P - C^P)$, is related to disposable private income, Y^P, by the average propensity to save, s.

The complexity and level of disaggregation of the national income model class is virtually unlimited. Two examples of the more complex models are those developed by the Simulmatics Corporation and the Social Science Research Council.

The Simulmatic's model was developed as a dynamic model for simulating the Venezuelan economy.[24] Three sectors are defined in the model; the definition of sectors reflects the importance of the petroleum industry in Venezuela. The petroleum, non-petroleum, and public sectors are modeled. Capital formation and output capability are related for each sector. Import and consumption functions are developed. Definitional equations are used to convert the models assumptions into national income accounting terms.

Over one-hundred equations are involved in the presentation of the Venezuelan model.[25] These include definitional, behavioral, and technical equations of varying complexity. The model is presented not as a hypothetical illustration but as a model based upon the Venezuelan situation; it is designed for policy makers as a tool.

The Social Science Research Council developed a national income model designed for short run forecasting in the United States.[26] In the original model, seven industrial sectors were defined; a thirty sectorial model is planned. In the model, numerous equations (over one hundred and fifty) of varying complexity are used to construct the model.

Models such as the two previously mentioned are difficult to summarize. In a discussion of the SSRC model, one person commented, ". . . the SSRC model of the United States . . . is a very large one, and I hope that I shall be forgiven if I do not discuss it equation by equation."[27] No equation by equation evaluation is attempted here either.

Trends

Models of the national income type have, as indicated above, become highly complex. In the original model by Harrod no industrial sectoring was attempted while in the SSRC model seven industrial sectors are defined and the introduction of twenty-three more is planned. The original Harrod model used the simple Keynesian consumption function while the SSRC model introduces six equations, estimated by least-squares method, to describe the consumption functions for different categories of goods.

The complexity of national income models has resulted from a combination of two factors. Disaggregation or sectoring of the economic system is one factor. Increased sophistication of the perception of economic relationships is the second factor.

Sectoring has resulted in the consideration of more than one component of a basic national income component such as production or consumption. A number of industrial sectors or consumption types are defined using economic relationships of basically the same type. This factor is analogous to expanding the number of defined industrial sectors in a Leontief model. The complexity of the model is increased due to size rather than more complicated economic relationships.

Increased sophistication of economic relationships also complicates the form of a national income model. As the influence of such factors as taxes, inventory, government expenditure patterns, and population trends are considered the model becomes more difficult to develop.

In general, while the trend in input-output analysis has been toward more sophisticated handling of production oriented problems, national income models have concentrated on improved estimations of final demand and capital-output relationships.

Evaluation

The commercial or distribution sector has been completely ignored in all but the most recent national income models. Of the models reviewed, only the SSRC model had reference to a distribution sector. In the SSRC model, inventory levels, employment, and price levels at the wholesale level were included as factors in the model.[28]

Although referred to in the SSRC model, the distribution sector is certainly not an integrated part of the model. Employment, level of inventory, and prices as they relate to the distribution sector were included in the model because these factors had to be considered in the estimation of final demand; the distribution sector itself was not modeled.

Summary

The two basic types of economic models, input-output and national income, are discussed above. Within each type so many varied forms exist that the term "input-output" or "national income" is really insufficient to describe any particular model. As they become more complex, the differences seem slight.

The most important observation concerning existing economic models, with respect to the problem of measuring the economic impact of marketing change, is that the distribution sector of an economic system is treated in only a superficial manner. In input-output analysis the emphasis is placed on the industrial sector and, when included, the distribution sector is treated as a productive sector also. In a national income framework, the distribution sector is usually not defined. When reference to the trade sector is made, as in the SSRC model, the purpose is to improve estimations of the model with no particular concern for integrating the distribution sector into the model.

Aspects of input-output and national income models are relevant to the problem of measuring the impact of marketing change even though the distribution sector itself is not treated in either type in the manner required. The input-output model provides techniques for tracing the impact of distribution changes to output changes of different industrial sectors. The national income models provide techniques for tracing the impact of distribution change to the final demand sectors.

The following chapter describes the mathematical modeling technique to be used. To assist the reader in the transition from the more familiar model types to a systems model, a simplified example will be used for demonstrating both the technique of systems theory and the conceptual framework for introducing a distribution sector into a model of an economic system.

CHAPTER IV

THE METHODOLOGY OF SYSTEMS THEORY: A QUALITATIVE EXPLANATION

The objective of this chapter is to explain the methodology of systems theory and relate it to the modeling of a socio-economic system. The chapter is designed to familiarize the reader with the basic concepts of systems theory and explain, by the use of a highly simplified example, what systems theory does and does not provide.

Systems Theory in Socio-Economic Modeling

According to Boulding:

> General systems theory is the skeleton of science in the sense that it aims to provide a framework or structure of systems on which to hang the flesh and blood of particular disciplines and particular subject matters in an orderly and coherent corpus of knowledge.[1]

Miller and Blalock state that general systems theory is:

> . . . a general mode of analysis used in all sciences. Systems are seen from three perspectives (1) that involving the relationships between system and environment, (2) that involving interaction between several systems, and (3) that involving one type of system composed of other types of systems.[2]

"Systems engineering," "systems theory," the "systems approach," and "systems analysis" are all terms used to describe techniques originating in the field of engineering. At the onset, the engineering sub-field of general systems theory was restricted to the analysis of physical systems. The methodologies developed within the engineering field are now being applied in the social sciences.

The term "systems theory," as used in this thesis, identifies a specific formalized mathematical methodology developed within the field of systems engineering for the study of physical systems; the modeling procedures are rigidly defined.[3,4,5,6] General systems theory, as noted above, is the broader term used to define the inquiry into the assertions applicable to all systems, whether physical, biological, or behavioral, by a variety of modern scientific techniques.

Systems theory is still used primarily to develop mathematical models of physical systems. With the aid of a systems model, the mathematical description of a system, the behavior of a physical system can be studied on a computer. The inherent stability of a physical system and the sensitivity of that system to changes in its structure can be evaluated with the model.

Systems models serve as basic tools for controlling and optimizing the behavior of a physical systems and for designing new systems. Using the technique of systems theory a physical system can be "built" in mathematical terms and its' behavior analyzed on a computer prior to its actual construction.

It seems natural that a formal quantitative methodology for analyzing the behavior of a system has been developed and first applied in the analysis of physical systems. The components of physical systems are easily identified and may be physically uncoupled from the system. The behavior of an uncoupled physical component can be studied in isolation and under a wide range of laboratory conditions. Well defined measurement units and measurement tools are in existence to assist in the analysis of physical components.

A limited source of material exists describing attempts to apply the methodology of systems theory to the study of non-physical systems. Such diverse "systems" as a university, a recreational system, a church, and a company have been studied using systems theory as the basic research technique.[7,8,9,10,11,12]

No one familiar with the methodology of systems theory claims that its application will lead to the immediate development of sophisticated models of socio-economic systems. The basic value of systems theory in modeling socio-economic systems at this stage, in the authors opinion, is in the structured approach it provides for the development of a mathematical model. The methodology provides a technique for constructing a model of a system as an explicit function of the behavior of the identified components and their interactions.

The modeling of physical systems has been developed to the point where sophisticated mathematical techniques are used. Complicated mathematical descriptions of physical systems are common. At this stage in the application of systems theory to modeling socio-economic systems, knowledge of certain more advanced techniques is not required. Much more must be known both about the behavior of socio-economic systems and the "art" of applying systems theory to modeling socio-economic systems to fully utilize more advanced techniques such as control theory and system optimization.

This chapter, as stated above, is concerned with describing the basic concepts of systems theory applicable to the modeling of socio-economic systems. These concepts are discussed in abstract terms so that the inherent flexibility of the methodology can be demonstrated; a specific example pertaining to a socio-economic system is used to clarify these concepts.

It is convenient to distinguish between two broad areas of systems theory:

1. modeling theory, which deals with the development of a systems model from the models of the components of the system; and,

2. behavior theory, which is concerned with the use of a systems model to study the behavior of the system in response to various changes in the structure of the system.

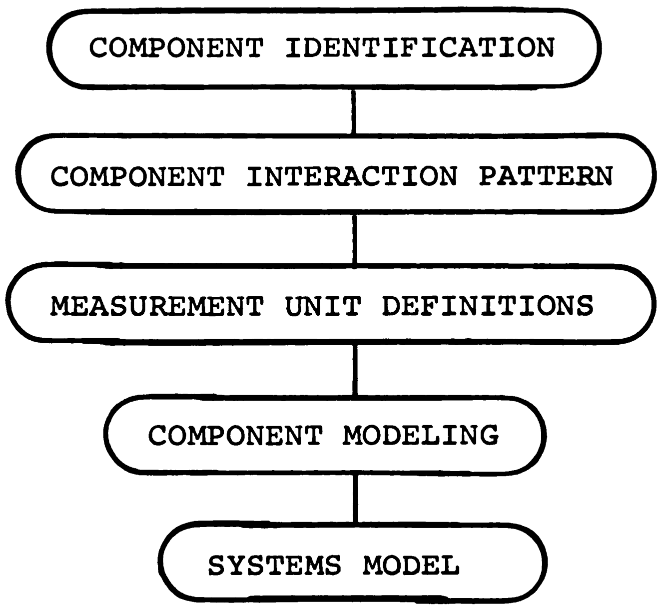
Modeling theory is discussed below. Behavioral theory is demonstrated in Chapter V and Chapter VI using the systems models developed in those chapters.

The following material on modeling theory is based primarily on the published and unpublished writings of Koenig.[13,14,15] An attempt has been made to combine and restructure material primarily from Koenig's various writings, to orient the presentation toward socio-economic systems modeling. Where portions of the methodology are treated lightly, references to more detailed discussions are supplied.

Modeling Theory

Modeling theory is concerned with the procedures used to obtain a mathematical description of certain features of classes of systems. Figure 4.1 represents one outline of the steps which must be taken to develop such a mathematical model.

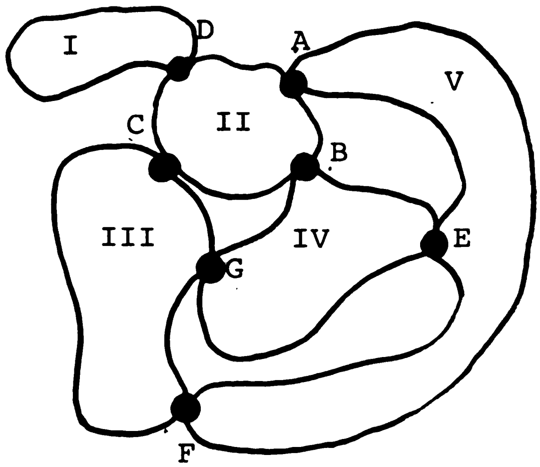
The first three steps are concerned with establishing a modeling structure. The identification of the components of the system, the description of the interconnections existing between the components, and the definition of measurement units establishes a modeling structure. The development of mathematical models of each component is then required. The systems model is obtained by combining the component models.



Steps in Model Construction
Figure 4.1

Modeling Structure

Consider an abstract system, S, which has five identified components (I, II, III, IV, V). Figure 4.2 describes a pattern of interconnection between the identified components of system S.

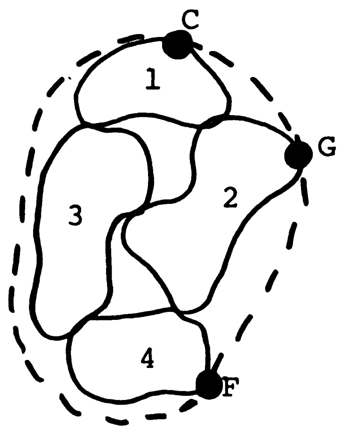


An Abstract System
Figure 4.2

No procedures or rules which result in the unique identification of the components of any system. It is assumed in systems theory that, in fact, no unique way exists to identify the components of any system. Given any system, physical or non-physical, the components of that system can be defined in a variety of ways.

The abstract system, S, described in Figure 4.2 has five components. It is possible to subdivide or "sub-componentize" any of these five components. Figure 4.3 shows component III as being composed of four subcomponents (1,2,3,4).

The component model of component III would be developed from the models of these four subcomponents. Methodologically, component III is treated as if it were a system, S*. The model of S* is developed from models of its "components." The model of component III, developed from the model of its' "components" would be used to develop the model of system S by combining it with the models of components I, II, IV and V.



Subcomponents of Component III
Figure 4.3

This technique of "breaking down" a defined component is an extremely useful one. While difficulty may be encountered in describing the behavior of component III in its aggregate form, its behavior might be more readily described in terms of the behavior of its' subcomponents (1,2,3,4).

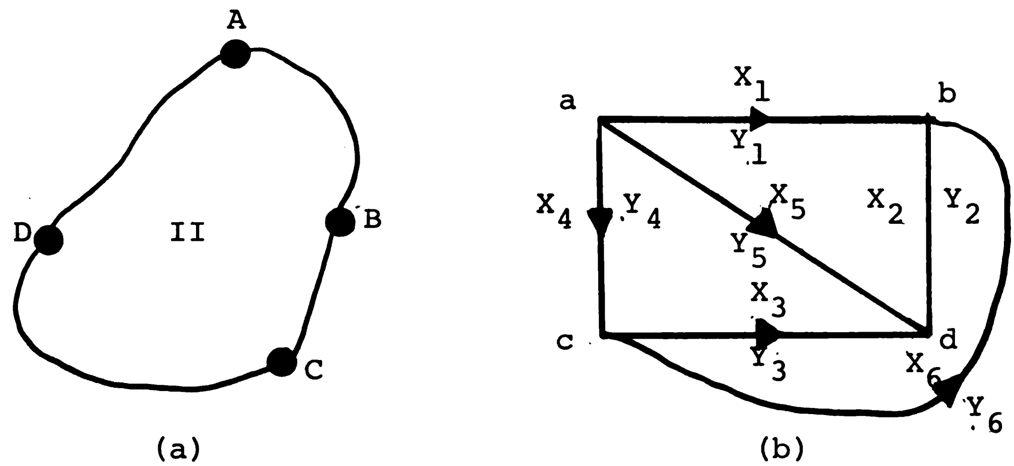
The number of components which are explicitly identified for modeling purposes is not fixed. There is no need to develop a unique method of identifying the components of a system when the methodology of systems theory has the inherent flexibility demonstrated for redefining components; beginning with some initial identification of the components of a system it is always possible to refine the model by going "within" some identified component.

The interfaces or points of contact between the components identified in Figure 4.2 are called terminals. These terminals (A,B,C,D,E,F,G), are easily identified and understood in terms of a physical system. If a radio were defined as a system and a vacuum tube in that radio were identified as a component of the radio, the prongs on the vacuum tube would identify an interface. The prongs would be used to connect the vacuum tube (a component) to another component in the radio (the system).

A restriction imposed by the use of systems theory is that the two basic systems variables, flow and propensity, have specific measurement characteristics.[16] In order to facilitate the discussion of these measurement restrictions some additional concepts and terminology must be introduced.

It is useful to "picture" a component in a diagrammatic form which is referred to as a map. For example, Component II from Figure 4.2 is shown in Figure 4.4 (a) and mapped in Figure 4.4 (b). An edge, or line, is shown between all of the terminals identified for that component. There are six edges shown for this four terminal component. Each edge has two measurement variables associated with it. These two variables are referred to as the propensity variable, X, and the flow variable, Y.

The arrow on each edge signifies a direction concept. Edge 1 of Figure 4.4 (b) can be used to explain the concept of direction. The end points "a" and "b" are called vertices and they correspond to terminals A and B of Component II. The propensity variable X_1 is directed from a to b if $X_1>0$ and from b to a if $X_1<0$. The flow is directed from a to b if $Y_1>0$ and from b to a if $Y_1<0$. The direction assigned to an edge by the arrow is arbitrary; the concept of a direction of an edge is, however, a necessary convention in modeling complex systems.[17]



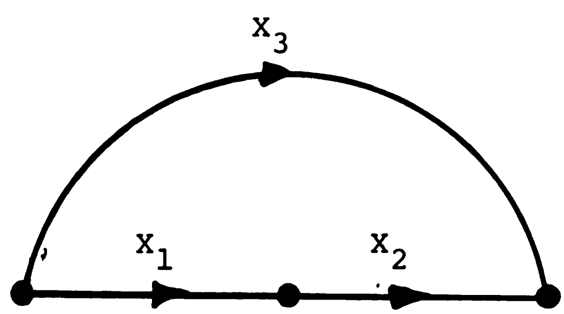
Map of Component II
Figure 4.4

In the physical sciences the flow and propensity variables are clearly defined. Some examples are given in Table 4.1[18]

The propensity variables have a special property: for a closed path of edges, such as in Figure 4.5, this property can be stated: $X_1 + X_2 + X_3 = 0$. This property is often referred to as the associative law of the real numbering system. If $X_1 = 2$, $X_2 = 3$; then X_3 must equal -5.

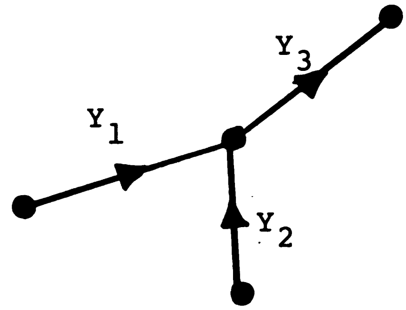
Table 4.1--Variable identification

General Phenomena	Electrical	Mechanical	Hydrolic	Thermal
X (propensity)	voltage	velocity	pressure	temp-erature
Y (flow)	current	force	flow rate	heat flux



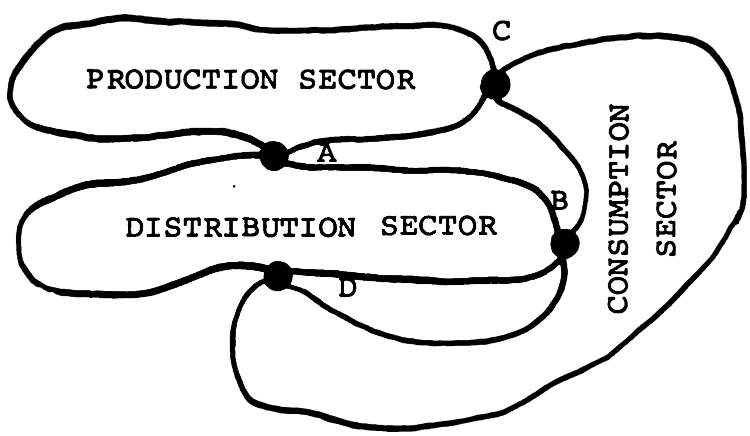
Propensity Variable
Figure 4.5

The flow variables also have a special measurement property: for a set of edges, such as shown in Figure 4.6, the sum of the flows at a vertex equals zero. For Figure 4.6, this property can be stated: $Y_1(n) + Y_2(n) = Y_3(n)$. This property is sometimes referred to as the continuity property. If $Y_1(n) = 4$, $Y_2(n) = 6$; then $Y_3(n)$ must equal 10.



Flow Variable
Figure 4.6

That part of modeling theory dealing with the establishment of a modeling structure can be illustrated using, as an example, a three component model of a socio-economic system. Figure 4.7 describes three identified sectors of the economic system and their points of contact.



Three Component Socio-Economic System
Figure 4.7

A production, a distribution and a consumption sector of the socio-economic system are identified. In the socio-economic system where the distribution sector is an identified component, a food distribution subsector and a nonfood distribution subsector could be identified as subcomponents of the distribution component. This process could be continued by identifying "types" of food distributors within the food distribution subsector, modern or traditional "types" for example. The terminals A,B,C, and D in Figure 4.7 identify interfaces at which the movement of certain items takes place between the three sectors. Terminal A might represent the flow of goods from the production sector into the distribution sector. Terminal B could represent the flow of the same goods from the distribution sector to the consumption sector. Terminals D and E might represent the labor used by the distribution and production sectors.

The terminals on a sector (the component) of a country (the system) are not easily identified. The distribution sector, for example, interfaces with the other defined sectors of the socio-economic system; an interface therefore exists between the production sector and the distribution sector. Although a single point called a terminal would not be visible, an interface does exist. Physical units of goods move between these sectors and thus form an interface. Other flows between these two identified sectors can also be described: money and labor, for example.

When the types of flows which exist between the identified components of a system are defined, the pattern of interconnection existing between the components is established. Goods, money, and labor are examples of the types of items which can be used to establish interconnections between components in a socio-economic system.

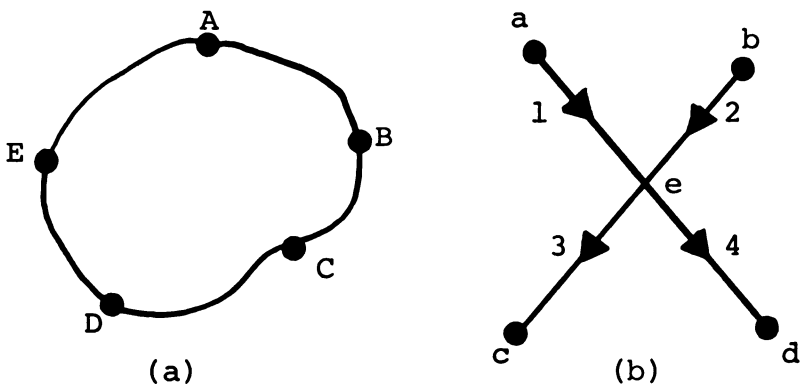
Measurement units to describe the items moving between these sectors need to be explicitly defined. The flow variable, Y, might be defined as a unit of flow of goods or labor per some specified time period. The propensity variable, X, might be defined as the price per unit of the defined goods or labor. The flow variable could also be a measure of dollar value for some time period while the propensity variable could be defined as a price index.

The identification of the components of the system, a description of how these sectors interface, and the definition of measurement units for items moving between sectors establishes a modeling structure. Within this structure the mathematical models of each component must be developed.

Component Modeling

Once the modeling structure is defined the methodology of systems theory is used to explicitly state what mathematical relationships required to model the components.

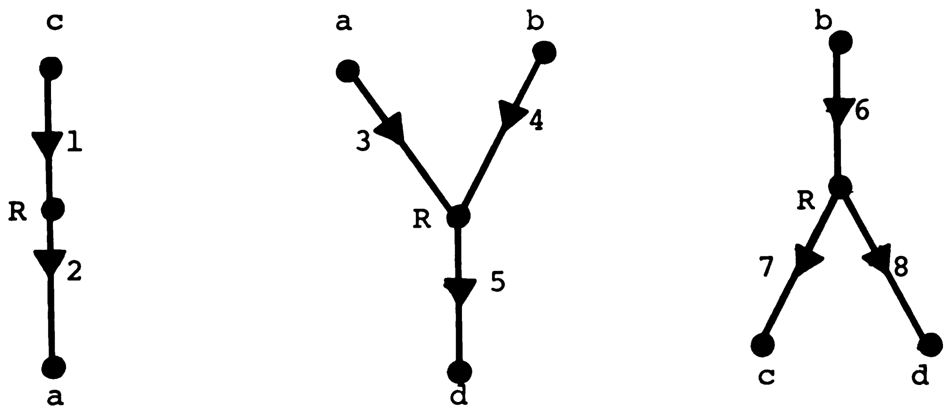
Consider any component with N terminals. A set of N-1 edges connecting the N terminals of the component but forming no closed path is called a terminal graph of the component. One possible terminal graph for the five terminal component in Figure 4.8 (a) is given in Figure 4.8 (b). The set of edges shown in Figure 4.8 (b) (1,2,3,4), is referred to as a tree of edges.



Terminal Graph
Figure 4.8

The first postulate of systems theory is that a relationship needs to be established for only those complimentary variables (X and Y) which correspond to a tree of edges on the N terminals of a component.[19] Thus, N-1 equations relating the 2(N-1) variables (a flow and propensity variable for each edge) are required to develop the component model. In terms of the graph in Figure 4.8 (b), four equations relating any four variables in the set (X_1, Y_1, X_2, Y_2, X_3, Y_3, X_4, Y_4) to the remaining four variables specify a model of that component.

The component mappings for the three components of the socio-economic system shown in Figure 4.7 are given in Figure 4.9.



Production Sector (a) Distribution Sector (b) Consumption Sector (c)

Component Mappings
Figure 4.9

For the production component model two equations relating any two variables in the set (X_1, Y_1, X_2, Y_2) to the remaining two are required. For the distribution component, three equations relating three variables in the set $(X_3, Y_3, X_4, Y_4, X_5, Y_5)$ to the remaining three are required. Finally, for the consumption component three equations relating three variables from the set $(X_6, Y_6, X_7, Y_7, X_8, Y_8)$ to the remaining three are required. The source of the equations which describes the assumed relationship between these variables is the actual behavior of the component.

A model of a component is designed to describe, in mathematical terms, the relationship which exists between the systems variables defined in the component models. Referring to the three component socio-economic system, it was stated that three equations were required to model the consumption component. These equations would describe the relationship existing between the systems variables as defined for this component (X_3, Y_3, X_4, Y_4, X_5, and Y_5).

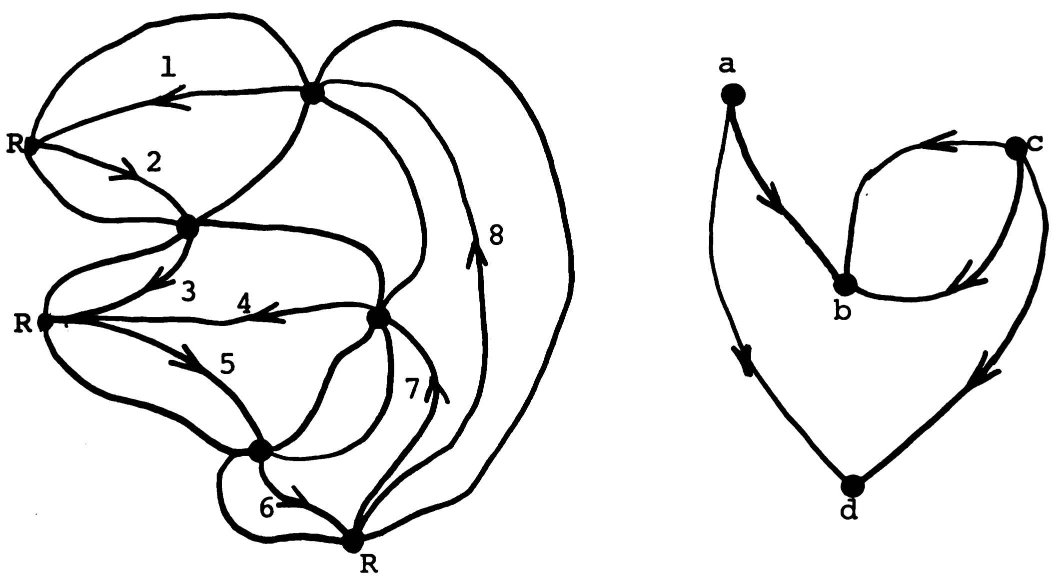
The methodology of systems theory does not provide a mathematical form which can be used to describe the behavior of this specific component. Systems theory does not provide a technique for defining the relationship between the values of X_3, Y_3, X_4, Y_4, X_5, and Y_5; systems theory specifies the relationships which must be established.

The form of the relationship that must be established is dictated by the behavior of the component and the objectives of the modeler. The form of the relationship will be an expression of how the systems variables, and what they were defined as measuring, are assumed to relate. The systems models developed in the next two chapters will assume a set of relationships to exist between the defined variables for each sector of the socio-economic system defined.

<u>The Systems Model</u>

Once the component models are developed, it is a mathematical problem to construct a model of the entire system.

A systems graph of the three component socio-economic systems described in Figure 4.10 (a) is shown in Figure 4.10 (b).



(a) (b)

System Graph
Figure 4.10

A systems graph is a union of all of the edges used to model the identified components. The graph has v vertices corresponding to the interfaces, and e edges corresponding to the edges in the component models. In this example there are four vertices and five edges.

If there are e edges defined for a certain component, the component model requires a minimum of e equations to relate the 2e unknowns (an X and Y variables for each edge). Since the model of a system is described as a set of simultaneous equations, as many equations as there are unknowns must be available to obtain the systems model.

An interconnection model, developed from the system graph provides e additional independent equations.[20] All e of these equations, or a subset of e equations from the interconnection model, may be used in combination with the equations of the component models to construct the systems model.

The construction of the interconnection model is based on the properties of the propensity and flow variables. The definition of the previously discussed X and Y variables is such that it is possible to obtain additional independent equations which may be needed to construct the systems model.

The exact form of the systems model depends on the form of the component models and their interconnection pattern. The behavioral characteristics of the system are implicit in the systems model.

Summary

In such a brief review it is impossible, and perhaps unwise, to raise all of the issues which must be understood to apply the concepts and techniques of systems theory. The basics of systems theory are surprisingly simple however.

The methodology of systems theory states that the user may view some system in a manner which is most useful and meaningful to him. The system may be broken into components or parts as the user deems necessary. By observing the restrictions placed on the definitions of the two variables, flow and propensity, the user is guaranteed that enough independent equations can be generated to make the entire system of equations, the model itself, solvable.

Transition

Up to this point, three major areas have been reviewed; the role of marketing in economic development, existing economic models and their treatment of the distribution sector, and the methodology of systems theory.

The model developed in the next chapter represents an attempt to merge a modeling technique and certain concepts and features of existing economic models into an approach for measuring the economic consequences of changes within the distribution sector of an economic system.

The economic system will be viewed as a collection of interrelated economic sectors. The literature on the role of marketing in economic development has described the need to consider the economic system in this manner.

The methodology of systems theory is based upon the concept of viewing a system as a set of interrelated sectors. Existing economic models, such as input-output and national income, have dealt with the problems of modeling certain economic sectors such as production and consumption and establishing relations between those sectors.

The distribution sector will be explicitly included in the model of the economic system. In order to alter facets of distribution and mathematically simulate the reactions of the economic system, the distribution sector must be included in the model explicitly. The technique of systems theory provides an approach for modeling the distribution sector as an integrated part of the system. Existing models can assist in the task of modeling other sectors and allow for more attention to be focused on the problem of introducing the distribution sector.

Operationally defined variables such as physical flow and prices will serve as measures of the economic reactions of the economic system. Economic flow variables such as physical output and employment were discussed as appropriate measures of economic development. The review of marketing in economic development contained repeated references to changes in prices and flows between sectors as factors which must be considered in measuring the consequences of a marketing reform. Existing models, such as input-output, can be expressed in unit flow and price terms thus making features of these models more directly usable.

CHAPTER V

MARKETING MODELS: MOD ONE

Introduction

The first of the two systems models is presented in this chapter. The model, identified as MOD ONE, presents a basic framework and demonstrates the application of the methodology of systems theory.

For the most part, the presentational format used in this chapter follows that used in the previous chapter to describe the methodology. First, a model structure is defined. The structure of the model defines the components to be modeled, the pattern of interconnections existing between the components, and the measurement units to be used for the systems variables. The modeling structure is a framework within which a specific model is developed.

Second, component models are developed. The component models are built from assumptions made about the behavior of the component; these assumptions are made within the framework specified.

Third, the systems model is developed. The model itself is a set of equations which relate certain system variables, flows and propensity variables, to some set of variables, the values of which are assumed to be known, using the parameters defined in the construction of the component models.

Fourth, the model is made operational. The values of parameters are estimated and a computer program written to assist in the simulations.

Finally, the model is used to simulate the responses of certain system variables to changes in parameter values. All of the simulations represent attempts to more clearly identify the consequences of certain changes occurring within the distribution sector and to determine how improvements in the model can be made.

Mod One

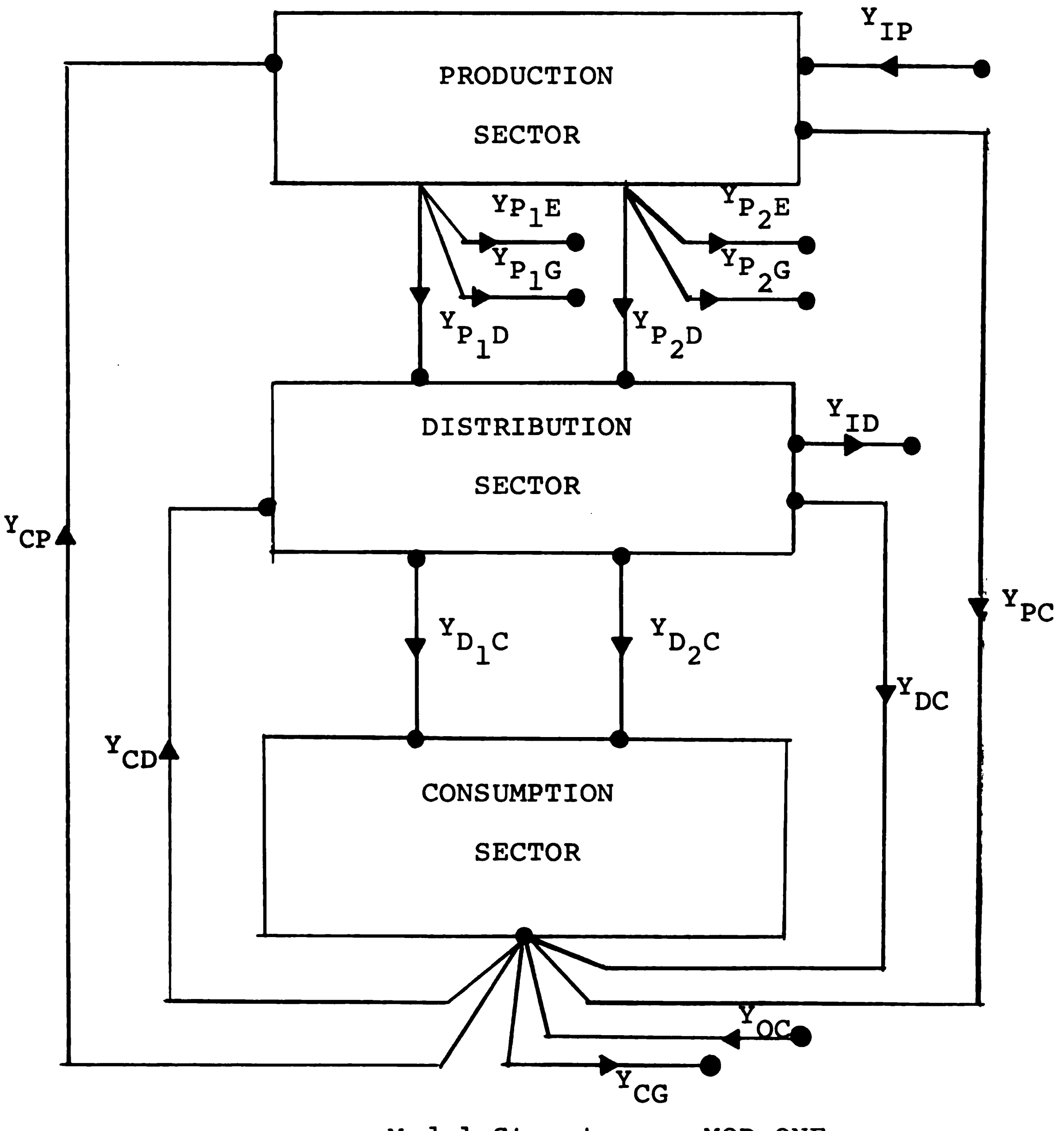
Structure

Three economic sectors are defined in MOD ONE. These sectors, or "components," are:

1. the production sector (P);
2. the distribution sector (D); and
3. the consumption sector (C).

The component models of these sectors are developed from models of the subsectors contained within each.

The pattern of interconnection for the three economic sectors, as defined by connecting lines or "edges," is described in Figure 5.1. The subsectors are not shown in order to keep the figure as clear as possible.



Model Structure: MOD ONE
Figure 5.1

A convention is used in this and the following chapter to label the connecting edges. An edge, in MOD ONE, is labeled with a letter Y. Two subscripted letters are associated with each Y; the two letters define sectors or terminal points.

The edge Y_{DC} represents a connection between the distribution sector (D) and the consumption sector (C). The arrow on the edge and the order of the two subscripted letters serve the same basic purpose; they signify a "direction" for the edge. The edge Y_{DC} signifies a movement between these two sectors from the distribution sector (D) to the consumption sector (C).

The letter Y is used in MOD ONE to define a flow in terms of dollars. Y_{DC} is thus a variable representing a dollar value of flow moving from the distribution sector to the consumption sector.

The letters E, I, G, and O represent "export," "import," "government," and "other" respectively. The variable Y_{IP} represents the dollar value of imports to the production sector. Edges which have an I, E, G, or O as subscripted letters are called terminal edges; they connect components within the system to points defined as external to the system being modeled.

On eight edges, the numbers 1 or 2 appear as subscripts to the first subscripted letter; $Y_{P_1 D}$ is one of those edges. The numbers refer to the subsectors or "subcomponents" within a sector.

The sixteen edges identified in Figure 5.1 and the types of flows they represent will become clear when the sectors themselves are more clearly defined. The other system variable, the propensity variable, X, is not shown on the edges. In MOD ONE the propensity variable is defined as a price index. At no place in the development of the model is an X variable related to another variable. The assumption made is that the value of the propensity variable for each edge is equal to one.

The production sector has two defined subsectors. The production units of the economic system being modeled are viewed as being in one or the other subsector depending upon their output; those units producing edible commodities are contained in production subsector P_1, those producing non-edible goods and producing services are in P_2.

It is, of course, possible to treat the production sector as a single aggregate unit or as a multi-industrial unit. In MOD ONE, the "food-nonfood" dicotomy is made to allow for the tracing of these two types of commodities throughout the model; one or more than two production subsectors could have been defined.

The edge labeled Y_{IP} represents the flow of imports into the production sector. These imports may be thought of as factors of production used by either or both of the production subsectors. Unmilled rice, fertilizer, chemicals, and baby chickens are types of items whose value, in total, would be represented by Y_{IP}.

Labor, from the consumption sector, used by the production sector to produce the outputs of that sector is measured by the variable Y_{CP}. Labor is used by both production subsectors.

The two outputs of the production sector are measured by the sum of the flow variables on six edges: Y_{P_1D}, Y_{P_1G}, Y_{P_1E}, Y_{P_2D}, Y_{P_2G}, Y_{P_2E}. The first three edges represent the total output of the food producing subsector, the last three the total output of the nonfood producing subsector.

The variables Y_{P_1G} and Y_{P_1E} measure the dollar value of food produced and sold to government and for export, respectively. The variables Y_{P_2G} and Y_{P_2E} measure nonfood goods and services produced and sold to government and for export. The variables Y_{P_1D} and Y_{P_2D} measure the value of food and nonfood items produced within the production sector and sold to the distribution sector.

The variable Y_{PC} represents the value of nonwage income generated by the production sector and distributed to the consumption sector. It should be noted that the variable Y_{CP} provides wage income. The sum of Y_{CP} and Y_{PC} represents income generated by the production sector.

When the component model of the production sector is developed, it relates the nine systems variables described above. The level of imports, Y_{IP}, the amount of labor, Y_{CP}, and the nonwage income generated, Y_{PC}, are related to the output of the production sector. The variables

Y_{P_1G}, Y_{P_1E}, Y_{P_2G}, and Y_{P_2E} are assumed to be known values; they are terminal variables.

An economic entity engaged in distribution, a wholesaler or retailer for example, may not necessarily be viewed as part of the distribution sector as defined in MOD ONE. Note that in Figure 5.1, no connection is made between the distribution sector and the production sector in the direction from distribution to production. Certain wholesalers, in reality, sell to production units. Imports may be purchased by wholesalers and then sold to production units. Not all entities which are normally classed as part of the distribution or trade sector are thus included in the distribution sector of MOD ONE.

The two subsectors of the distribution sector are defined in order to attach labor requirements and relate the dollar value of inputs to the distribution sector to the value of certain of the outputs of the distribution sector.

Labor required for the distribution of food and nonfood items to the consumption sector, Y_{CD}, is a defined input to the distribution sector. Imports of food and nonfood items which are to be consumed or used within the consumption sector are first shown as inputs to the distribution sector, Y_{ID}. Nonwage income, Y_{CD}, generated by the distribution sector is shown as an output of the distribution sector.

The consumption sector is composed of three subsectors. The subsectors represent a grouping of consumers into income categories; high, medium, and low. The purpose of defining three categories of consumers is to consider differences in consumption patterns. Income level is taken as a surrogate for classifying consumers into groups which differ in average propensities to consume food and nonfood items.

Eight systems variables are associated with the consumption sector. Two of these, Y_{CG} and Y_{OC}, are terminal variables and the values of these variables are assumed to be known. Y_{CG} represents the governmental demand for labor and Y_{OC} represents the net value of income to consumers from sources other than the production and distribution sectors.

Of the remaining six systems variables associated with the consumption sector, two relate to the items available for consumption, Y_{D_1C} and Y_{D_2C}, and the other four pertain to income sources; both wage income, Y_{CD} and Y_{CP}, and nonwage income, Y_{DC} and Y_{PC}.

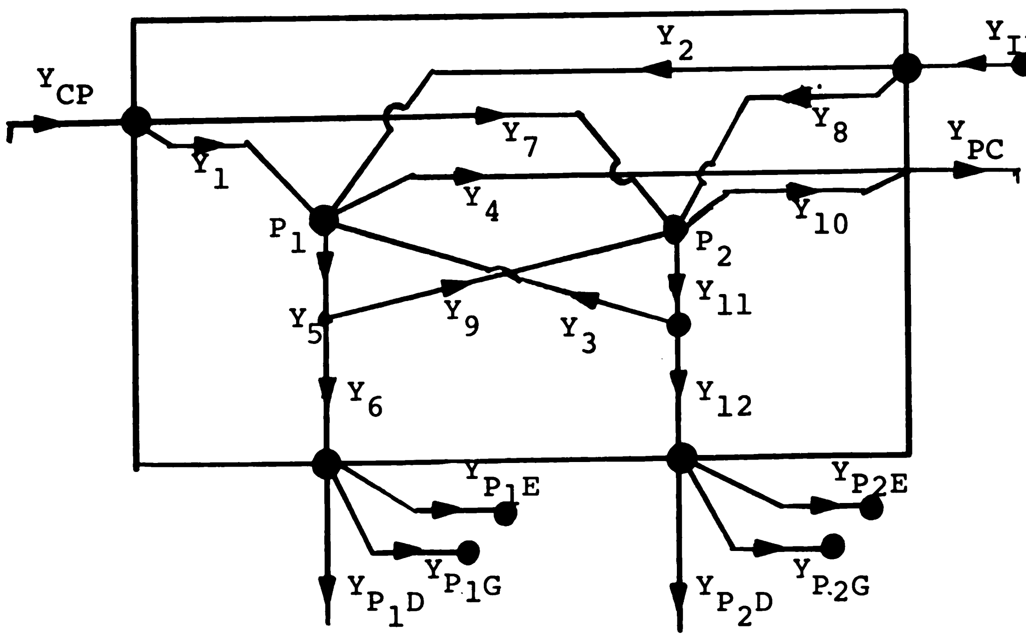
A relatively simple model structure is defined for MOD ONE. Three economic sectors are defined and a total of seven subsectors are identified. The system variables, flow variables, are defined as scalers; eight systems variables and eight terminal variables are defined in MOD ONE.

A simple model structure does not imply that the systems model is "simple" in either a mathematical or theoretical sense. A very complex mathematical model could be developed using complex behavioral assumptions about the relationships existing between the defined systems variables.

Component Models

Production Models

Figure 5.2 describes the production sector in detail. The figure is referred to as a "component graph."



Production Component: MOD ONE
Figure 5.2

The identified edges within the sector are labeled with the letter Y and a numeric subscript. The component model is expressed in terms of the systems variables described in Figure 5.1; the variables defined in the component graphs are used in intermediate steps to develop the component model.

The component model of the production sector must relate the variables in the set [Y_{CP}, Y_{IP}, Y_{PC}, Y_{P_1D}, Y_{P_1E}, Y_{P_1G}, Y_{P_2D}, Y_{P_2G}, Y_{P_2E}]. The model developed relates the systems variables in the set [Y_{CP}, Y_{IP}, Y_{PC}] to the systems variables in the set [Y_{P_1D}, Y_{P_1G}, Y_{P_1E}, Y_{P_2D}, Y_{P_2G}, Y_{P_2E}].

Edges 1 and 7, or variables Y_1 and Y_7, represent the dollar value of labor going to production subsectors P_1 and P_2 respectively. Variables Y_2 and Y_8 represent imports, measured in dollar value, used by the food and nonfood production subsectors as factors of production. Variables Y_3 and Y_9 represent, respectively, the dollar volume of the output of the nonfood producing subsector used by the food producing subsector and the dollar volume of the output of the food producing subsector used by the nonfood producing subsector.

Variables Y_1, Y_2 and Y_3, and variables Y_7, Y_8, and Y_9 represent inputs to the defined subsectors. The variables may be viewed as representing factors of production. Variables Y_5 and Y_{11} represent the total dollar value of the outputs of the two subsectors.

The total output of the food producing subsector, Y_5, equals Y_9 plus Y_6. The value of the variable Y_6 is equal to the dollar value of food items leaving the production sector; the amount exported, Y_{P_1E}, the amount purchased by government, Y_{P_1G}, and the amount purchased by the defined distribution sector, Y_{P_1D}. The total output of the nonfood production subsector, Y_{11}, equals the sum of Y_3 and Y_{12}, where Y_{12} equals the sum of Y_{P_2E}, Y_{P_2G}, and Y_{P_2D}.

Variables Y_4 and Y_{10} represent the dollar value of nonwage income generated by the two subsectors.

To build the component model, assumptions are made concerning the relationships existing between the internal variables. Two basic assumptions are used to build the component model of the production sector.

First, it is assumed that the dollar value of the inputs to a subsector are related in fixed proportion to the dollar value of the total output of that subsector. For the food producing subsector, the equation stating this assumption is:

$$\begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} Y_5 \quad . \qquad (5.1)$$

The parameters a_1, a_2, a_3, represent the fixed proportions relating Y_1, Y_2, and Y_3 to Y_5. Labor, imports, and nonfood items, used by the food producing sector, are assumed to be related to the output of the food producing sector as described in equation 5.1.

Second, it is assumed that the nonwage income generated by the food producing subsector, Y_4, is equal to some percentage, b_4, of the total dollar value of the output, Y_5. This assumption is stated mathematically as:

$$Y_4 = b_4 Y_5 \quad . \tag{5.2}$$

Equations 5.1 and 5.2 relate the inputs to the food producing subsector to the total output of that sector.

The same assumptions used above, applied to the non-food producing subsector would yield:

$$\begin{bmatrix} Y_7 \\ Y_8 \\ Y_9 \\ Y_{10} \end{bmatrix} = \begin{bmatrix} a_7 \\ a_8 \\ a_9 \\ b_{10} \end{bmatrix} Y_{11} \quad . \tag{5.3}$$

As stated, the total outputs of the two subsectors are:

$$Y_5 = Y_9 + Y_6 \quad , \tag{5.4}$$

and

$$Y_{11} = Y_3 + Y_{12} \quad . \tag{5.5}$$

All of the variables in the above equations, with the exceptions of Y_3, Y_9, Y_5 and Y_{11}, are directly relatable to systems variables. The variable Y_6, for example, equals the sum of Y_{P_1D}, Y_{P_1G}, and Y_{P_1E}. By eliminating the variables not directly relatable to a systems variable, Y_3, Y_9, Y_5, and Y_{11}, all of the systems variables associated with the production sector can be related.

From equations 5.1, 5.2, and 5.3, the following equation can be constructed:

$$\begin{bmatrix} Y_1 \\ Y_7 \\ Y_2 \\ Y_8 \\ Y_4 \\ Y_{10} \end{bmatrix} = \begin{bmatrix} a_1 & 0 \\ 0 & a_7 \\ a_2 & 0 \\ 0 & a_8 \\ b_4 & 0 \\ 0 & b_{10} \end{bmatrix} \begin{bmatrix} Y_5 \\ Y_{11} \end{bmatrix} . \tag{5.6}$$

Substituting a_9Y_{11} for Y_9, from equation 5.3, into equation 5.4, and substituting a_3Y_5 for Y_3, from equation 5.1, into equation 5.5, and rearranging, yields:

$$\begin{bmatrix} Y_6 \\ Y_{12} \end{bmatrix} = \begin{bmatrix} 1 & -a_9 \\ -a_3 & 1 \end{bmatrix} \begin{bmatrix} Y_5 \\ Y_{11} \end{bmatrix} , \tag{5.7}$$

or

$$\begin{bmatrix} Y_5 \\ Y_{11} \end{bmatrix} = \begin{bmatrix} 1 & -a_9 \\ -a_3 & 1 \end{bmatrix}^{-1} \begin{bmatrix} Y_6 \\ Y_{12} \end{bmatrix} . \tag{5.8}$$

By obtaining the inverse, equation 5.8 is written as:

$$\begin{bmatrix} Y_5 \\ Y_{11} \end{bmatrix} = \frac{1}{1 - a_3a_9} \begin{bmatrix} 1 & a_9 \\ a_3 & 1 \end{bmatrix} \begin{bmatrix} Y_6 \\ Y_{12} \end{bmatrix} . \tag{5.9}$$

Combining equations 5.6 and 5.9 yields:

$$\begin{bmatrix} Y_1 \\ Y_7 \\ Y_2 \\ Y_8 \\ Y_4 \\ Y_{10} \end{bmatrix} = \frac{1}{1 - a_3 a_9} \begin{bmatrix} a_1 & a_1 a_9 \\ a_3 a_7 & a_7 \\ a_2 & a_2 a_9 \\ a_3 a_8 & a_8 \\ b_4 & b_4 a_9 \\ a_3 b_{10} & b_{10} \end{bmatrix} \begin{bmatrix} Y_6 \\ Y_{12} \end{bmatrix} \quad . \tag{5.10}$$

The variables Y_3, Y_9, Y_5 and Y_{11} have been eliminated; there remains only the task of relating the variables in equation 5.10 to systems variables to complete the component model.

The vector in equation 5.10 containing variables Y_6 and Y_{12} can be expressed as:

$$\begin{bmatrix} Y_6 \\ Y_{12} \end{bmatrix} = \begin{bmatrix} Y_{P_1 D} \\ Y_{P_2 D} \end{bmatrix} + \begin{bmatrix} Y_{P_1 G} \\ Y_{P_2 G} \end{bmatrix} + \begin{bmatrix} Y_{P_1 E} \\ Y_{P_2 E} \end{bmatrix} \quad . \tag{5.11}$$

Entries in the other vector in equation 5.10 can also be expressed in terms of system variables. The labor flow from consumption to production, Y_{CP}, equals the sum of Y_1 and Y_7 or,

$$Y_{CP} = [1 \;\; 1] \begin{bmatrix} Y_1 \\ Y_7 \end{bmatrix} \quad . \tag{5.12}$$

Similarly,

$$Y_{IP} = [1\ 1]\begin{bmatrix} Y_2 \\ Y_8 \end{bmatrix} . \qquad (5.13)$$

and

$$Y_{PC} = [1\ 1]\begin{bmatrix} Y_4 \\ Y_{10} \end{bmatrix} . \qquad (5.14)$$

The link between the systems variable Y_{CP} and the six systems variables in equation 5.11 is through equation 5.10. Combining equations 5.12, part of 5.10, and 5.11 yields:

$$Y_{CP} = P\begin{bmatrix} Y_{P_1D} \\ Y_{P_2D} \end{bmatrix} + P\begin{bmatrix} Y_{P_1G} \\ Y_{P_2G} \end{bmatrix} + P\begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \end{bmatrix}$$

where, (5.15)

$$P = \begin{bmatrix} \dfrac{a_1 + a_3a_7}{1 - a_3a_9} & \dfrac{a_7 + a_1a_9}{1 - a_3a_9} \end{bmatrix} .$$

In a similar manner, the following equations can be derived:

$$Y_{IP} = Q\begin{bmatrix} Y_{P_1D} \\ Y_{P_2D} \end{bmatrix} + Q\begin{bmatrix} Y_{P_1G} \\ Y_{P_2G} \end{bmatrix} + Q\begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \end{bmatrix}$$

where, (5.16)

$$Q = \begin{bmatrix} \dfrac{a_2 + a_3a_8}{1 - a_3a_9} & \dfrac{a_8 + a_2a_9}{1 - a_3a_9} \end{bmatrix} ;$$

and,

$$Y_{PC} = R\begin{bmatrix} Y_{RD} \\ Y_{P_2D} \end{bmatrix} + R\begin{bmatrix} Y_{P_1G} \\ Y_{P_2G} \end{bmatrix} + R\begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \end{bmatrix}$$

where (5.17)

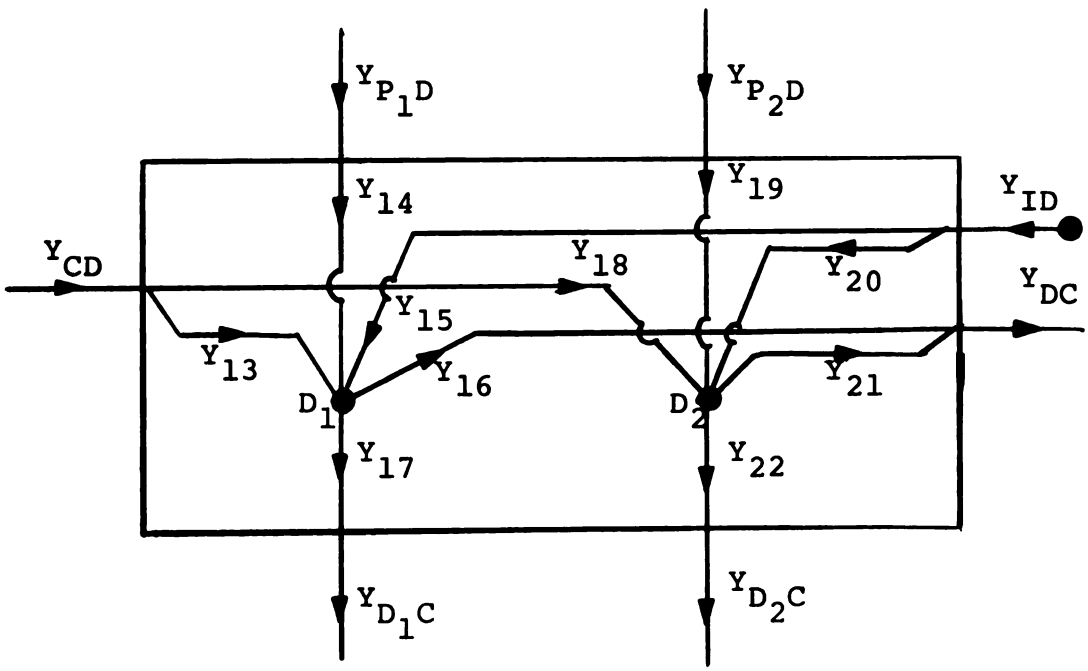
$$R = \begin{bmatrix} \frac{b_4 + b_{10}a_3}{1 - a_3a_9} & \frac{b_{10} + b_4a_9}{1 - a_3a_9} \end{bmatrix} .$$

Equations 5.15, 5.16, 5.17 constitute a component model of the production sector. The variables in the set $[Y_{CP}, Y_{IP}, Y_{PC}]$ are related to the variables in the set $[Y_{P_1D}, Y_{P_2D}, Y_{P_1G}, Y_{P_2G}, Y_{P_1E}, Y_{P_2E}]$ using the parameters in the set $[a_1, a_2, a_3, a_7, a_8, a_9, b_4, b_{10}]$. The variables Y_{P_1G}, Y_{P_2G}, Y_{P_1E}, and Y_{P_2E} are terminal variables and their values are assumed to be known.

Distribution Sector

Figure 5.3 describes the distribution sector in detail. The convention used to label the internal edges of the distribution sector is the same as described above for the production sector.

The component model of the distribution sector must relate the variables in the set $[Y_{ID}, Y_{P_1D}, Y_{P_2D}, Y_{DC}, Y_{CD}, Y_{D_1C}, Y_{D_2C}]$. The component model developed relates the variables in the set $[Y_{ID}, Y_{P_1D}, Y_{P_2D}, Y_{CD}, Y_{DC}]$ to the variables Y_{D_1C} and Y_{D_2C}.



Distribution Sector: MOD ONE
Figure 5.3

Variables Y_{13} and Y_{18} represent the dollar value of labor used in the distribution of food and nonfood items respectively. Variables Y_{15} and Y_{20} represent imports, measured in dollar value, which are food or nonfood consumption items distributed by the two distribution subsectors. Variables Y_{14} and Y_{19} are food and nonfood consumption items distributed by the two subsectors and produced by the production sectors. Variables Y_{16} and Y_{21} represent, respectively, the dollar value of nonwage income generated by the distribution subsectors.

Variable Y_{17} represents the dollar value output of food items; variables Y_{14} and Y_{15} represent the dollar values of food items entering the food distribution subsector from internal (production) and external (import) sources respectively. Variables Y_{19} and Y_{20} represent, respectively, nonfood items produced from within the system and imported to the system into the nonfood distribution subsector. No food items are distributed via the nonfood distribution subsector nor are nonfood items distributed via the food distribution subsector.

The component model of the distribution sector is developed from assumptions analogous to those used to develop the component model of the production sector. The model is actually simpler in a mathematical sense because part of the output of one subsector is not used as an input to the other subsector.

Assume that the dollar values of the inputs to the food distribution subsector, Y_{13}, Y_{14}, and Y_{15} are related to the dollar value of the total output of that subsector, Y_{17}, in fixed proportion. Assume also that the nonwage income generated by the operation of the food distribution subsector is equal to a percentage, b_{16}, of the total dollar output. These two assumptions yield:

$$\begin{bmatrix} Y_{13} \\ Y_{14} \\ Y_{15} \\ Y_{16} \end{bmatrix} = \begin{bmatrix} a_{13} \\ a_{14} \\ a_{15} \\ b_{16} \end{bmatrix} Y_{17} \quad . \qquad (5.18)$$

The same two assumptions applied to the nonfood distribution subsector, yields the relationship:

$$\begin{bmatrix} Y_{18} \\ Y_{19} \\ Y_{20} \\ Y_{21} \end{bmatrix} = \begin{bmatrix} a_{18} \\ a_{19} \\ a_{20} \\ b_{21} \end{bmatrix} Y_{22} \quad . \qquad (5.19)$$

All of the variables in equations 5.18 and 5.19 are directly expressed in terms of systems variables associated with the distribution sector. For example, variables Y_{17} and Y_{22} equal, respectively, Y_{D_1C} and Y_{D_2C}. Variables Y_{18} and Y_{13}, sum to equal the variable Y_{CD}.

It is clear from the component graph in Figure 5.3 that:

$$Y_{CD} = [1\ 1] \begin{bmatrix} Y_{13} \\ Y_{18} \end{bmatrix} \quad , \qquad (5.20)$$

$$Y_{ID} = [1\ 1] \begin{bmatrix} Y_{15} \\ Y_{20} \end{bmatrix} \quad , \qquad (5.21)$$

and

$$Y_{DC} = [1\ 1] \begin{bmatrix} Y_{16} \\ Y_{21} \end{bmatrix} \quad . \qquad (5.22)$$

Combining equations 5.18 through 5.22 yields the following four equations which constitute the component model for the distribution sector. The substitutions required to develop these equations are basic and no proof is offered.

$$Y_{CD} = [a_{13}\ a_{18}] \begin{bmatrix} Y_{D_1C} \\ Y_{D_2C} \end{bmatrix} \tag{5.23}$$

$$Y_{ID} = [a_{15}\ a_{20}] \begin{bmatrix} Y_{D_1C} \\ Y_{D_2C} \end{bmatrix} \tag{5.24}$$

$$Y_{DC} = [b_{16}\ b_{21}] \begin{bmatrix} Y_{D_1C} \\ Y_{D_2C} \end{bmatrix} \tag{5.25}$$

$$\begin{bmatrix} Y_{P_1C} \\ Y_{P_2C} \end{bmatrix} = \begin{bmatrix} a_{14} & 0 \\ 0 & a_{19} \end{bmatrix} \begin{bmatrix} Y_{D_1C} \\ Y_{D_2C} \end{bmatrix} \tag{5.26}$$

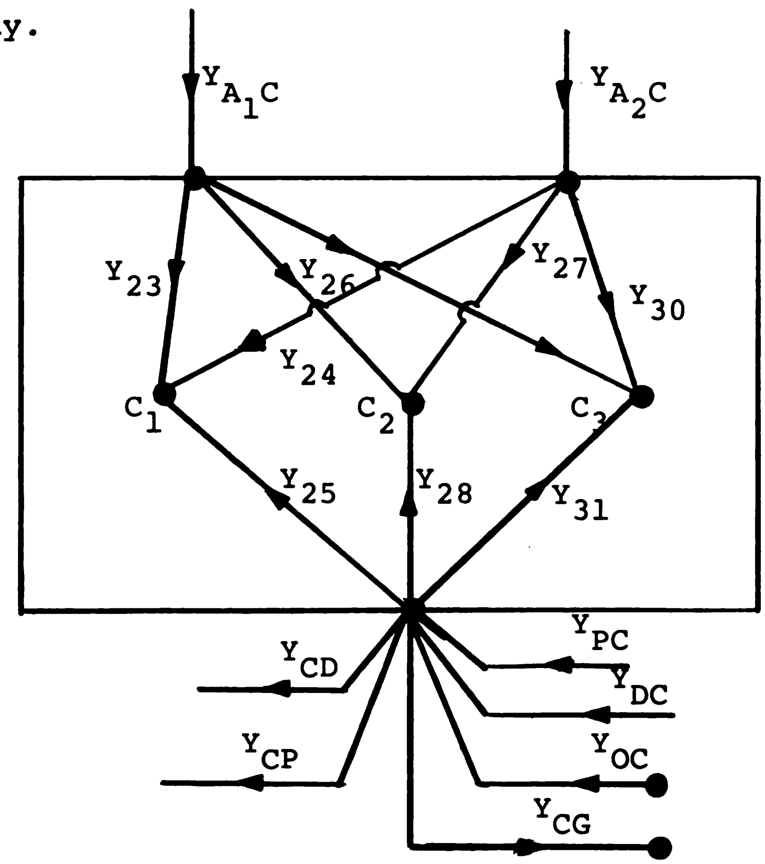
The component model relates the system variables in the set [Y_{CD}, Y_{ID}, Y_{DC}, Y_{P_1D}, Y_{P_2D}] to the system variables Y_{D_1C} and Y_{D_2C} using the parameters in the set [a_{13}, a_{18}, a_{15}, a_{20}, b_{16}, b_{21}, a_{14}, a_{19}]. No known terminal variable is used in the construction of the model; the terminal variable Y_{ID} is related to both Y_{D_1C} and Y_{D_2C}; yet it is not assumed to have a known value.

Consumption Sector

Figure 5.4 is the component graph of the consumption sector. Three subsectors are shown in this sector.

The component model of the consumption sector relates the systems variables in the set [Y_{D_1C}, Y_{D_2C}, Y_{CP}, Y_{CD}, Y_{CG}, Y_{PC}, P_{DC}, Y_{OC}]. The terminal variables Y_{CG}, the dollar amount of labor used by the government, and Y_{OC}, the dollar value of nonwage income earned from sources other than defined in the model, are assumed to have known values.

Variables Y_{25}, Y_{28}, Y_{31} represent the total dollar income to the consumption subsectors C_1, C_2, and C_3 respectively. Variables Y_{23} and Y_{24}, Y_{25} and Y_{27}, and Y_{29} and Y_{30} represent the dollar value of food and nonfood consumption expenditures by the subsectors, C_1, C_2 and C_3, respectively.



Consumption Component: MOD ONE
Figure 5.4

The variables Y_{25}, Y_{28}, and Y_{31} define total dollar value of income going to the three consumption subsectors. Total income to the consumption sectors equals income from wage [Y_{CP}, Y_{CD}, Y_{CG}] and nonwage sources [Y_{PC}, Y_{DC}, Y_{OC}]. Income to a consumption subsector is, obviously, only a part of total income.

Let I equal the total income received by the consumption sector. Total income is expressible as:

$$I = Y_{CP} + Y_{CD} + Y_{CG} + Y_{PC} + Y_{DC} + Y_{OC} \quad . \tag{5.27}$$

Assume that the income received by a subsector, i, is defined as some percentage, d_i, of total income. For consumer subsector C_1, the income received, Y_{25}, equals d_1 times I, or,

$$Y_{25} = d_1 I \quad . \tag{5.28}$$

For all three subsectors, the following equation describes their income:

$$\begin{bmatrix} Y_{25} \\ Y_{28} \\ Y_{31} \end{bmatrix} = \begin{bmatrix} d_1 \\ d_2 \\ d_3 \end{bmatrix} I \quad . \tag{5.29}$$

The percentage of total income to the consumption sector received by each subsector is defined in equation 5.29. How a consumption subsector disposes of this income, in terms of the purchase of food and nonfood items, remains to be stated.

At this point it is necessary to define the distinguishing characteristic between the three subsectors. Income level, defined as "high," "medium," and "low," is the characteristic used to distinguish between the subsectors. Income level is used as a surrogate to distinguish between consumers of differing average propensities to purchase food and nonfood items.

Consider consumption subsector C_1, the high income subsector. This subsector has d_1I or Y_{25} dollars worth of income. The income to the subsector is, of course, stated in terms relative to the total income, I, received by the consumption sector. Variables Y_{23} and Y_{24} represent, respectively, the dollar expenditures of the high income subsector on food and nonfood items.

Assume that subsector C_1 will spend f_1 percentage of its income on food and n_1 percentage of its income on nonfood. The parameters f_1 and n_1 are not required to sum to less than, equal to, or greater than 1; the subsector is not required to save, spend all of its income on food and nonfood items, or spend more than its income on food and nonfood items.

Equations 5.30, 5.31, and 5.32 represent the above assumptions for subsectors C_1, C_2, and C_3 respectively;

$$\begin{bmatrix} Y_{23} \\ Y_{24} \end{bmatrix} = \begin{bmatrix} f_1 \\ n_1 \end{bmatrix} d_1 I \quad , \qquad (5.30)$$

$$\begin{bmatrix} Y_{26} \\ Y_{27} \end{bmatrix} = \begin{bmatrix} f_2 \\ n_2 \end{bmatrix} d_2 I \quad , \qquad (5.31)$$

and

$$\begin{bmatrix} Y_{29} \\ Y_{30} \end{bmatrix} = \begin{bmatrix} f_3 \\ n_3 \end{bmatrix} d_3 I \quad . \tag{5.32}$$

The total dollar value of food items purchased by the consumption sector is equal to the systems variable Y_{D_1C}. The variable Y_{D_1C} is equal to the sum of Y_{23}, Y_{26}, and Y_{29}; the sum of the dollar value of food items purchased by the three consumption subsectors. Stated in equational form,

$$Y_{D_1C} = [1 \;\; 1 \;\; 1] \begin{bmatrix} Y_{23} \\ Y_{26} \\ Y_{29} \end{bmatrix} \quad . \tag{5.33}$$

The total dollar value of nonfood items purchased by the consumption sector is Y_{D_2C}, and

$$Y_{D_2C} = [1 \;\; 1 \;\; 1] \begin{bmatrix} Y_{24} \\ Y_{27} \\ Y_{30} \end{bmatrix} \quad . \tag{5.34}$$

Combining equations 5.33 and 5.34 with equations 5.30, 5.31, 5.32 yields the following equations:

$$Y_{D_1C} = (f_1 d_1 + f_2 d_2 + f_3 d_3) I \quad , \tag{5.35}$$

and

$$Y_{D_2C} = (n_1 d_1 + n_2 d_2 + n_3 d_3) I \quad . \tag{5.36}$$

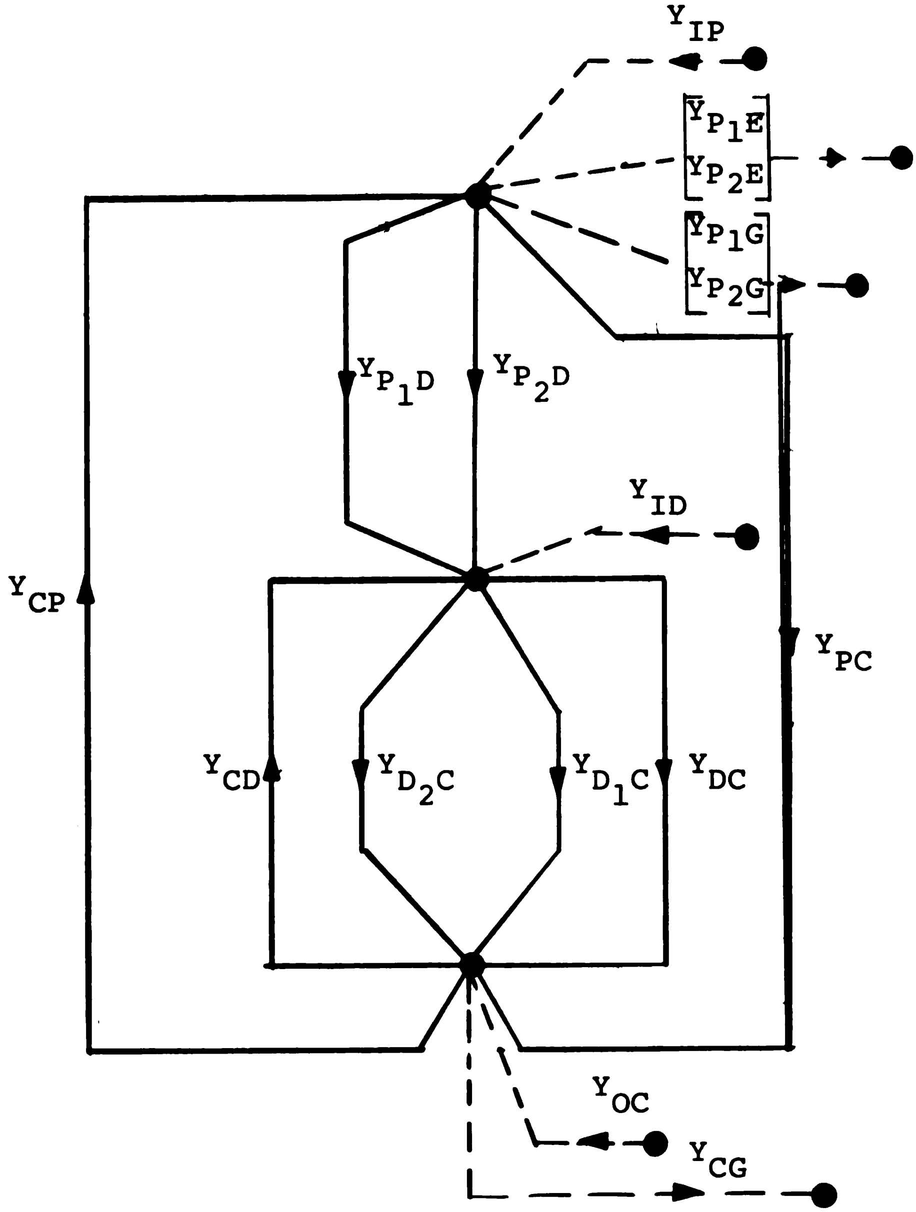
The variable I in equations 5.35 and 5.36 is simply a "shorthand" notation for the sum of six systems variables [Y_{CP}, Y_{CD}, Y_{PC}, Y_{DC}, Y_{CG}, Y_{OC}]. Without actually substituting equation 5.27 into both equation 5.35 and 5.36, equations 5.35 and 5.36 are taken as the component model of the consumption sector.

In the component model of the consumption sector, the systems variables Y_{D_1C} and Y_{D_2C} are related to systems variables in the set [Y_{CP}, Y_{CD}, Y_{PC}, Y_{DC}, Y_{CG}, Y_{OC}] using the parameters in the set [d_1, f_1, n_1, d_2, n_2, f_2, d_3, f_3, n_3]. The variables Y_{CG} and Y_{OC} are terminal variables and their values are assumed to be known.

Systems Model

The "systems graph" for MOD ONE is shown in Figure 5.5. The "edges" are shown as solid lines or broken lines; the broken lines indicate a terminal variable is associated with the edge. The broken lines connect a component with something external to the system. The system variables associated with the solid lines have been defined previously.

There are sixteen edges shown in Figure 5.5; there are sixteen flow variables defined. Of the sixteen flow variables, eight are referred to as systems variables: Y_{P_1D}, Y_{P_2D}, Y_{D_1C}, Y_{D_2C}, Y_{PC}, Y_{DC}, Y_{CP}, Y_{CD}. The remaining eight are called terminal variables. Of the eight terminal variables, all but Y_{IP} and Y_{ID} are assumed to have known values.



Systems Graph: MOD ONE
Figure 5.5

It is possible to develop equations which describe a relationship between any systems variable and some set of variables, the values of which are assumed to be known. Based upon the component models developed in the previous section the relationships existing between the eight systems variables and the known terminal variables can be determined; the developed relationship defines the systems model.

The first relationship is established for Y_{D_1C} and Y_{D_2C}; the other systems variables are expressed as functions of these two variables.

Combining equations 5.35 and 5.36 with the equation 5.27 yields:

$$\begin{bmatrix} Y_{D_1C} \\ Y_{D_2C} \end{bmatrix} = E[1\ 1] \begin{bmatrix} Y_{CP} \\ Y_{PC} \end{bmatrix} + E[1\ 1] \begin{bmatrix} Y_{CD} \\ Y_{DC} \end{bmatrix} + E[1\ 1] \begin{bmatrix} Y_{CG} \\ Y_{OC} \end{bmatrix} \qquad (5.37)$$

where

$$E = \begin{bmatrix} e_{1,1} \\ e_{2,1} \end{bmatrix} ,$$

and

$$e_{1,1} = f_1 d_1 + f_2 d_2 + f_3 d_3 ,$$

$$e_{2,1} = n_1 d_1 + n_2 d_2 + n_3 d_3 .$$

The vector containing Y_{CP} and Y_{PC} in equation 5.37 is expressed in the following form by combining equations 5.15 and 5.17:

$$\begin{bmatrix} Y_{CP} \\ Y_{PC} \end{bmatrix} = S \begin{bmatrix} Y_{P_1D} \\ Y_{P_2D} \end{bmatrix} + S \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \end{bmatrix} \begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \\ Y_{P_1G} \\ Y_{P_2G} \end{bmatrix} \qquad (5.38)$$

where S is a 2 x 2 matrix with entries;

$$s_{1,1} = \frac{a_1 + a_3 a_7}{1 - a_3 a_9} \quad ,$$

$$s_{1,2} = \frac{a_7 + a_1 a_9}{1 - a_3 a_9} \quad ,$$

$$s_{2,1} = \frac{b_4 + b_{10} a_3}{1 - a_3 a_9} \quad ,$$

and

$$s_{2,2} = \frac{b_{10} + b_4 a_9}{1 - a_3 a_9} \quad .$$

The vector containing Y_{P_1D} and Y_{P_2D} in equation 5.38 is expressed in terms of Y_{D_1C} and Y_{D_2C}; equation 5.26. An equation equal in content to equation 5.26 is repeated below:

$$\begin{bmatrix} Y_{P_1D} \\ Y_{P_2D} \end{bmatrix} = T \begin{bmatrix} Y_{D_1C} \\ Y_{D_2C} \end{bmatrix} \qquad (5.26)$$

where T is a 2 x 2 matrix with entries;

$$t_{1,1} = a_{14} \quad ,$$

$$t_{1,2} = t_{2,1} = 0.0 \quad ,$$

and

$$t_{2,2} = a_{19} \quad .$$

The vector containing the variables Y_{CD} and Y_{DC} in equation 5.37 is expressed in the following form by combining equations 5.23 and 5.25:

$$\begin{bmatrix} Y_{CD} \\ Y_{DC} \end{bmatrix} = V \begin{bmatrix} Y_{D_1C} \\ Y_{D_2C} \end{bmatrix} \qquad (5.39)$$

where V is a 2 x 2 matrix with entries;

$$v_{1,1} = a_{13} \quad ,$$

$$v_{1,2} = a_{18} \quad ,$$

$$v_{2,1} = b_{16} \quad ,$$

and

$$v_{2,2} = b_{21} \quad .$$

Substituting equation 5.26 into 5.38, and then substituting the result and equation 5.39 into equation 5.37, and rearranging terms, yields:

$$\begin{bmatrix} Y_{D_1C} \\ Y_{D_2C} \end{bmatrix} = W \begin{bmatrix} Y_{D_1C} \\ Y_{D_2C} \end{bmatrix} + X \begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \\ Y_{P_1G} \\ Y_{P_2G} \\ Y_{CG} \\ Y_{OC} \end{bmatrix} \qquad (5.40)$$

where W is a 2 x 2 matrix with entries;

$$w_{1,1} = e_1[v_{1,1} + v_{2,1} + t_{1,1}(s_{1,1} + s_{2,1})] \quad ,$$

$$w_{1,2} = e_1[n_{1,2} + n_{2,2} + t_{2,2}(s_{1,2} + s_{2,2})] \quad ,$$

$$w_{2,1} = e_2[n_{1,1} + n_{2,1} + t_{1,1}(s_{1,1} + s_{2,1})] \quad ,$$

and

$$w_{2,2} = e_2[n_{1,2} + n_{2,2} + t_{2,2}(s_{1,2} + s_{2,2})] \quad ,$$

and X is a 2 x 6 matrix with entries;

$$x_{1,1} = x_{1,3} = e_1(s_{1,1} + s_{2,1}) \quad ,$$

$$x_{1,2} = x_{1,4} = e_1(s_{1,2} + s_{2,2}) \quad ,$$

$$x_{2,1} = x_{2,3} = e_2(s_{1,1} + s_{2,1}) \quad ,$$

$$x_{2,2} = x_{2,4} = e_2(s_{1,2} + s_{2,2}) \quad ,$$

$$x_{1,5} = x_{1,6} = e_1 \quad ,$$

and

$$x_{2,5} = x_{2,6} = e_2 \quad .$$

Or,

$$\begin{bmatrix} Y_{D_1C} \\ Y_{D_2C} \end{bmatrix} = [U - W]^{-1} X \begin{bmatrix} Y_{D_1E} \\ Y_{D_2E} \\ Y_{P_1G} \\ Y_{P_2G} \\ Y_{CG} \\ Y_{OC} \end{bmatrix} \quad . \qquad (5.41)$$

Equation 5.41 uses the defined parameters to relate the variables Y_{D_1C} and Y_{D_2C} to the six defined terminal variables reported on the right side of the equation. Equation 5.41 summarizes all the previous assumptions and equations as they relate to determining the numeric values of Y_{D_1C} and Y_{D_2C}.

The six remaining systems variables are expressed first as functions of the variables Y_{D_1C} and Y_{D_2C} and then as functions of parameters and known terminal variables.

The variables Y_{P_1D} and Y_{P_2D}, for example, are related to Y_{D_1C} and Y_{D_2C} in equation 5.26. Combining equations 5.26 and 5.41 yields:

$$\begin{bmatrix} Y_{P_1D} \\ Y_{P_2D} \end{bmatrix} = T[U - W]^{-1} \times \begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \\ Y_{P_1G} \\ Y_{P_2G} \\ Y_{CG} \\ Y_{OC} \end{bmatrix} . \qquad (5.42)$$

Substituting equation 5.41 into equation 5.39 will provide a relationship between Y_{CD} and Y_{DC} and known terminal variables. Substituting equation 5.41 into equation 5.38 will relate the variables Y_{CP} and Y_{PC} to known terminal variables. The equations which result from the above substitutions are, respectively:

$$\begin{bmatrix} Y_{CD} \\ Y_{DC} \end{bmatrix} = V[U - W]^{-1} \times \begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \\ Y_{P_1G} \\ Y_{P_2G} \\ Y_{CG} \\ Y_{OC} \end{bmatrix} , \qquad (5.43$$

and

$$\begin{bmatrix} Y_{CP} \\ Y_{PC} \end{bmatrix} = ST[U - W]^{-1} X \begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \\ Y_{P_1G} \\ Y_{P_2G} \\ Y_{CG} \\ Y_{OC} \end{bmatrix} + \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \end{bmatrix} \begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \\ Y_{P_1G} \\ Y_{P_2G} \end{bmatrix} . \quad (5.44)$$

Equations 5.41, 5.42, 5.43, and 5.44 are the equations developed for MOD ONE. Each equation relates systems variables to known terminal variables using the parameters defined in the development of the component models.

Operationalization

The values of the parameters and terminal variables of MOD ONE are estimated from data concerning the economic situation in Puerto Rico in 1963. The year 1963 is chosen as the most recent census year; both the Census of Business and the Census of Manufacturers are available. Census information, coupled with other data, provides the basis for estimating the values of the parameters and terminal variables in MOD ONE.

Two basic reasons underly the effort to use "hard" data for parameter valuation. First, by estimating parameter and terminal variable values within a real data framework, consistency between the values derived for the parameters and terminal variables is possible; to simply assume some set of values would not provide this consistency. Second, parameter estimation is an important aspect of the total modeling effort; it is necessary to determine the practical problems of data collection for the class of models being developed.

It is difficult to estimate the accuracy of the parameter and terminal variable values determined for MOD ONE. The accuracy most certainly varies between parameters. Certain of the parameters and terminal variables are rather easily determined, others are estimated from more than one data source.

The method used to determine parameter and terminal variable values for MOD ONE is simple to describe. It involves first drawing a rather large diagram showing all of the component graphs of MOD ONE. Dollar values for each edge in the graphs, and thus each flow variable defined in MOD ONE are determined. Given a value for each flow variable, it is a simple task to obtain values for each parameter.

Each parameter in MOD ONE is obtained as a ratio of two defined flow variables; for example, the parameter a_{13}, associated with the distribution sector, is equal to the ratio of Y_{13} to Y_{17}, or;

$$a_{13} = \frac{Y_{13}}{Y_{17}} \quad . \tag{5.36}$$

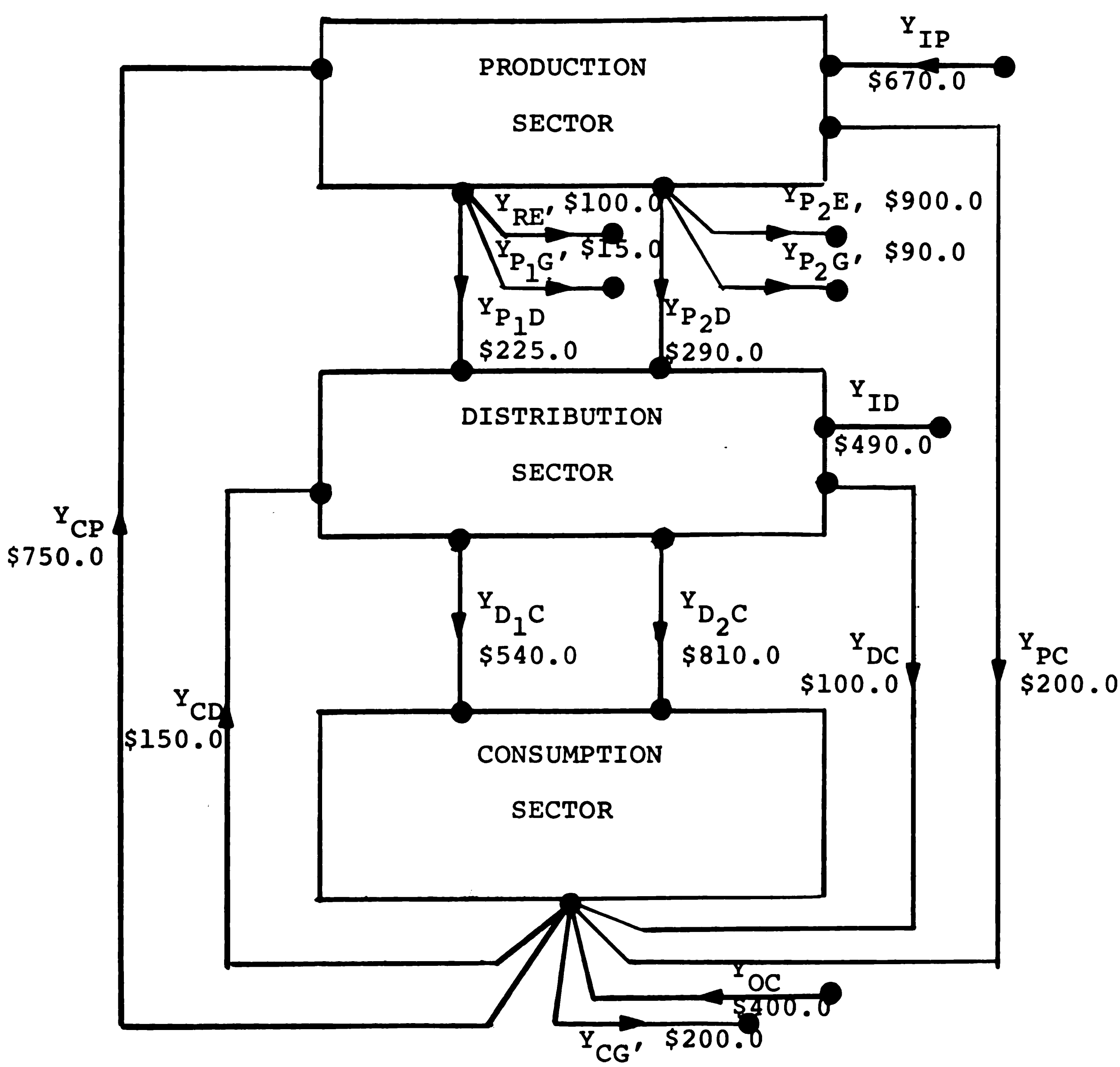
Once the values for Y_{13} and Y_{17} are estimated, it is a simple task to compute a_{13}.

Figure 5.6 records the values estimated for each system flow variable defined in MOD ONE. The values, in millions of 1963 dollars, are estimated from five basic data sources; "1963 Census of Business,"[1] "1963 Census of Manufactures,"[2] "Ingress Y Producto--1964,"[3] "Ingresos Y Gastos de Familias, Puerto Rico, 1963,"[4] and "1963 External Trade Statistics."[5] The values shown for six of the system flow variables (Y_{P_1E}, Y_{P_2E}, Y_{P_1G}, Y_{P_2G}, Y_{CG}, Y_{OC}) are the terminal variable values.

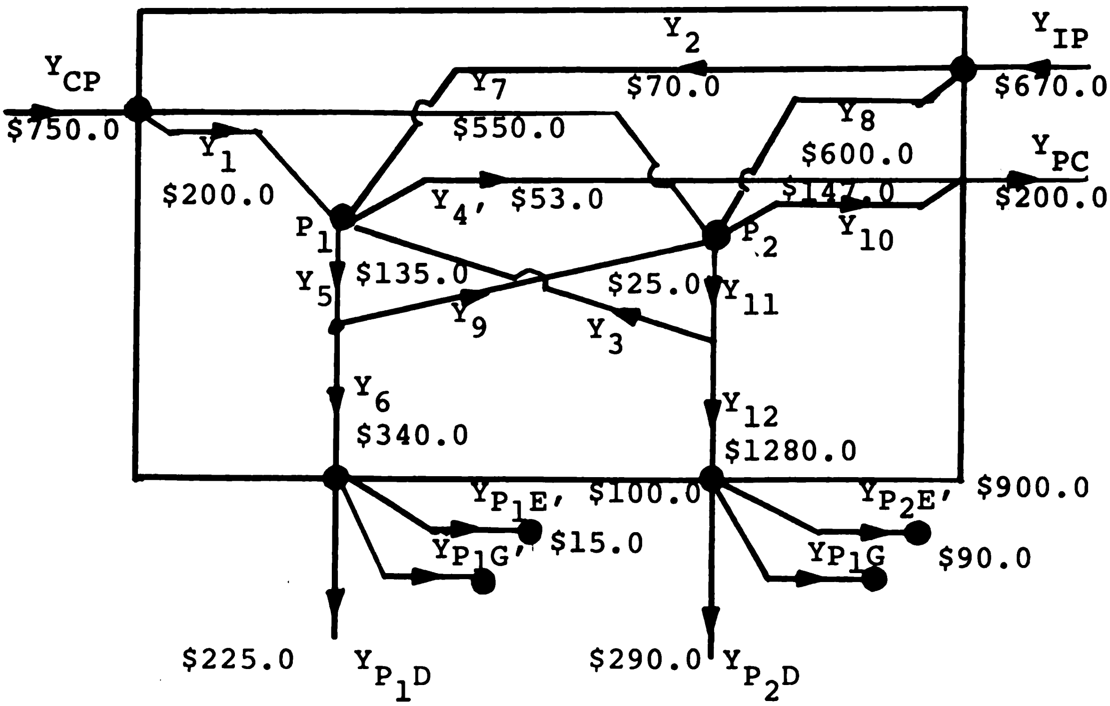
Figures 5.7, 5.8, and 5.9 record the values of the variables described in the component graphs of the production, distribution, and consumption sectors respectively.

The parameter values, all of which are unitless, shown in Table 5.1 are derived from the values shown in the three previous figures; the actual ratios used can be determined by reviewing the equations used to develop the component models.

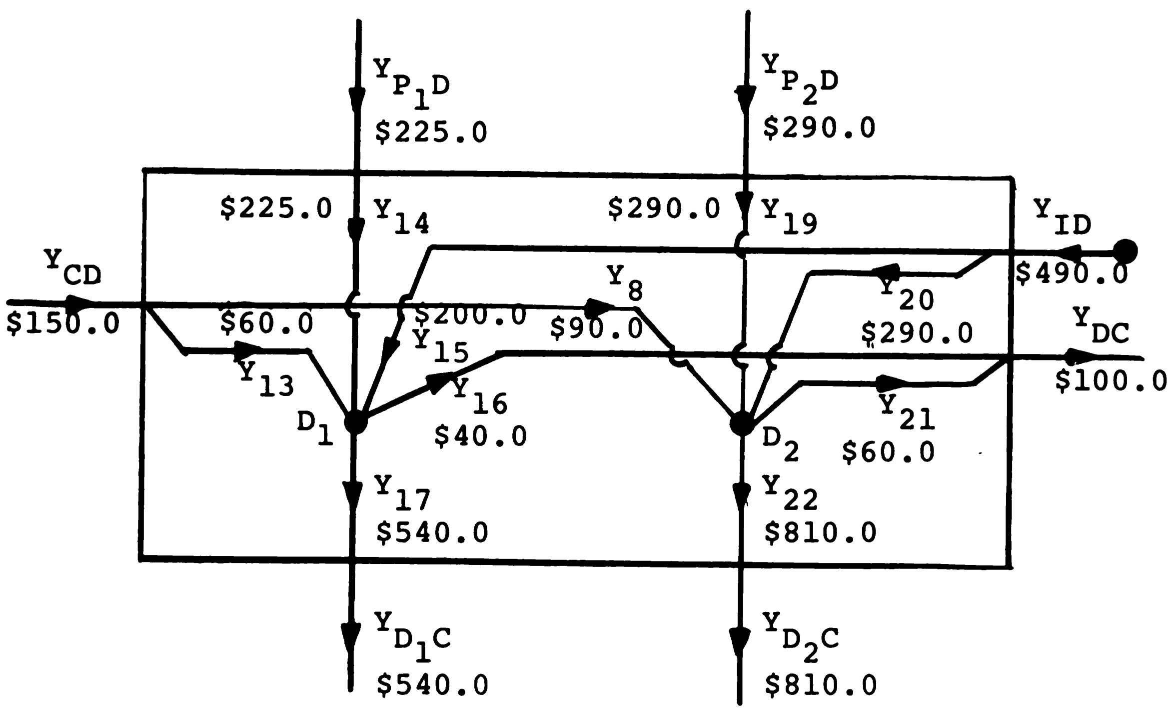
The data sources used to develop parameter estimates reported information in terms not always consistent with that sought nor with each other. Since only one value can be used for a defined variable, it is necessary to balance estimates to arrive at a compromise estimate of the variables of the model.



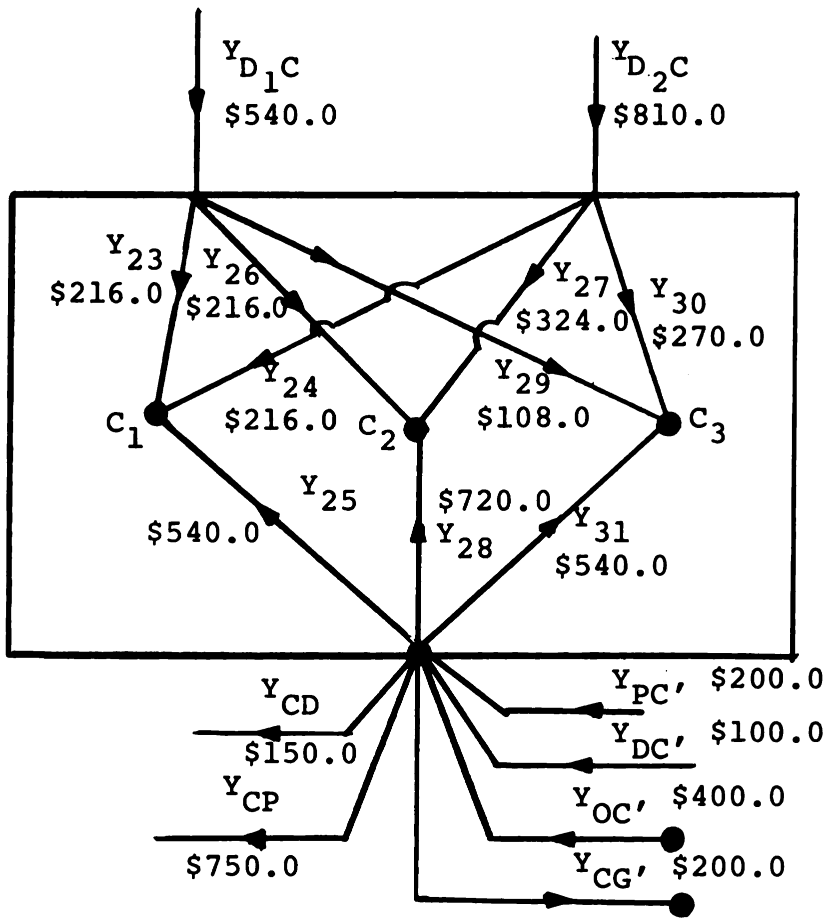
Estimated System Variable Values: MOD ONE
(Dollars in Millions)
Figure 5.6



Estimated Variable Values: MOD ONE, Production Sector
(Dollars in Millions)
Figure 5.7



Estimated Variable Values: MOD ONE, Distribution Sector
(Dollars in Millions)
Figure 5.8



Estimated Variable Values: MOD ONE, Consumption Sector
(Dollars in Millions)
Figure 5.9

Table 5.1--Parameter values: MOD ONE.

Production Sector		
a_1 = 0.421	a_3 = 0.053	b_4 = 0.112
a_7 = 0.421	a_9 = 0.103	b_{10} = 0.113
Distribution Sector		
a_{13} = 0.111	a_{14} = 0.375	b_{16} = 0.074
a_{18} = 0.111	a_{19} = 0.358	b_{21} = 0.074
Consumption Sector		
d_1 = 0.30	f_1 = 0.40	n_1 = 0.40
d_2 = 0.40	f_2 = 0.30	n_2 = 0.45
d_3 = 0.30	f_3 = 0.20	n_3 = 0.50

Some of the values for the defined flow variables may be estimated in a fairly direct manner. The value of imports into Puerto Rico in 1963 are reported as $1,195.7 million: $671.1 million are classed as raw materials, intermediate goods, and capital goods, and $488.6 million as consumer goods.[6] Assuming that raw materials, intermediate goods, and capital goods are used by the production sector, the values of Y_{IP} and Y_{ID} are approximated as $670.0 and $490.0 million respectively.

Of the $488.6 million in consumer goods imports, $201.1 million are classed as food, and the balance, $287.5 million, as nonfood.[7] Nonfood items included autos ($43.3), electrical appliances ($35.4), other consumer durables ($35.6), alcohol and tobacco ($19.0), and other consumer nondurables ($154.2). The values of Y_{15}, food imports to distribution, and Y_{20}, nonfood imports to diskribution are approximated as $200.0 million and $290.0 million respectively.[8]

Splitting $670.0 million worth of imports between the two production subsectors presents a more difficult task since the destination of imports are not reported.

The definition used for the food production subsector is such that it would include what is normally thought of as the agricultural sector and a portion of the "food and kindred products" classification of the manufacturing sector (S.I.C. code 20). The manufacturing concerns included within the food production subsector are meat processing plants (S.I.C. 201), dairies (S.I.C. 202), canning plants (S.I.C. 203), grain mills (S.I.C. 204), bakery plants (S.I.C. 205), candy plants (S.I.C. 207), and miscellaneous foods and kindred products (S.I.C. 209). Excluded from the food production subsector, yet contained within the food and kindred products classification of the manufacturing sector are sugar refining and alcoholic beverage plants; this exclusion is made to match the commodity classifications used in both the distribution and consumption sectors of the model.

By scanning the import data, an approximate value of $70.0 million is assigned to the food production subsector.[9] Included in this estimate are the import values of such items as unmilled rice ($26.9), fodders and feeds ($6.8), agricultural machinery ($1.7), and fertilizers

($2.4). The values of Y_2 and Y_8 are approximated as $70.0 million and $600.0 million respectively.

Determining the values for the parameters associated with the consumption sector involves the use of many sources of data. The first estimates of parameter values for the consumption sector are derived from data on consumption and income patterns obtained in a 2,648 household survey conducted by the Department of Labor of Puerto Rico; the data was collected in 1964 and covered income and expenditure information for all of 1963.[10]

Reported data is regrouped into income classifications of high ($7,500 and over per year), medium ($3,000 to $7,499), and low (less than $3,000) income per family.[11] Income distribution percentages are obtained by summing the reported incomes (average family income times the number of families) within the three income ranges and dividing by the total income (average family income for all families times the total number of families). Income distributions (d_1, d_2, and d_3) for the high, medium, and low income categories are computed as 28.7%, 39.9%, and 31.4% respectively.

For determining the percentages of total income by income group spent on food and on nonfood, the reported expenditure data by income group is used.[12] The value of total food expenditures for each income group is determined and that value divided by the total income computed for the income group. The percentages of income spent on food

(f_1, f_2, and f_3) for the three income groups are computed as 21.0%, 31.1%, and 43% for the high, medium, and low income groups respectively.

The percentage of income spent on nonfood by income group is obtained by first summing expenditures on selected nonfood items for each income group and then dividing by the total income for the income group. Nonfood expenditures included expenditures on items defined in the study as clothing, housefurnishings, transportation, alcoholic beverages and tobacco, personal care, and recreation. The percentages of income spent on nonfood items (n_1, n_2, and n_3) for the high, medium, and low income groups are computed as 43.2%, 42.3%, and 36.1% respectively.

To arrive at the values for the consumption sector parameters actually used in MOD ONE requires introducing values determined for Y_{D_1C}, Y_{D_2C}, and I; Y_{D_1C} is the value of food consumer, Y_{D_2C} is the value of nonfood items consumed, and I is total income.

For a given value of I, the values of the nine parameters for the consumption sector dictate what the values of Y_{D_1C} and Y_{D_2C} will be; equation 5.36 is a mathematical statement of this relationship. It is important to note that a change in the value of any of the three income distribution parameters or the six percentage expenditure parameters alters the relationship between Y_{D_1C} and and Y_{D_2C} and total income, I. Shifting a higher percentage of income to the lower income group will, for example, increase food consumption as a percentage of total income since the lower income group expends a relatively higher percentage of its income on food. Determining the values for Y_{D_1C}, Y_{D_2C} and total income, and the nine consumption sector parameters must thus be done simultaneously to arrive at the desired balance.

Three data sources are used to obtain estimates of income and food and nonfood consumption levels. The survey data described above on income and expenditure provides one source, the Census of Business and the Census of Manufacturers combines to provide a second, and Ingreso Y Producto a third source.

In Ingreso Y Producto, food consumption expenditures are reported as $498.7 million for 1963. Nonfood expenditures, including expenditures on alcoholic beverages and tobacco, clothing and accessories, personal care, household operations, transportation, and recreation, equaled $1,018.4 million.[13] Ingreso Y Producto reported income as $1,927.0 million.[14]

Using the income distribution and consumption expenditures parameters obtained from the survey data and the value of $1,927.0, values of $619.0 and $782.6 million respectively for food and nonfood consumption, Y_{D_1C} and Y_{D_2C}, are obtained.

The census information from businesses and manufacturers can also be used to obtain approximate values of Y_{D_1C} and Y_{D_2C}. Retail sales of food stores and eating and drinking places to the general public are reported as $391.1 million.[15] Withdrawals by the owners of these establishments are reported as $15.7 million.[16] Wholesalers in the groceries and related products trade reported selling $11.9 million to the general public and withdrawing $0.2 million for personal use.[17,18] The manufacturers in the food and kindred products classification, defined previously as part of the food production subsector, reported to have sold $32.2 million directly to consumers.[19] By summing, a value of sales equal to $451.1 million is obtained. Although some nonfood sales are included, the estimate of $451.1 million is used to approximate food sales; it does not include the value of sales of agricultural products not sold through those firms reporting in either census.

By subtracting the above estimate of $451.1 for Y_{D_1C} from the total reported sales and withdrawals for manufacturers, wholesalers, and retailers of $1,241.5 million, an estimate of $790.4 million for Y_{D_2C} of nonfood items reported as sales to consumers is obtained.[20]

Estimates arrived at from the Department of Labor survey are $1,508.8 million for income, $494.9 for food expenditures, and $611.1 for expenditures on the selected nonfood items.[21]

Each of the above sources provide different values for Y_{D_1C}, Y_{D_2C}, and I. It is necessary to obtain a workable balance between these figures and the values for the nine parameters as obtained from the survey material. The values of Y_{D_1C} and Y_{D_1C} actually used are \$540.0 million and \$810.0 million respectively with a value of \$1,800.0 million for income. The percentages of income spent on food and upon the specified nonfood items are thus 30% and 45% respectively; the income distribution values and the percentage expenditure values by income groups as reported in Table 5.1 combine to yield these two percentages.

The values for the terminal variables Y_{CG} and Y_{OC} are obtained from information in Ingreso Y Producto. The government is reported to have compensated employees \$244.5 million;[22] the value for Y_{CG} is estimated as \$200.0 million. The value of other income sources is computed as \$445.1 million;[23] this would include wage income from households and nonprofit institutions (\$45.3 million), wage income from the "rest of world" (\$114.0 million), transfer payments (\$260.8 million), rent income (\$101.4 million), minus contributions to social insurance (\$48.3 million). The value for Y_{OC} is estimated as \$400.0 million.

The Census of Business reports an annual payroll of \$150.5 million for wholesale and retail firms.[24] This value is taken as an approximation of Y_{CD}. The total wage bill is split in direct proportion to the estimated throughput

($540.0 and $810.0 million) of the two distribution subsectors and the values for Y_{13} and Y_{18} computed.

The Census of Manufacturers reports sales to wholesalers and retailers of $287.2 million;[25] this value excludes sales to wholesalers and retailers of the previously defined food and kindred product group classified within the food production subsector. The value of Y_{P_2D}, and thus Y_{19}, is estimated as $290.0 million.

The food and kindred product subgroup from the Census of Manufacturers defined within the food production subsector reported sales to wholesalers and retailers of approximately $126.1 million.[26] An approximate value of $100.0 million represents agricultural value to distribution. The $100.0 million estimate is derived by subtracting an estimated $135.0 million and $48.0 million from a $293.0 million estimate of agricultural output valuation;[27] the $125.0 million is for sugar cane, tobacco, and coffee which is assumed to move to the nonfood production sector and the $48.0 million is for the reported value of agricultural exports excluding sugar, molasses, alcohol, and malt beverages.[28,29] The sum of $126.1 and $100.0 is used to obtain an estimated value of $225.0 million for Y_{P_1D} and thus Y_{14}.

The values for Y_{16} and Y_{21} are most difficult to estimate. Ingreso Y Producto reports $326.4 million in income generated by unincorporated business profit, partnerships, and dividends;[30] no indication of source is given.

On an arbitrary basis, \$200.0 is estimated as generated from within the production sector and \$100.0 from within the distribution sector.

The \$100.0 million valuation for Y_{DC} is split between the food and nonfood distribution subsectors on a proportional basis to total sales; Y_{D_1C} and Y_{D_2C}. The values for Y_{16} and Y_{21} are estimated as \$40.0 and \$60.0 million respectively.

Four of the six terminal variables of MOD ONE are associated with the production sector; Y_{P_1E}, Y_{P_1G}, Y_{P_2E}, and Y_{P_2G}. The estimated values for Y_{P_1G} and Y_{P_2G}, \$15.0 million and \$90.0 million, are obtained from the reported sales to the government and "other" in both the Census of Business and the Census Manufactures. Reported sales of \$8.3 million and \$7.4 million to the government are obtained from these two sources for food; \$64.5 million and \$32.3 million are reported for nonfood sales.[31,32]

The estimated value of food exports, Y_{P_1E}, is \$100.0 million; this value is estimated from a reported export value of \$48.3 million for certain agricultural products and \$54.5 million in reported value of exports from the food industries in the Census of Manufacturers.[33,34] The estimated value of nonfood exports, Y_{P_2E}, is \$900.0 million; this value is estimated from \$168.8 million reported value of exported sugar and alcoholic beverages and

\$742.2 million which is reported as export from manufacturers in the Census of Manufacturers.[35,36]

By definition, the value for Y_6 is the sum of Y_{P_1D}, Y_{P_1G}, and Y_{P_1E} and the value of Y_{12} is the sum of Y_{P_2D}, Y_{P_2G}, and Y_{P_2E}. The values for Y_6 and Y_{12} are thus \$340.0 and \$1280.0 million respectively.

The value for Y_5, \$475.0 million, is the sum of Y_6 and Y_9. Considering only the value of the principle crops of sugar cane, tobacco, and coffee, Y_9 is estimated as \$135.0 million.[37] The value for Y_{11}, \$1,305 million, is the sum of Y_{12} and Y_3. The value Y_3, \$25.0 million, is approximated from the product of the ratio of purchases of the agricultural sector from all other sectors to the total sales of the agricultural sector as reported in the 1963 Input-Output Table and the value of Y_5.[38]

Total wages reported by the productive sectors of the economy, excluding that generated by the trade or distribution sector, is reported in Ingreso Y Producto as \$799.0 million.[39] Summing the value of wages as reported in the Census of Manufacturers, wages reported by service industries within the Census of Business, and the reported wages of the agricultural, construction and mining, transportation, and financial sectors as reported in Ingreso Y Producto yields \$619.1 million.[40,41,42] The value of \$750.0 million is used for Y_{CP}. Split in direct proportion to the total output of the food production subsector and the nonfood production subsector yields approximate values of \$200.0 and \$550.0 million for Y_1 and Y_2 respectively.

In a written description of the approach used to arrive at values for the flow variables of MOD ONE it is most important to stress the fact that no single source nor any rigid sequence of steps is used to arrive at an estimated value for a variable. Values are sought from source documents, rounded, altered, and balanced against each other to arrive at a relatively consistent and balanced set of values for the flow variables. With better data, better estimates of the defined variables can be made and more accurate parameters computed. The values estimated above are thought to be accurate enough for the purpose of testing the model and for providing values which are consistent with each other even if any single value is in error in absolute terms.

A computer program is written to solve for the values of Y_{D_1C} and Y_{D_2C} as a function of the values of the terminal variables and parameters as expressed in equation 5.40. With the computer program and the set of reference values for the terminal variables and parameters the model is considered operational.

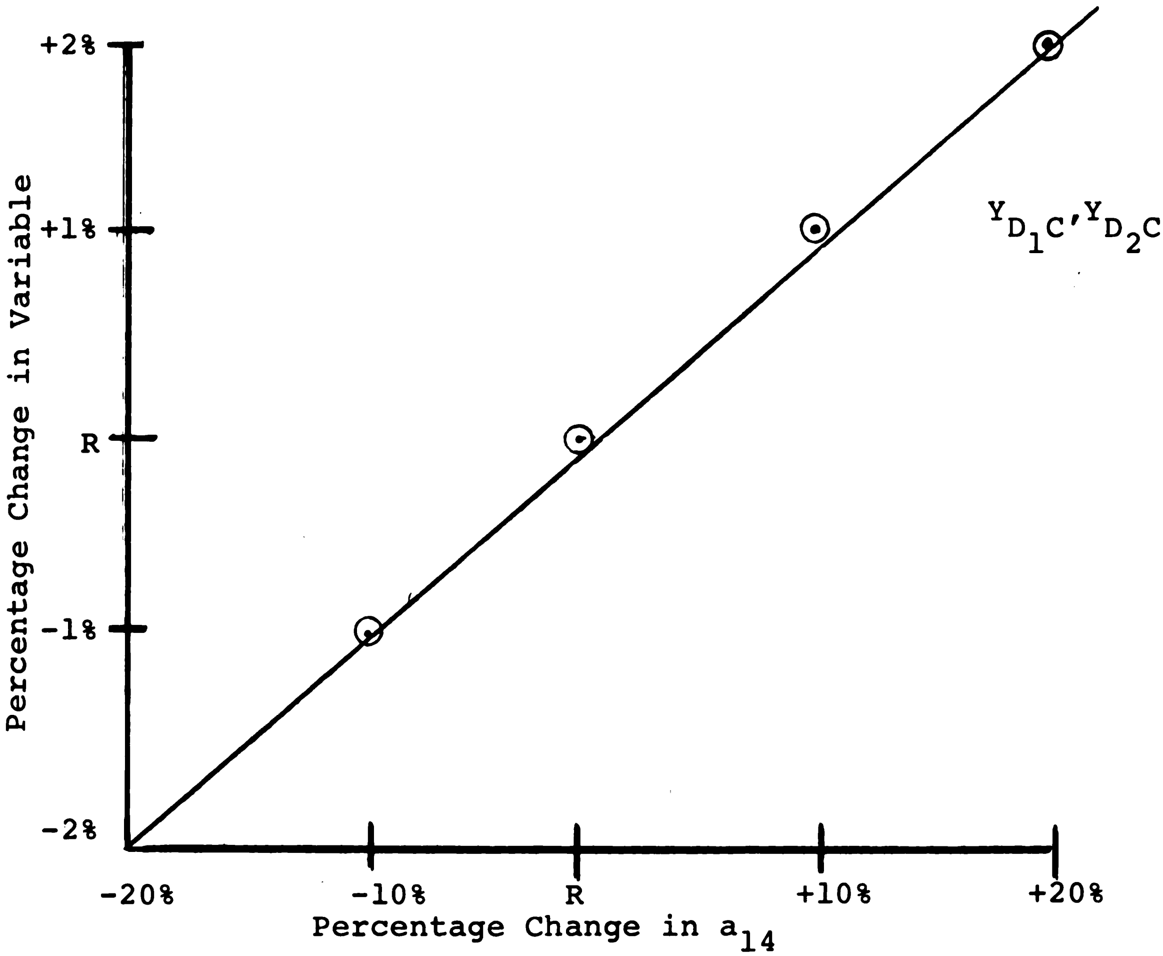
Testing

To test the responses of MOD ONE, the value of a parameter associated with the distribution sector is altered and the effect of this alteration traced in terms of the changes in the values of the variables Y_{D_1C} and Y_{D_2C}.

The object of this analysis is to record the model's reactions, in terms of changes in the level of consumption of food, Y_{D_1C}, and nonfood, Y_{D_2C}, when a change is made in the value of a_{14}. The parameter a_{14} defines the dollar value of food required from the production sector for each dollar of food which moves into the consumption sector from the distribution sector. For this test it is not necessary to conceive of some marketing related problem being studied with the alteration of the value of a_{14}; the test is designed simply for demonstration.

Graph 5.1 shows the percentage increases and decreases from the reference values of both Y_{D_1C} and Y_{D_2C} as they relate to different percentage changes in the value of a_{14}. The reference value of a_{14}, 0.417, is increased by 20% in increments of 10% and decreased by 20% in increments of 10%; all other parameters and the terminal variables are held equal to their reference values.

In Graph 5.1, a line is drawn to connect the values recorded for the percentage changes in Y_{D_1C} and Y_{D_2C}. Table 5.2 records the absolute values for Y_{D_1C}, Y_{D_2C}, and a_{14}.



Graph 5.1 Sensitivity Analysis: a_{14}, MOD ONE

Table 5.2--Sensitivity Analysis: a_{14}, MOD ONE

Y_{D_1C}[1]	551.2	545.5	540.0	534.6	529.3
Y_{D_2C}[1]	826.8	818.3	810.0	801.9	793.9
a_{14}[2]	0.500	0.458	0.417	0.375	0.333

[1]Millions of dollars (1963).

[2]Unitless

The line in Graph 5.1 has a positive slope; the greater the slope of the line, the more "sensitive" or responsive the variable is to the parameter whose value is being varied. A perfectly horizontal line would indicate that the variable is uneffected by changes in the value of the parameter.

As noted, the line labeled Y_{D_1C} and Y_{D_2C} in Graph 5.1 has a positive slope. As the value of a_{14} is increased, increasing the dollar value input of food from production required per dollar of output of food, the level of consumption of both food and nonfood items increases; in MOD ONE the percentage increases are identical.

It is important to understand why MOD ONE responds as indicated in Graph 5.1. Explaining the reaction of MOD ONE to a change in the value of a_{14} is most easily accomplished if the fact that the model is a set of simultaneous equations is ignored. To understand the reaction, conceive of some initial set of values for the parameters, terminal variables, and systems variables of MOD ONE and then consider the reaction to a change in the value of one parameter.

Consider the case where the value of the parameter a_{14} is reduced. For the original value recorded for Y_{D_1C}, a lower value for a_{14} would require a lower value for Y_{P_1D}. This means that if the ratio between the dollar value of food consumed, Y_{D_1C}, and the dollar value required from production, Y_{P_1D}, is reduced, less Y_{P_1D} is required for any value of Y_{D_1C}.

When the value of Y_{P_1D} is reduced, the values of Y_{CP} and Y_{PC} are reduced according to the assumptions of the model; less labor is required and less nonwage income is generated with a lower dollar value output of the food production subsector.

Since both the wage and nonwage income generated by the production sector are reduced, all three consumer subsectors are able to spend less money on food and nonfood items. The reduction in both Y_{D_1C} and Y_{D_2C} caused by the income reduction would cause further reductions of the types described above since less demand would lower output and thus income. Given the assumptions used to construct the model, the responses as recorded in Graph 5.1 are logical; reductions in a_{14} reduce the values of Y_{D_1C} and Y_{D_2C} while increases in a_{14} would increase the values of Y_{D_1C} and Y_{D_2C}. Since the values of Y_{D_1C} and Y_{D_2C} are described as fixed percentages of income, the percentage changes in their values should be identical.

It is of course possible to record the values of any or all of the eight systems variables under an endless variety of conditions; the values of any or all of the twenty-five parameters and six terminal variables could be altered in innumerable ways. Only one test, altering the value of a_{14}, is reported for MOD ONE.

Conclusions

Each of the defined sectors of MOD ONE, production, distribution, and consumption are linked through the exchange of economic goods of various types. The measurement term used to record the movement of these economic goods is dollar value.

Each of the component models of the defined sectors are developed from assumptions about how the inputs and outputs of that economic sector, as measured in dollar value, are related. Assumptions about the relationships are, of course, conditioned by the definition of the measurement term.

The response of MOD ONE to a change in the value of a parameter of the distribution sector was perhaps anticipated by some. The parameter altered, a_{14}, is defined as the ratio of the dollar value of food inputs to the food distribution subsector from production and the output of the food distribution subsector to consumption. Since labor inputs, and thus wages, are positively tied to the magnitude of a system flow variable, reducing a parameter such as a_{14} can result in no other condition than a decline in all values for the system flow variables given that all other parameter values are held constant.

Both the variable recording the dollar value of food from production to distribution, $Y_{P\,D_1}$ or Y_{14}, and from distribution to consumption, Y_{D_1C} or Y_{17}, are the products of per unit prices and unit volumes; a reduction in a_{14}, reducing Y_{P_1D} relative to Y_{D_1C}, could result from a variety of changes in the relative values of these prices per unit and unit volumes.

Until these components of dollar value, price per unit and unit volume, are explicitly defined in the model, responses by other sectors to certain changes within distribution cannot be studied effectively. For example, a change within distribution affecting the price of food output which, in turn, could affect unit flow volume due to consumer demand changes cannot be studied using the flow variable as defined in MOD ONE.

In MOD TWO, the model developed in the next chapter, the definition of the system variable measurement units associated with the distribution and consumption sectors are altered. By defining both unit and price per unit terms, technical relationships and price-quantity relationships can be studied.

The basic value of MOD ONE, and the reason for its inclusion in this theses, is its ability to demonstrate two aspects of the modeling approach being tested. First, MOD ONE demonstrates the methodology; from the definition of model structure to the testing of the model on a computer with parameters estimated from source data on a socio-economic system. Second, MOD ONE demonstrates the modeling approach;

when considered with MOD TWO the concept of building one model upon the framework of another is clearly shown.

CHAPTER VI

MARKETING MODELS: MOD TWO

Introduction

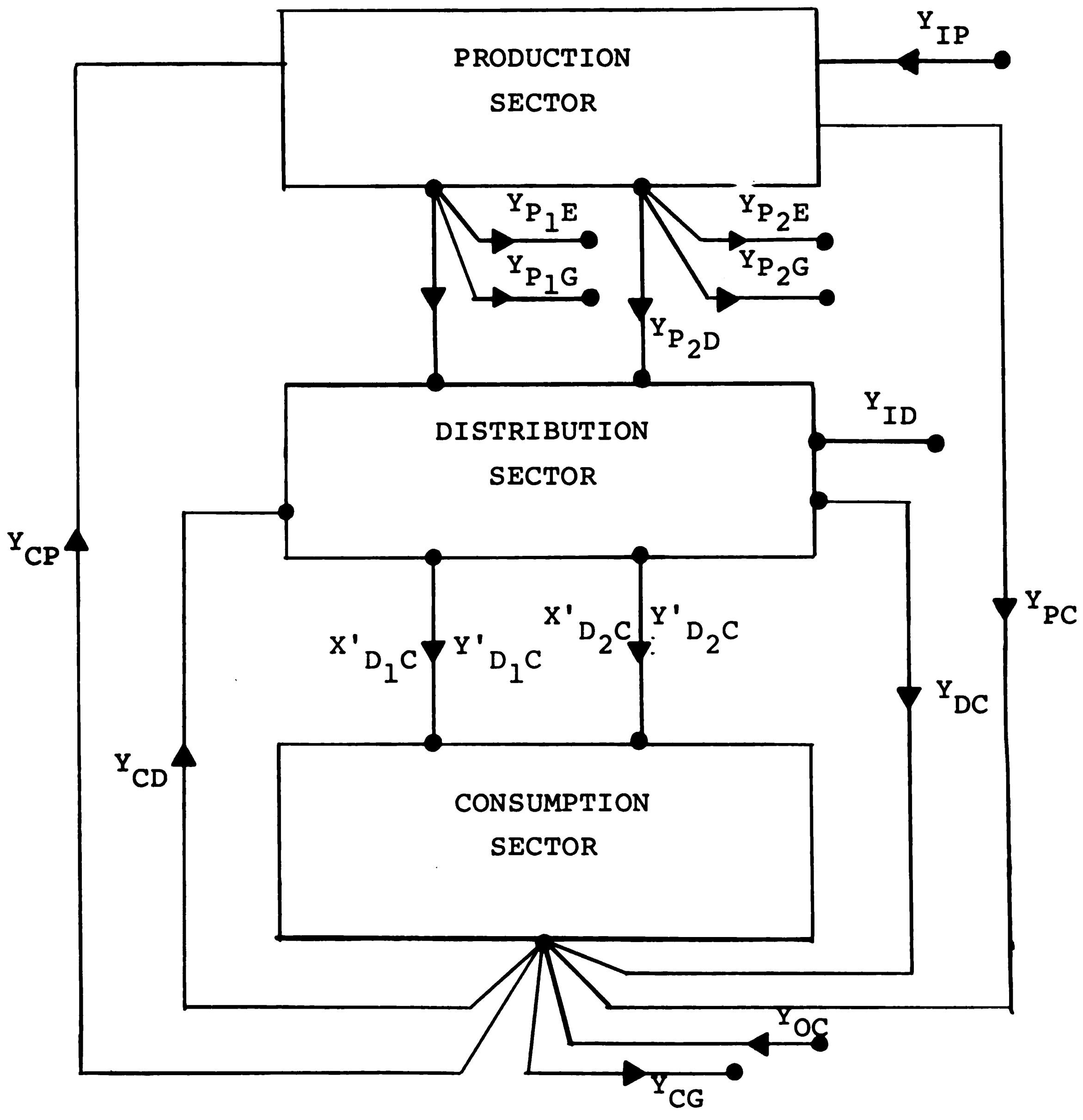
The second systems model developed in this thesis, MOD TWO, is presented in this chapter. The component model of the production sector of MOD TWO is identical to that developed in the previous chapter for MOD ONE.

The need to deal with the reaction of the consumption sector to price changes in food and nonfood items has lead to a redefinition of a subset of the system variables as used in MOD ONE. Altering the definition of these variables has allowed a new set of assumptions to be used in developing the component models of the distribution and consumption sectors. The altered component models result, of course, in the development of a new systems model.

Mod Two

Structure

MOD TWO defines the same three basic economic sectors as does MOD one: production, distribution, and consumption. Figure 6.1 describes the pattern of interconnection for these three sectors; the same pattern of interconnection as used in MOD ONE.



Model Structure: MOD TWO
Figure 6.1

A comparison of Figures 5.1 and 6.1 would reveal few differences. The only difference, apparent at this stage, are in the labels used for the flow and propensity variables associated with the edges connecting the distribution and consumption sectors. In Figure 5.1, the variables Y_{D_1C} and Y_{D_2C} are used; in Figure 6.1, the variables X'_{D_1C} and Y'_{D_1C}, and X'_{D_2C} and Y'_{D_2C} are used.

In MOD ONE, the variables Y_{D_1C} and Y_{D_2C} represent the annual 1963 dollar value "flow" of food and nonfood items from the distribution sector to the consumption sector. The variables X_{D_1C} and X_{D_2C} are assumed equal to one, defined as price indicies, and not shown in the model structure diagram.

In MOD TWO, the variables Y'_{D_1C} and Y'_{D_2C} represent, respectively, the annual unit "flow" of food and nonfood items from the distribution sector to the consumption sector. The variables X'_{D_1C} and X'_{D_2C} are 1963 price per unit measures of the Y'_{D_1C} and Y'_{D_2C} units, respectively.

There is, of course, a rather obvious relationship between the two sets of system variables defined above. The product of X'_{D_1C} and Y'_{D_1D} equals Y_{D_1C} since X_{D_1C} equals one; in 1963 the price index equal one and X'_{D_1C} is defined in 1963 prices.

Simply defining Y'_{D_1C} or Y'_{D_2C} as an annual flow of physical unit does not make it an operationally defined variable. The variable Y'_{D_1C} could, for example, be defined as pounds per year or tons per year. The complimentary variable, X'_{D_1C}, would be defined as 1963 dollars per pound or per ton depending upon which unit measure were chosen for Y'_{D_1C}. The use of such unit terms as pounds would be satisfactory if the variable Y'_{D_1C} were measuring some single item or group of similar items; this is, of course, not the case since Y'_{D_1C} measures all types of food items.

When more than one item is explicitly identified with an edge, the systems variable is treated as a vector. Assume for the moment that Y'_{D_1C} is a vector; an entry in Y'_{D_1C} is Y'_i, where i = 1, j and j equals the number of food items explicitly defined.

An entry Y'_i could represent beef and measure its flow in pounds, it could represent eggs and measure its flow in dozens, or it could represent milk and measure its flow in quarts. The complimentary variable X'_i would record 1963 price per pound, or per dozen, or per quart.

Dealing with a vector definition of Y'_{D_1C} makes it easy to visualize the measurement units for the flow and propensity variables. Actually using a vector definition in MOD TWO would, however, introduce two problems which need to be recognized: mathematical complexity resulting from dealing at such a disaggregated level, and parameter evaluation problems which would result by the great increase in component parameters required to model a sector with vector inputs.

While a vector measure presents certain problems, using a scalar definition for the flow and propensity variables is not without its own problem. The Y'_{D_1C} variable in scalar terms represents the flow of a wide variety of food items whose normal units of measure are pounds, dozens, quarts, cans, and cases. The X'_{D_1C} variable represents the price per "unit" of an assortment of items which differ in measurement units and unit prices.

Working with vector measures would raise, in the opinion of the author, more problems in terms of mathematical complexity and parameter evaluation than in justifiable at this stage. Defining the system variables in scalar terms, using price per unit and unit flow measures, is a compromise which balances the gains and losses. Additional problems associated with the new definitions of these system variables are treated when the parameters of MOD TWO are estimated.

Except for the change in the definitions of certain systems variables, the structure of MOD TWO is the same as that described for MOD ONE. The production sector has two subsectors producing food or nonfood items. The distribution sector has two subsectors engaged in the distribution of food or nonfood items. The consumption sector has three subsectors identified as three different types of consumers. The same inputs to and outputs from the defined sectors and subsectors are as in MOD ONE.

While the model structure of MOD TWO has been repeatedly compared to MOD ONE it should not be assumed that the systems models developed from similar structures behave in a similar manner. It is not, in fact, until the component models are developed that the differences between MOD TWO and MOD ONE become apparent.

Component Models

Production Sector

The component model of the production sector of MOD TWO is the same as that used in MOD ONE. For convenience, the component model is repeated below in the form of equations 6.1, 6.2, and 6.3.

$$Y_{CP} = P\begin{bmatrix} Y_{P_1D} \\ Y_{P_2D} \end{bmatrix} + P\begin{bmatrix} Y_{P_1G} \\ Y_{P_2G} \end{bmatrix} + P\begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \end{bmatrix}, \qquad (6.1)$$

$$Y_{IP} = Q\begin{bmatrix} Y_{P_1D} \\ Y_{P_2D} \end{bmatrix} + Q\begin{bmatrix} Y_{P_1G} \\ Y_{P_2G} \end{bmatrix} + Q\begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \end{bmatrix}, \qquad (6.2)$$

and

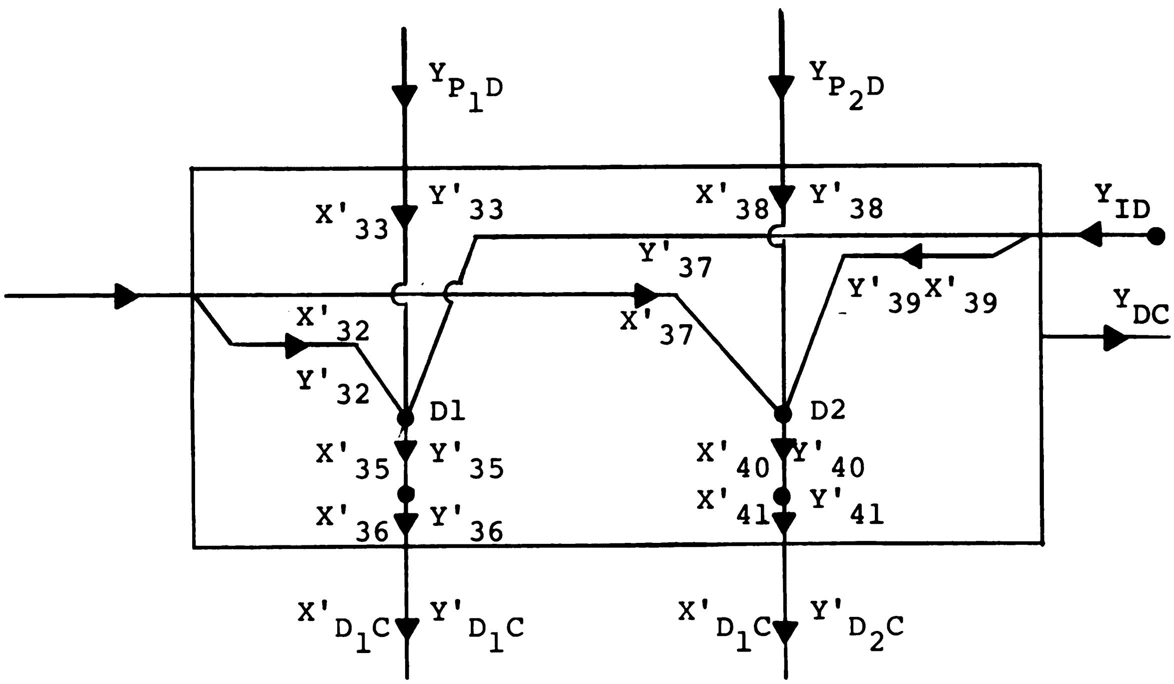
$$Y_{PC} = R\begin{bmatrix} Y_{P_1D} \\ Y_{P_2D} \end{bmatrix} + R\begin{bmatrix} Y_{P_1G} \\ Y_{P_2G} \end{bmatrix} + R\begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \end{bmatrix}. \qquad (6.3)$$

where the entries in P, Q, and R are as defined in the previous chapter.

The variables Y_{CP}, Y_{IP}, and Y_{PC} are expressed as functions of the variables Y_{P_1D}, Y_{P_2D}, Y_{P_1G}, Y_{P_2H}, Y_{P_1E}, and Y_{P_2E}. The parameters in the set $[a_1, a_2, a_3, a_7, a_8, a_9, b_4, b_{10}]$ are as previously defined. As before, the terminal variables Y_{P_1G}, Y_{P_2G}, Y_{P_1E}, Y_{P_2E} are assumed to have known values.

Distribution Sector

Figure 6.2 is the component graph of the distribution sector of MOD TWO. The convention used to label internal edges is as in the previous chapter. The numbering of edges begins as 32 to avoid confusion with MOD ONE.



Distribution Sector: MOD TWO
Figure 6.2

The component model of the distribution sector will relate the variables in the set $[Y_{CD}, Y_{P_1D}, Y_{P_2D}, Y_{ID}, Y_{DC}]$ to Y'_{D_1C} and Y'_{D_2C}. The variables X'_{D_1C} and X'_{D_2C} will be expressed as functions of the propensity variables shown internal to the sector.

The variables defined in Figure 6.2 should be clear. Each Y' variable is measuring, in physical units, the flow of an item associated with some edge. Y'_{33} and Y'_{38} represent the physical units food and nonfood items moving from the production sector to the distribution sector. Y'_{32} and Y'_{37} measure the units of labor employed in the distribution of food and nonfood items. Y'_{34} and Y'_{39} measure the units of food items and nonfood items entering the distribution sector from other socio-economic systems. Variables Y'_{35} and Y'_{36} are equal and measure the total unit output of the food distribution subsector. Similarly, variables Y'_{40} and Y'_{41} are equal and measure the total unit output of the nonfood distribution subsector.

There are no internal edges shown connecting with the terminal marked Y_{DC}. The variable Y_{DC} represents the 1963 dollar value of nonwage income generated for the consumption sector. An expression relating this variable to variables X'_{D_1C}, Y'_{D_1C}, X'_{D_2C}, and Y'_{D_2C} is given below.

The propensity variables X'_{32}, X'_{33}, X'_{34}, X'_{37}, X'_{37}, and X'_{39} are in terms of 1963 dollar per unit. If, for example, Y'_{32} were reported in man-hour units, X'_{32} would be in 1963 dollars per man-hour.

Variables X'_{35} and X'_{40} represent the "imputed cost" per unit of food or nonfood item. How these "imputed costs" are derived is explained below. Variables X'_{36} and X'_{41} represent the value per unit added to the imputed cost to arrive at the price per unit of food or nonfood item at exit from the distribution sector.

The component model of the distribution sector is based upon assumptions concerning the relationships between the defined variables.

Assume that the number of physical units of the inputs to the food distribution subsector, Y'_{32}, Y'_{33} and Y'_{34}, are related to the number of physical units of output of that subsector, Y'_{35}, as shown in equation 6.4. The equation states that the inputs are related in fixed proportion to the output. The parameters, k_{32}, k_{33}, and k_{34}, represent ratios; for example, k_{32} units of Y'_{32} are required for each unit of Y'_{35}.

$$\begin{bmatrix} Y'_{32} \\ Y'_{33} \\ Y'_{34} \end{bmatrix} = \begin{bmatrix} k_{32} \\ k_{33} \\ k_{34} \end{bmatrix} Y'_{35}. \qquad (6.4)$$

The assumption used to develop equation 6.4 is similar to that used in MOD ONE's component model of the distribution sector. The parameter k_{33} is analogous to the parameter a_{13}; the parameter k_{33} is, however, a "unit-to-unit" ratio and the parameter a_{13} is a "dollar-to-dollar" ratio.

The same assumption applied to the nonfood distribution subsector yields equation 6.5:

$$\begin{bmatrix} Y'_{37} \\ Y'_{38} \\ Y'_{39} \end{bmatrix} = \begin{bmatrix} k_{37} \\ k_{38} \\ k_{39} \end{bmatrix} Y'_{40} \quad . \qquad (6.5)$$

Since Y'_{35} equals Y'_{36} and since Y'_{40} equals Y'_{41}, equation 6.4 and 6.5 can be written as in equation 6.6 and 6.7 respectively:

$$\begin{bmatrix} Y'_{32} \\ Y'_{33} \\ Y'_{34} \end{bmatrix} = \begin{bmatrix} k_{32} \\ k_{38} \\ k_{34} \end{bmatrix} Y'_{36} \quad , \qquad (6.6)$$

and

$$\begin{bmatrix} Y'_{37} \\ Y'_{38} \\ Y'_{39} \end{bmatrix} = \begin{bmatrix} k_{37} \\ k_{38} \\ k_{39} \end{bmatrix} Y'_{41} \quad . \qquad (6.7)$$

In developing the component model of the distribution sector it is assumed that the following propensity variables are known: X'_{32}, X'_{37}, X'_{34}, X'_{39}, X'_{33}, and X'_{38}.

The variable X'_{35} is related to X'_{32}, X'_{33} and X'_{34}. The variable X'_{35} is best described as the "imputed cost" of producing one unit of output of the food distribution subsector. The value of the variable is defined as

$$X'_{35} = k_{32}\, X'_{32} + k_{33}\, X'_{33} + k_{34}\, X'_{34} \quad . \qquad (6.8)$$

The imputed cost, X'_{35}, is equal to the sum of the cost of each input required to produce one unit of output. Equation 6.8 sums the cost of labor inputs, food inputs from the production sector, and food inputs from other socioeconomic systems per unit of Y'_{35}.

Apply the same assumption to the nonfood distribution subsectors yields:

$$X'_{40} = k_{37}\, X'_{37} + k_{38}\, X'_{38} + k_{39}\, X'_{39} \qquad (6.9)$$

The propensity variables X'_{36} and X'_{41} represent the dollars per unit added to imputed cost per unit to arrive at an exit price per unit from the distribution sector. The assumption used is that X'_{36} or X'_{41} equals a fixed percentage, m_{36} or m_{41}, of imputed cost, X'_{35} or X'_{41}. Stated mathematically:

$$X'_{36} = m_{36}\, X'_{35} \quad , \qquad (6.10)$$

and

$$X'_{41} = m_{41}\, X'_{40} \quad . \qquad (6.11)$$

Having related all of the internal variables, the remaining task is to relate the systems variables to the internal variables and then eliminate the internal variables.

The systems variable Y_{CD}, representing the dollar value of labor input to the distribution sector, is related to the variables Y'_{D_1C} and Y'_{D_2C}. Y_{CD} equals the dollar value of labor to both the food and nonfood subsectors; this is the sum of the products $X'_{32}\, Y'_{32}$ and $X'_{37}\, Y'_{37}$. Using the relationships established in equations 6.6 and 6.7 for variables Y'_{32} and Y'_{37} yields:

$$Y_{CD} = [X'_{32}\;\; X'_{37}] \begin{bmatrix} k_{32} & 0 \\ 0 & k_{37} \end{bmatrix} \begin{bmatrix} Y'_{AC} \\ Y'_{D_2C} \end{bmatrix} \quad . \qquad (6.12)$$

The variables X'_{32} and X'_{37} are assumed to be known and Y'_{D_1C} and Y'_{D_2C} are, of course, system variables.

The expressions relating Y_{ID}, Y_{P_1D}, and Y_{P_2D} are developed in a manner analogous to that described above for variable Y_{CD}. The following equations describe the developed relationships:

$$Y_{ID} = [X'_{34}\ X'_{39}] \begin{bmatrix} k_{34} & 0 \\ 0 & k_{39} \end{bmatrix} \begin{bmatrix} Y'_{D_1C} \\ Y'_{D_2C} \end{bmatrix} , \qquad (6.13)$$

$$\begin{bmatrix} Y_{P_1D} \\ Y_{P_2D} \end{bmatrix} = \begin{bmatrix} X'_{33}k_{33} & 0 \\ 0 & X'_{38}k_{38} \end{bmatrix} \begin{bmatrix} Y'_{D_1C} \\ Y'_{D_2C} \end{bmatrix} . \qquad (6.14)$$

The variable X'_{D_1C} is equal to the sum of X'_{35} and X'_{36}; the sum of imputed cost and the margin added. Similarly, X'_{D_2C} equals X'_{40} plus X'_{41}.

Since X'_{36} equals $m_{36}X'_{35}$ and X'_{41} equals $m_{41}X'_{40}$, the variables X'_{D_1C} and X'_{D_2C} can be expressed as:

$$X'_{D_1C} = X'_{35} + m_{36}X'_{35} , \qquad (6.15)$$

and

$$X'_{D_2C} = X'_{40} + m_{41}X'_{40} . \qquad (6.16)$$

The variables X'_{35} and X'_{40} are expressed as functions of known variables in equations 6.8 and 6.9 respectively. Substituting equation 6.8 into 6.14 and equation 6.9 into 6.15 yields:

$$X'_{D_1C} = (1 + m_{36})[k_{33}k_{34}k_{35}] \begin{bmatrix} X'_{33} \\ X'_{34} \\ X'_{35} \end{bmatrix} , \qquad (6.17)$$

$$X'_{D_2C} = (1 + m_{41})[k_{37}k_{38}k_{39}]\begin{bmatrix} X'_{37} \\ X'_{38} \\ X'_{39} \end{bmatrix} . \qquad (6.18)$$

The remaining variable to be related is Y_{DC}, nonwage income generated by the distribution sector. The assumption used is that the nonwage income generated by the food distribution subsector equals some percentage, b_1, of the dollar value output of the food distribution subsector, $X'_{D_1C}Y'_{D_1C}$; and, the nonwage income generated by the nonfood distribution subsector equals a percentage, b_2, of the nonfood dollar value output, $X'_{D_2C}Y'_{D_2C}$. Or,

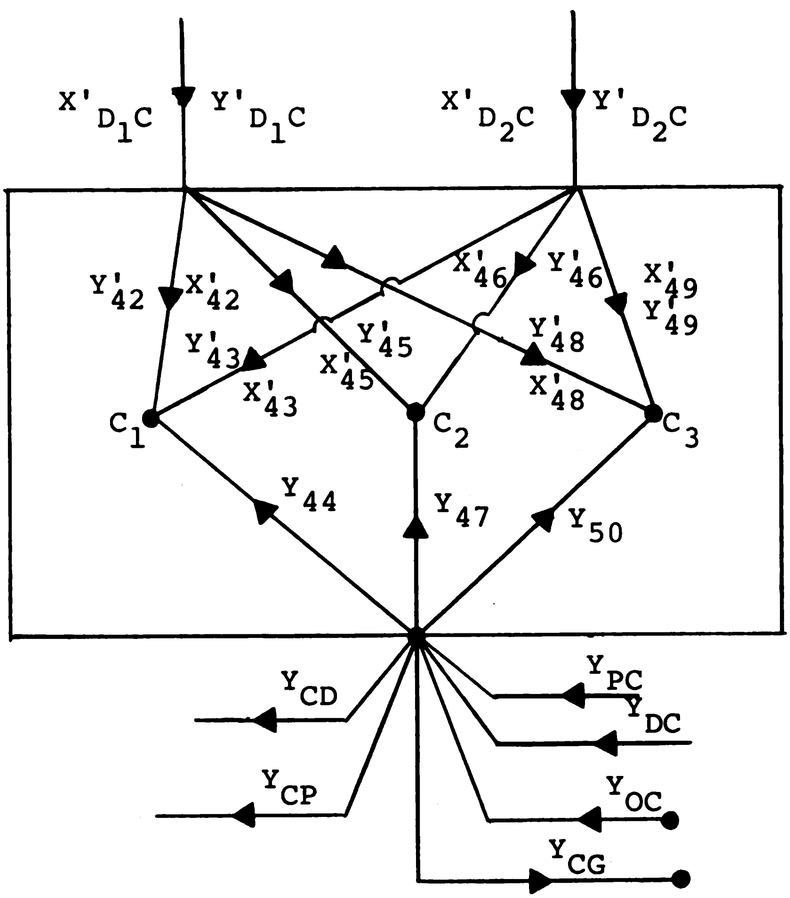
$$Y_{DC} = [b_1 \ b_2] \begin{bmatrix} X'_{D_1C} \ Y'_{D_1C} \\ X'_{D_2C} \ Y'_{D_2C} \end{bmatrix} . \qquad (6.19)$$

Equations 6.12, 6.13, 6.14, 6.17, 6.18, and 6.19 constitute the component model of the distribution sector. The systems variables in the set $[Y_{CD}, Y_{P_1D}, Y_{P_2D}, Y_{ID}]$ are related to Y'_{D_1C} and Y'_{D_2C} using the parameters in the set $[k_{32}, k_{33}, k_{34}, k_{37}, k_{38}, k_{39}]$. The systems variables X'_{D_1C} and X'_{D_2C} are related to six variables whose values are assumed to be known $[X'_{32}, X'_{33}, X'_{34}, X'_{37}, X'_{38}, X'_{39}]$, using the six parameters described above plus the parameters m_{36} and m_{41}.

Consumption Sector

Figure 6.3 is the component graph of the consumption sector. Three subsectors, as defined in MOD ONE, are shown.

The component model of the consumption sector must relate the variables in the set [Y'_{D_1C}, X'_{D_1C}, Y'_{D_2C}, X'_{D_2C}, Y_{CP}, Y_{CD}, Y_{CG}, Y_{PC}, Y_{DC}, Y_{OC}]; the model developed expresses the variables Y'_{D_1C} and Y'_{D_2C} as functions of the remaining eight.



Consumption Component: MOD TWO
Figure 6.3

Variables Y_{44}, Y_{47}, and Y_{50} represent the dollar income to consumption subsectors C_1, C_2, and C_3 respectively. These variables are the same as variables Y_{25}, Y_{28}, and Y_{31} defined and used in MOD ONE.

Total income to the consumption sector is defined as in the previous chapter,

$$I = Y_{CP} + Y_{CD} + Y_{CG} + Y_{PC} + Y_{OC} \quad . \qquad (6.20)$$

Total income from wages $[Y_{CP} + Y_{CD} + Y_{CG}]$ and nonwage income $[Y_{PC} + Y_{DC} + Y_{OC}]$ are summed in equation 6.20.

Assuming, as in MOD ONE, that the income received by a consumption subsector, i, is a percentage, d_i, of the total income, I, then, for the three consumption subsectors, i = 1, 2, 3;

$$\begin{bmatrix} Y_{44} \\ Y_{47} \\ Y_{50} \end{bmatrix} = \begin{bmatrix} d_1 \\ d_2 \\ d_3 \end{bmatrix} I \quad . \qquad (6.21)$$

The income received by a subsector is defined in equation 6.21; the question of how that income is spent remains. The major reason, it should be remembered, for altering the definition of certain systems variables was to allow for the consideration of consumers responses to price changes.

In MOD ONE, the consumption sector operated in units of total dollar flow along any internal edge; the consumption subsector models simply related total dollars expended upon food and nonfood to total dollar income.

The internal edges of the consumption sector shown in Figure 6.3 have both flow and propensity variables associated with them. Variables Y'_{42}, Y'_{45}, and Y'_{48} represent the unit flow rate of food items while variables X'_{42}, X'_{45}, and X'_{48} represent their prices per unit. Variables Y'_{43}, Y'_{46}, and Y'_{49} represent the unit flow rate of nonfood items while variables X'_{43}, X'_{46}, and X'_{49} represent their prices per unit.

The distinguishing characteristic used to define consumption subsectors is income level; income level is used as a surrogate to distinguish between consumers with different average propensities to purchase food and nonfood.

A subsector, i, had d_iI dollars worth of income. Assume, as in MOD ONE, that the subsector spends f_i percentage of d_iI on food and n_i percentage of d_iI on nonfood. The dollar amount spent by C_i on food is f_id_iI; this amount is definable as so many units of food at a certain price per unit.

Consider consumer subsector C_1. This subsector receives d_iI dollars of income. This subsector spends f_id_iI dollars on food; the product of $X'_{42}Y'_{42}$ equals f_id_iI.

The following three equations express the above assumptions for subsectors C_1, C_2, and C_3;

$$\begin{bmatrix} X'_{42}Y'_{42} \\ X'_{43}Y'_{43} \end{bmatrix} = \begin{bmatrix} f_1 \\ n_1 \end{bmatrix} d_iI \quad , \qquad (6.22)$$

$$\begin{bmatrix} X'_{45}Y'_{45} \\ X'_{46}Y'_{46} \end{bmatrix} = \begin{bmatrix} f_2 \\ n_2 \end{bmatrix} d_2 I \quad , \tag{6.23}$$

and

$$\begin{bmatrix} X'_{48}Y'_{48} \\ X'_{49}Y'_{49} \end{bmatrix} = \begin{bmatrix} f_3 \\ n_3 \end{bmatrix} d_3 I \quad . \tag{6.24}$$

Assuming that X'_{42}, X'_{45}, and X'_{48} equal X'_{D_1C} and X'_{43}, X'_{46}, X'_{49} equal X'_{D_2C}, equations 6.22, 6.23, and 6.24 can be simplified to:

$$X'_{D_1C}Y'_{D_1C} = (f_1d_1 + f_2d_2 + f_3d_3)I \quad , \tag{6.25}$$

and

$$X'_{D_2C}Y'_{D_2C} = (n_1d_1 + n_2d_2 + n_3d_3)I \quad . \tag{6.26}$$

Equations 6.25 and 6.26 are analogous to equations 5.35 and 5.36 in the previous chapter. The differences are in the expressions on the left hand side of the equations. In MOD ONE, the variables Y_{D_1C} and Y_{D_2C} are used while in MOD TWO, the product of X'_{D_1C} and Y'_{D_1C} and the product of X'_{D_2C} and Y'_{D_2C} are used.

Since the variable I in equations 6.25 and 6.26 is a shorthand notation for the sum of six systems variables associated with the consumption sector, these two equations constitute a component model of the consumption sector. The variables Y_{CG} and Y_{OC} are terminal variables and their values are assumed to be known. As in MOD ONE, the parameters used are in the set $[d_1, f_1, n_1, d_2, f_2, n_2, d_3, f_3, n_3]$.

The component model of the consumption sector can be written as:

$$\begin{bmatrix} Y'_{D_1C} \\ \\ Y'_{D_2C} \end{bmatrix} = \begin{bmatrix} \frac{1}{X'_{D_1C}} & 0 \\ \\ 0 & \frac{1}{X'_{D_2C}} \end{bmatrix} E \cdot I \qquad (6.27)$$

where E is a 2 x 1 matrix and

$$e_{1,1} = f_1 d_1 + f_2 d_2 + f_3 d_3 \text{, and}$$

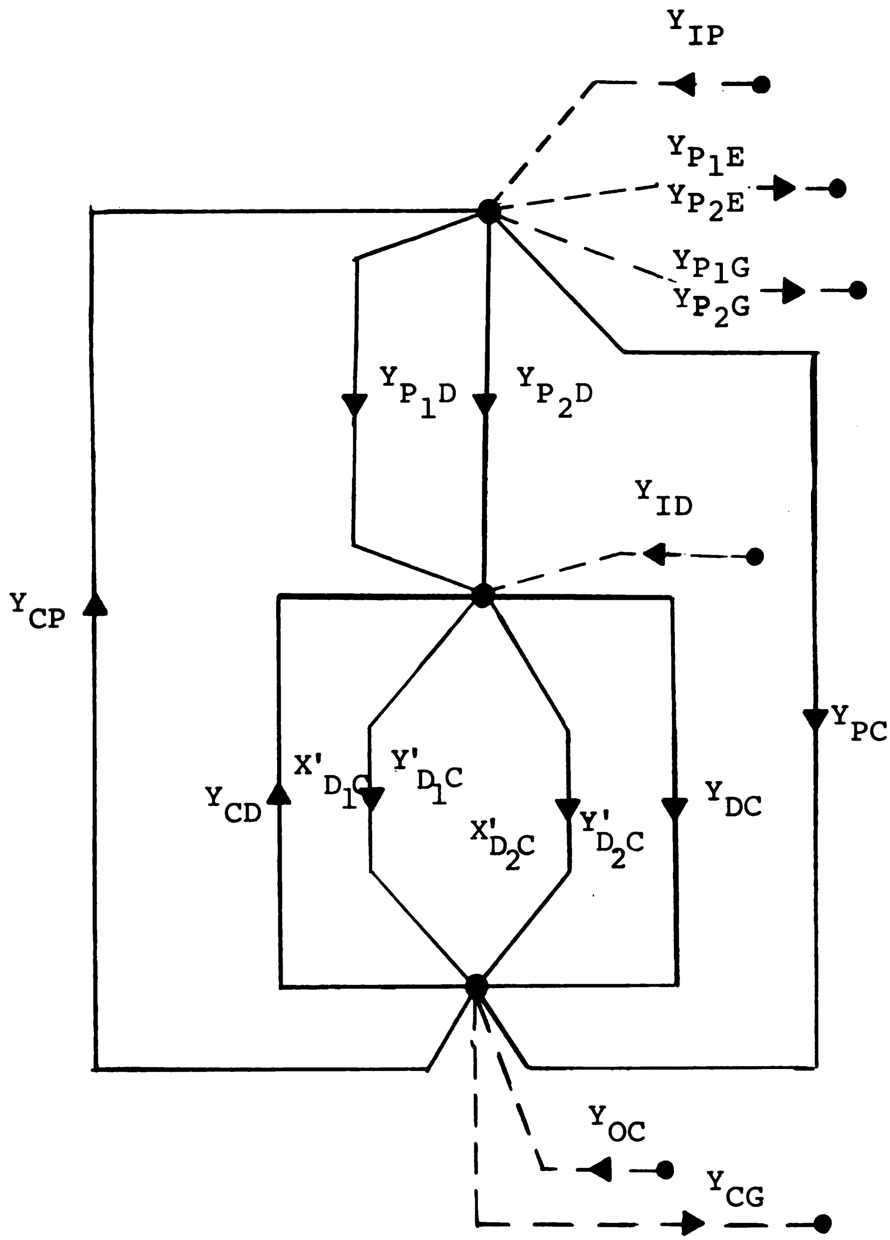
$$e_{2,1} = n_1 d_1 + n_2 d_2 + n_3 d_3 \quad .$$

This form of expression is to distinguish it more clearly from the consumption sector component model of MOD ONE.

Systems Model

The systems graph for MOD TWO is shown in Figure 6.4. The edges represented by solid lines have associated with them the defined system variables; those edges represented by broken lines indicate an association with a terminal variable.

There are sixteen edges shown in Figure 6.4; sixteen flow variables and two propensity variables are defined. Eight of the sixteen flow variables are system variables: Y_{P_1D}, Y_{P_2D}, Y'_{D_1C}, Y'_{D_2C}, Y_{PC}, Y_{DC}, Y_{CP}, Y_{CD}. The remaining eight flow variables are terminal variables; the values for all but Y_{IP} and Y_{ID} are assumed to be known. The two



Systems Graph: MOD TWO
Figure 6.4

propensity variables are X'_{D_1C} and X'_{D_2C}; these variables are also referred to as systems variables.

The systems variables listed above may be expressed as functions of known terminal variables or known variables such as those in the set [X'_{32}, X'_{33}, X'_{34}, X'_{37}, X'_{38}, X'_{39}]. The functional relationship would be expressed, in all cases, with some set of parameters used to develop the three component models; there were twenty-three parameters used.

There are ten variables in MOD TWO which can be expressed as functions of known variables; the six system flow variables, the two system propensity variables, and two terminal variables, Y_{IP} and Y_{ID}.

Two system flow variables, Y'_{D_1C} and Y'_{D_2C}, and two system propensity variables, X'_{D_1C} and X'_{D_2C} are, as in MOD ONE, of greatest interest. All of the other system variables can be expressed as functions of these variables.

Equation 6.28 provides a starting point for building MOD TWO; it is a reformulation of the component model of the consumption sector:

$$\begin{bmatrix} X'_{D_1C} & Y'_{D_1C} \\ X'_{D_2C} & Y'_{D_2C} \end{bmatrix} = E[1\ 1]\begin{bmatrix} Y_{CP} \\ Y_{PC} \end{bmatrix} + E\,Y_{CD} + E\,Y_{DC} + E[1\ 1]\begin{bmatrix} Y_{CG} \\ Y_{OC} \end{bmatrix} \tag{6.28}$$

The vector containing Y_{CP} and Y_{PC} in equation 6.28 can be expressed in the following form by combining equations 5.15 and 5.17:

$$\begin{bmatrix} Y_{CP} \\ Y_{PC} \end{bmatrix} = S\begin{bmatrix} Y_{P_1D} \\ Y_{P_2D} \end{bmatrix} + S\begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \end{bmatrix}\begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \\ Y_{P_1G} \\ Y_{P_2G} \end{bmatrix} \tag{6.29}$$

Equation 6.29 is obtained from equations developed in the previous chapter since the production sector component model is identical in MOD TWO and MOD ONE. The S matrix is composed of entries as defined with equation 5.38; the entries are expressed as combinations of the parameters used to develop the production sector component model.

The vector in equation 6.29 containing the variables Y_{P_1D} and Y_{P_2D} can be expressed in terms of the variables, Y'_{D_1C} and Y'_{D_2C}. The equation 6.30 is from equation 6.14.

$$\begin{bmatrix} Y_{P_1D} \\ Y_{P_2D} \end{bmatrix} = A \begin{bmatrix} Y'_{D_1C} \\ Y'_{D_2C} \end{bmatrix} \tag{6.30}$$

where A is a 2 x 2 matrix and;

$$a_{1,1} = X'_{33}k_{33} \quad ,$$

$$a_{1,2} = a_{2,1} = 0.0 \quad , \text{ and}$$

$$a_{2,2} = X'_{38}k_{38} \quad .$$

The variable Y_{CD} in equation 6.28 is expressible in terms of Y'_{D_1C} and Y'_{D_2C}. The source of equation 6.31 is equation 6.12.

$$Y_{CD} = B \begin{bmatrix} Y'_{D_1C} \\ Y'_{D_2C} \end{bmatrix} \tag{6.31}$$

where B is a vector, and;

$$b_{1,1} = X'_{32}k_{32} \quad , \text{ and}$$

$$b_{1,2} = X'_{37}k_{37} \quad .$$

The variable Y_{DC} in equation 6.28 is also definable in terms of Y'_{D_1C} and Y'_{D_2C}. Equation 6.32 is from equation 6.19.

$$Y_{DC} = C\begin{bmatrix} X'_{D_1C} & Y'_{D_1C} \\ X'_{D_2C} & Y'_{D_2C} \end{bmatrix} \qquad (6.32)$$

where C is a vector, and;

$$c_{1,1} = b_1 \quad , \text{ and,}$$

$$c_{1,2} = b_2 \quad .$$

The variables Y_{CG} and Y_{OC} in equation 6.28 are known terminal variables.

By substituting equation 6.30 into equation 6.29 and then substituting the result and equations 6.32, and 6.31 into equation 6.28 and rearranging terms yields:

$$\begin{bmatrix} X'_{D_1C} & Y'_{D_1C} \\ X'_{D_2C} & Y'_{D_2C} \end{bmatrix} = F\begin{bmatrix} Y'_{D_1C} \\ Y'_{D_2C} \end{bmatrix} + G\begin{bmatrix} X'_{D_1C} & Y'_{D_1C} \\ X'_{D_2C} & Y'_{D_2C} \end{bmatrix} + H\begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \\ Y_{P_1G} \\ Y_{P_2G} \\ Y_{CG} \\ Y_{OC} \end{bmatrix} \qquad (6.33)$$

where F is a 2 x 2 matrix, and;

$$f_{1,1} = e_{1,1}[a_{1,1}(s_{1,1} + s_{2,1}) + b_{1,1}] \quad ,$$

$$f_{1,2} = e_{1,1}[a_{2,2}(s_{1,2} + s_{2,2}) + b_{1,2}] \quad ,$$

$$f_{2,1} = e_{2,1}[a_{1,1}(s_{1,1} + s_{2,1}) + b_{1,1}] \quad \text{, and}$$

$$f_{2,2} = e_{2,1}[a_{2,2}(s_{1,2} + s_{2,2}) + b_{1,2}] \quad .$$

where G is a 2 x 2 matrix, and;

$$g_{1,1} = e_{1,1}c_{1,1} \quad ,$$

$$g_{1,2} = e_{1,1}c_{1,2} \quad ,$$

$$g_{2,1} = e_{2,1}c_{1,1} \quad \text{, and}$$

$$g_{2,2} = e_{2,1}c_{1,2} \quad .$$

where H is a 2 x 6 matrix, and;

$$h_{1,1} = h_{1,3} = e_{1,1}(s_{1,1} + s_{2,1}) \quad ,$$

$$h_{1,2} = h_{1,4} = e_{1,1}(s_{1,2} + s_{2,2}) \quad ,$$

$$h_{1,5} = h_{1,6} = e_{1,1} \quad ,$$

$$h_{2,1} = h_{2,3} = e_{2,1}(s_{1,1} + s_{2,1}) \quad ,$$

$$h_{2,2} = h_{2,4} = e_{2,1}(s_{1,2} + s_{2,2}) \quad ,$$

$$h_{2,5} = h_{2,6} = 2_{2,1} \quad .$$

Each of the entries in the matrices F, G, and H are expressible as combinations of entries in the matrices A, B, C, E, and S. Each entry in A, B, C, E, and S is, in turn, a combination of parameters;

$$a_{2,1} = \frac{a_7 + a_1a_9}{1 - a_3a_9}$$

for example, or parameters and variables whose values are assumed to be known; $b_{1,2} = k_{37}X'_{37}$ for example.

Equation 6.33 can be reduced to:

$$\begin{bmatrix} X'_{D_1C} & Y'_{D_1C} \\ X'_{D_2C} & Y'_{D_2C} \end{bmatrix} = [U - G]^{-1} F \begin{bmatrix} Y'_{D_1C} \\ Y'_{D_2C} \end{bmatrix} + [U - G]^{-1} H \begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \\ Y_{P_1G} \\ Y_{P_2G} \\ Y_{CG} \\ Y_{OC} \end{bmatrix} . \quad (6.34)$$

where U is a 2 x 2 unit matrix.

Equation 6.34 can be further reduced to:

$$\begin{bmatrix} Y'_{D_1C} \\ Y'_{D_2C} \end{bmatrix} = \left[U - Z[U - G]^{-1}F\right]^{-1} \cdot Z[U - G]^{-1} H \begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \\ Y_{P_1G} \\ Y_{P_2G} \\ Y_{CG} \\ Y_{OC} \end{bmatrix} . \quad (6.35)$$

where Z is a 2 x 2 matrix, and;

$$z_{1,1} = \frac{1}{X'_{D_1C}} \quad ,$$

$$z_{1,2} = z_{2,1} = 0.0 \quad , \text{ and}$$

$$z_{2,2} = \frac{1}{X'_{D_2C}} \quad .$$

The entires in Z require the values of X'_{D_1D} and X'_{D_2C}, the systems propensity variables. Equations 6.17 and 6.18 relate X'_{D_1C} and X'_{D_2C} to variables whose values are assumed to be known. Equation 6.20 and 6.35 thus relate four of the system variables defined in MOD TWO, Y'_{D_1C}, Y'_{D_2C}, X'_{D_1C}, and X'_{D_2C}.

The six remaining system variables, Y_{P_1D}, Y_{P_2D}, Y_{CP}, Y_{PC}, Y_{CD}, and Y_{DC} can be related to the variables Y'_{D_1C} and Y'_{D_2C} and thus to known variables. For example, Y_{P_1D} and Y_{P_2D} were related to Y'_{D_1C} and Y'_{D_2C} in equation 6.30. Substituting equation 6.35 and 6.30 yields:

$$\begin{bmatrix} Y_{P_1D} \\ Y_{P_2D} \end{bmatrix} = A\left[U - A[U - G]^{-1}\ F\right]^{-1} \cdot A[U - G]^{-1}\ H \begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \\ Y_{P_1G} \\ Y_{P_2G} \\ Y_{CG} \\ Y_{OC} \end{bmatrix} \quad . \quad (6.36)$$

Substituting equation 6.35 into 6.29 will relate the variables Y_{CP} and Y_{PC} to known variables. Substituting equation 6.35 into equation 6.31 and 6.32 would yield equations for relating Y_{CD} and Y_{DC} to known variables.

$$\begin{bmatrix} Y_{CP} \\ Y_{PC} \end{bmatrix} = SA\left[U - Z[U - G]^{-1} F\right]^{-1} \cdot Z[U - G]^{-1} H \begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \\ Y_{P_1G} \\ Y_{P_2G} \\ Y_{CG} \\ Y_{OC} \end{bmatrix}$$

$$+ S\begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \end{bmatrix} \begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \\ Y_{P_1G} \\ Y_{P_2G} \end{bmatrix} . \qquad (6.37)$$

$$Y_{CD} = B\left[U - Z[U - G]^{-1} F\right]^{-1} Z[U - G]^{-1} H \begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \\ Y_{P_1G} \\ Y_{P_2G} \\ Y_{CG} \\ Y_{OC} \end{bmatrix} . \qquad (6.38)$$

$$Y_{DC} = C \begin{bmatrix} X'_{D_1C} & 0 \\ 0 & X'_{D_2C} \end{bmatrix} \left[U - Z[U - G]^{-1} F \right]^{-1} Z[U - G]^{-1} H \begin{bmatrix} Y_{P_1E} \\ Y_{P_2E} \\ Y_{P_1G} \\ Y_{P_2G} \\ Y_{CG} \\ Y_{OC} \end{bmatrix} \tag{6.39}$$

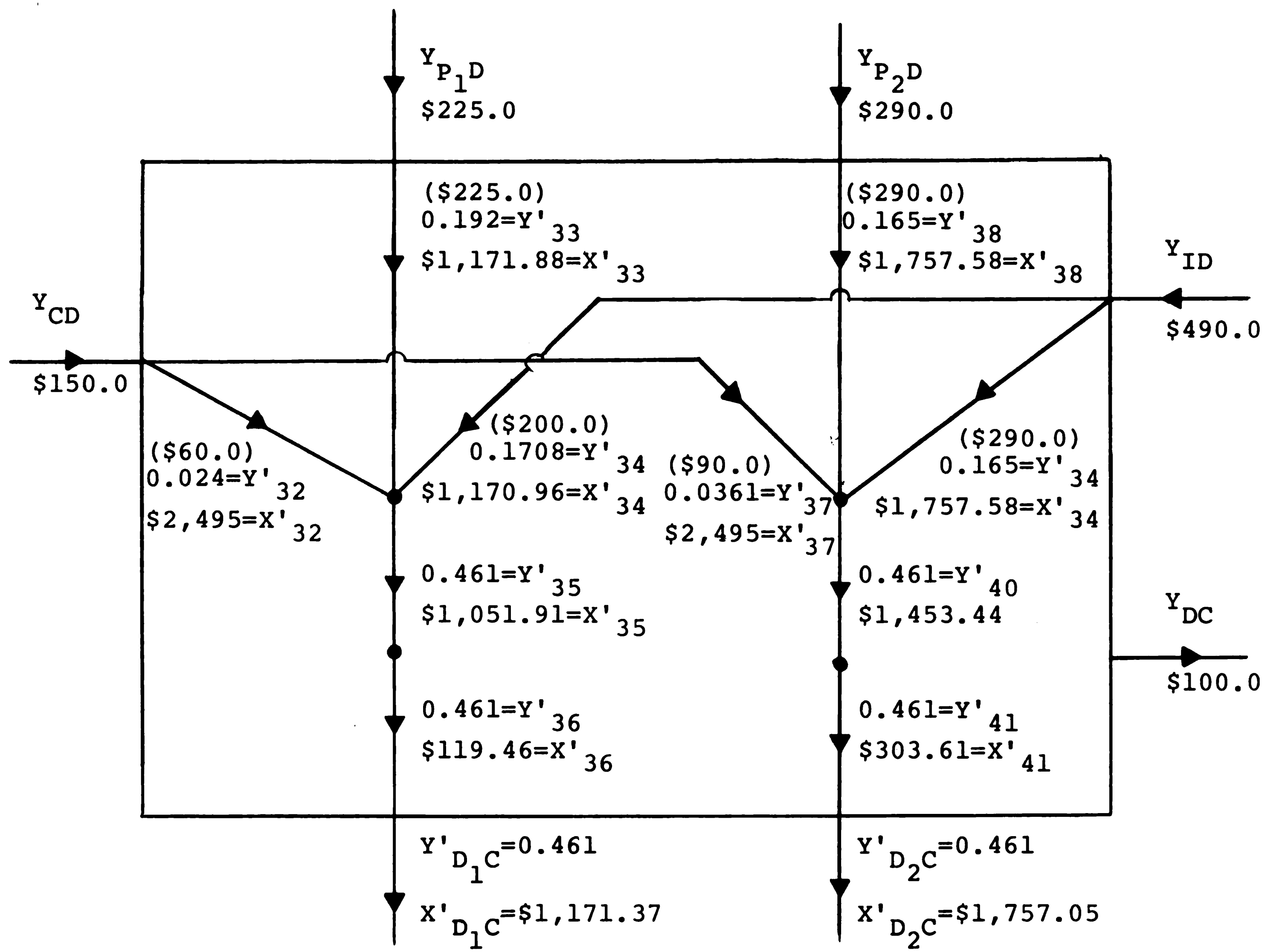
Equations 6.17, 6.18, 6.35, 6.36, 6.37, 6.38, and 6.39 are the equations developed to constitute MOD TWO. Each equation relates a system variable or set of system variables to terminal variables or known variables using the parameters defined in the development of the component models.

Operationalization

Except for the parameters associated with the distribution sector, the values of the terminal variables and parameters of MOD TWO are identical to those used for MOD ONE.

Figure 6.5 shows the distribution sector component graph of MOD TWO. Three values are shown with each edge in the graph. The values in parenthesis are equal to the product of the system variables associated with the edges; these values are obtained from corresponding edges in the distribution sector component graph of MOD ONE.

In Figure 6.5, the values of the flow variables are reported in millions of units. The values of the propensity variables are reported in dollars per unit.



Estimated Variable Values: MOD TWO Distribution Sector
Figure 6.5

Determining numeric values of the flow and propensity variables of the distribution sector is a difficult problem. As discussed previously, both of these variables are scalers; the flow variable Y'_{D_1C}, for example, represents a unit of flow of a variety of food items whose normal physical units of measure are pounds, dozens, quarts and cases.

Establishing some measure of "units" and "unit value" is, of course, essential to operationalize MOD TWO. The following approach is used in evaluating the parameters associated with the distribution sector of MOD TWO.

The dollar value figures approximated in the previous chapter for Y_{D_1C} and Y_{D_2C}, the dollar value of food and selected nonfood items consumed, are used as a basis to derive both per unit, Y', and price per unit, X', estimates.

The values of Y_{D_1C} and Y_{D_2C} are estimated as \$540.0 and \$810.0 million respectively. These values represent estimates of the expenditures of individuals and families within the socio-economic system for the year 1963 as measured by the summation of all purchases; each purchase being valued as the product of some price per unit times the number of units purchased. How many units of each item were purchased at different prices by each family is, obviously, unknown.

There were approximately 461,000 families in Puerto Rico in 1963.[1] As estimated, these families, in total, spent approximately \$540.0 million on food and \$810.0 million on selected nonfood items. By defining a "unit" as the package of goods an average family purchases in a year, values can be derived for the defined variables and, thus, the parameters of the distribution sector.

Assuming that 461,000 units of food were purchased, the value of Y'_{D_1C} equals 0.461 million units. Since the product of Y'_{D_1C} and X'_{D_1C} equals \$540.0 million, the value of X'_{D_1C} can thus be computed as \$1,171.96 per unit. The price per unit of the nonfood items can be computed as \$1,757.58 per unit in a similar manner.

The values of Y'_{D_1C} and Y'_{D_2C} could have been arbitrarily set at any values and the values of X'_{D_1C} and X'_{D_2C} computed accordingly. Faced with the necessity to establish some valuation procedure, the choice of units is made to reflect some useable base or reference figure.

As developed in MOD TWO, the values of both Y'_{35} and Y'_{36} equal Y'_{D_1C}; 0.461 million. The values of both Y'_{40} and Y'_{41} equal Y'_{D_2C}; 0.461 million.

The price per unit of labor, \$2,495, is obtained from the Census of Business by dividing the annual payroll value by the number of employees reported.[2] The values of X'_{32} and X'_{37} are assumed to be equal and thus \$2,495 is the value assigned to both of these variables. The number of units associated with these two variables are obtained by division; Y'_{32} equals \$60.0 million divided by \$2,495 or 0.024 million units, and Y'_{37} equals \$90.0 million divided by \$2,495 or 0.0361 million units. The \$60.0 and \$90.0 million figures represent the values determined for the corresponding variables in the previous chapter for MOD ONE.

For the flow variables Y'_{33}, Y'_{34}, Y'_{39}, the number of units are estimated from the values determined for Y'_{D_1C} and Y'_{D_2C} in accordance to the dollar per dollar ratios as estimated for MOD ONE. For example, the ratio of the value of food imports, \$200.0 million, to the value of Y_{D_1C}, \$540.0, is 0.3704. Since 0.3704 times 0.461 million units equals 0.1708 million units, the value of Y'_{34} is set equal to 0.1708 million units. The values of Y'_{33}, Y'_{38}, and Y'_{39} are established in the same manner.

If Y'_{34} equals 0.1708 units, X'_{34} equals \$1,170.96 per unit; \$200.0 million divided by 0.1708. The values of X'_{33}, X'_{38}, and X'_{39} are established in a similar manner. All of the system variable values for the distribution sector of MOD TWO are shown in Figure 6.5.

Once the value of each propensity variable is determined, the parameters k_{32}, k_{33}, k_{37}, k_{38}, and k_{39} can be obtained by simple division. The parameter k_{33}, for example, equals 0.192 million units divided by 0.461 million units or 0.4165. The values for all of the technical coefficient parameters are determined in like manner; the resultant values are given below in Table 6.1.

The values for X'_{35} and X'_{40} must be determined prior to establishing the values for the "mark up" parameters,

m_{36} and m_{41}. These values are determined as expressed in equations 6.8 and 6.9. The variables X'_{35} and X'_{40} are defined as "imputed cost"; they equal the summations of the products of the price per unit of an input and its technical coefficient k. Using the values for the per unit prices of inputs (X'_{32}, X'_{33}, X'_{34}, X'_{37}, X'_{38}, X'_{39}) and the technical coefficients (k_{32}, k_{33}, k_{34}, k_{37}, k_{38}, k_{39}) as derived above, X'_{35} and X'_{36} are computed to be $1,051.91, and 20.92%, $303.61 divided by $1,453.44, respectively. These values should be carefully interpreted in terms of MOD TWO; not all inputs are defined and these values do not translate directly into the standard meaning of "gross-margin."

Table 6.1--Parameter values: MOD TWO

Production Sector			
a_1 = 0.421	a_3 = 0.053	b_4 = 0.112	
a_7 = 0.421	a_9 = 0.103	b_{10} = 0.113	
Distribution Sector			
k_{32} = 0.052	k_{33} = 0.416	k_{34} = 0.370	m_{36} = 0.114
X'_{32} = 2495.00	X'_{33} = 1406.26	X'_{34} = 1170.96	b_1 = 0.074
k_{37} = 0.078	k_{38} = 0.358	k_{39} = 0.358	m_{41} = 0.209
k_{37} = 0.078	k_{38} = 0.358	k_{39} = 0.358	m_{41} = 0.209
X'_{37} = 2459.00	X'_{38} = 1757.58	X'_{39} = 1757.58	b_2 = 0.074
Consumption Sector			
d_1 = 0.300	f_1 = 0.400	n_1 = 0.400	
d_2 = 0.400	f_2 = 0.300	n_2 = 0.450	
d_3 = 0.300	f_3 = 0.200	n_3 = 0.500	

A computer program is written to solve for the values of the system variables of MOD TWO according to the equations of MOD TWO for differing sets of values for the parameters and terminal variables. With the computer program and the reference set of values for the model's parameters and terminal variable, MOD TWO is operational.

Testing

Two types of techniques are used in the testing of MOD TWO; sensitivity analysis and simulation. In sensitivity analysis, the value of a single parameter is altered and the response of the system variables recorded. The term simulation is used to describe the condition where more than one parameter will be altered at a time and the response of the systems variables recorded.

Sensitivity Analysis

The response of the systems variables of MOD TWO are studied in relation to changes in the values of five parameters associated with the food distribution subsector of the distribution sector; m_{36}, k_{32}, X'_{32}, k_{33}, X'_{33}.

Table 6.2 records the values for the specified system variables, total income, and the products $X'_{D_1C}Y'_{D_1C}$ and $X'_{D_2C}Y'_{D_2C}$, for five different values of the parameter m_{36}. The parameter m_{36} is the percentage of the imputed cost of one unit of food which is added to the imputed cost

Table 6.2--Sensitivity Analysis: MOD TWO, m_{36}

	Run 1	Run 2	Run 3	Run 4	Run 5
$X'_{D_1C}Y'_{D_1C}$	537.93[1]	538.45	540.02	540.28	541.57
$X'_{D_2C}Y'_{D_1C}$	789.11[1]	806.89	808.64	810.39	812.15
Y'_{D_1C}	0.450[2]	0.455	0.461	0.466	0.472
Y'_{D_2C}	0.460[2]	0.461	0.461	0.462	0.463
Y_{P_1D}	219.7[1]	222.2	224.8	227.5	230.3
Y_{P_2D}	289.4[1]	289.8	290.3	290.7	291.2
Y_{CP}	747.4[1]	748.7	750.1	751.5	752.9
Y_{PC}	199.3[1]	199.6	200.0	200.4	200.8
Y_{CD}	147.1[1]	147.9	148.7	149.6	150.4
Y_{DC}	99.6[1]	99.8	99.9	100.1	100.2
I	1793.4[1]	1796.0	1798.7	1801.5	1804.3
X'_{D_1C}	1195.4[3]	1183.4	1171.4	1159.4	1147.4
X'_{D_2C}	1754.1[3]	1754.1	1754.1	1754.1	1754.1
m_{36}	0.136[4]	0.125	0.114	0.102	0.091

[1]Millions of dollars (1963).

[2]Millions of units.

[3]Dollars (1963).

[4]Unitless.

to arrive at the value of X'_{D_1C}, the price per unit for food to the consumption sector.

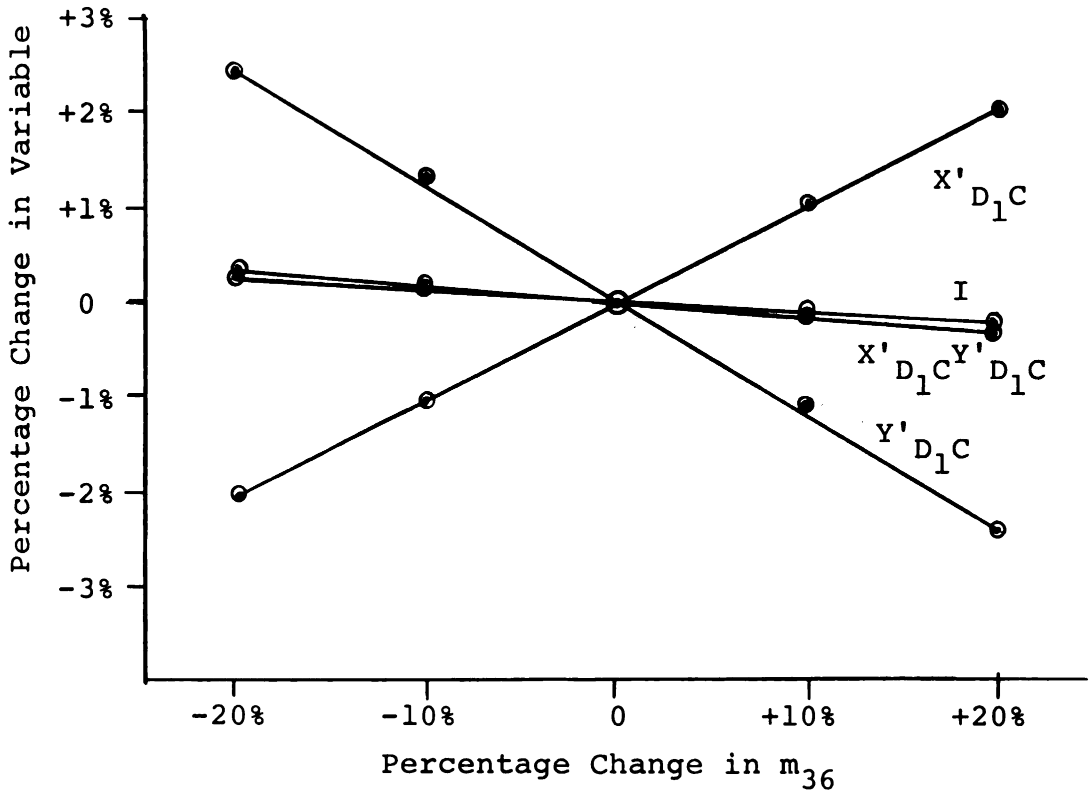
The reference value of m_{36} is 0.114 or 11.4%. The reference value is increased and decreased by 20% in increments of 10%. Runs 1, 2, 3, 4, and 5, identified in Table 6.2, record results for percentage changes from the reference value of m_{36} of +20.0%, +10.0%, 0.0%, -10.0%, and -20.0% respectively. The values of all other parameters and terminal variables are held constant and equal to their reference values.

A decrease in the value of m_{36} results in increases in the values of all system variables except the price per unit of food, which decreases, and the price per unit of nonfood, which remains constant.

For ease of analysis, Graph 6.1 records the percentage changes for selected variables; Y'_{D_1C}, X'_{D_1C} Y'_{D_1C}, X'_{D_1C}, and I.

Lowering the margin, the value of m_{36}, lowers the price per unit of food, X'_{D_1C}. Under the assumptions of the consumption sector component model, the three consumer subsectors purchase an increased volume of physical units, Y'_{D_1C}, given the lower price and the same total income, I.

Income does not remain constant, however, because of the model's response to increases in the value of Y'_{D_1C}. Increasing the value of Y'_{D_1C} causes more units of labor, Y_{CD}, and more units of input from the food production



Graph 6.1 Sensitivity analysis: MOD TWO, m_{36}

subsector, Y_{P_1D}, to be required by the food distribution subsector. Increasing Y_{P_1D} also requires that more labor, Y_{CP}, be supplied to the food production subsector. Nonwage income is also increased for both subsectors due to the increase in dollar volume of throughput.

With a higher level of income, both wage and nonwage, the three consumer subsectors spend an increased amount on food and nonfood items according to the income distribution and average consumption expenditure coefficients for food and nonfood items. Increases in the level of demand cause further increases in the values of the flow variables throughout the system.

Of interest to note is the order of magnitude of certain changes. Graph 6.1 shows that a 20% reduction in m_{36} results in an approximate 2% decrease in the price per unit of food and a 2.4% increase in the number of units of food consumed. A 0.3% increase in income and total dollars spent on food is recorded. The increase in the unit consumption of food is due both to a decrease in food price per unit and an increase in total income.

Table 6.3 records the values of the specified variables corresponding to five different values for the parameters X'_{32} and k_{32}; the price per unit of labor to the food distribution subsector and the unit per unit ratio of labor to output of the food distribution subsector.

The reference value of X'_{32} is \$2,495 and the reference value of k_{32} is 0.063. These values were altered by 20% above and below their reference values in increments of 10%. The reference values are given in Run 3. The models responses to these changes are identical in magnitude and direction since the effect on imputed cost, X'_{35}, and thus the price of output, X'_{D_1C}, will be the same for an identical percentage change in either the price per unit value or the technical coefficient of any input.

Decreases in the value of either k_{32} or X'_{32} cause some very interesting reactions to occur. The price per

Table 6.3--Sensitivity analysis: MOD TWO, k_{32} and X'_{32}

	Run 1	Run 2	Run 3	Run 4	Run 5
X'_{D_1C} Y'_{D_1C}	542.54[1]	540.77	540.02	538.00	535.83
$X'_{D_2C}Y'_{D_2C}$	813.9[1]	812.15	808.64	806.89	805.13
Y'_{D_1C}	0.452[2]	0.456	0.461	0.465	0.469
Y'_{D_2C}	0.464[2]	0.463	0.461	0.460	0.459
Y_{P_1D}	220.7[1]	222.7	224.8	227.0	229.1
Y_{P_2D}	291.9[1]	291.1	290.3	289.4	288.5
Y_{CP}	749.0[1]	749.5	750.1	750.6	751.2
Y_{PC}	199.7[1]	199.9	200.0	200.2	200.3
Y_{CD}	159.9[1]	154.3	148.7	143.0	137.2
Y_{DC}	100.5[1]	100.2	99.9	99.6	99.3
I	1809.1[1]	1804.0	1798.1	1793.4	1788.0
X'_{D_1C}	1200.3[3]	1185.9	1171.4	1157.0	1142.5
X'_{D_2C}	1754.1[3]	1754.1	1754.1	1754.1	1754.1
k_{32}	0.063[4]	0.057	0.052	0.047	0.042
X'_{32}	2994.90[3]	2744.50	2495.00	2245.50	1999.60

[1]Millions of dollars.

[2]Millions of units.

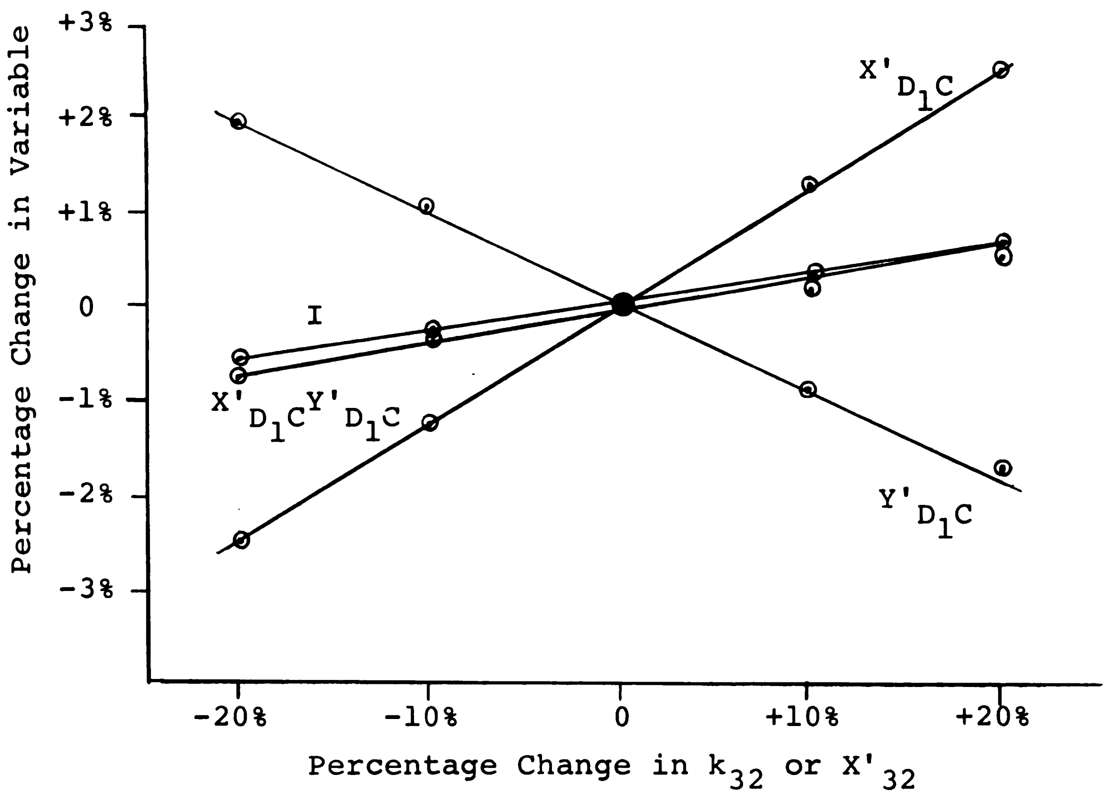
[3]Dollars.

[4]Unit/unit.

unit of food decreases, of course. The level of income, I, decreases, yet of the four sources of income whose values change, Y_{CP}, Y_{PC}, Y_{CD}, Y_{DC}, two increase in value, Y_{CP} and Y_{PC}, and two decrease in value, Y_{CD} and Y_{DC}.

The unit consumption of food increases while the unit consumption of nonfood decreases. Total dollars spent on both food and nonfood decrease.

Graph 6.2 shows the percentage changes in selected variables; Y'_{D_1C}, $X'_{D_1C}*Y'_{D_1C}$, X'_{D_1C}, and I. These variables were chosen to allow for comparison with the previous graph.



Graph 6.2 Sensitivity analysis: MOD TWO, k_{32} and X'_{32}

As the figures in Table 6.3 indicate, some interesting response patterns exist for changes in the input price, X'_{32}, or technical coefficient parameter, k_{32}. In fact, two opposing responses are set in motion when either of these parameters are altered.

Consider a reduction in the per unit cost of labor, X'_{32}, or in the technical coefficient for labor, k_{32}. Lowering either value lowers the imputed cost and thus the price of food to consumers, X'_{D_1C}. Lowering the value of X'_{D_1C}, if no other changes are involved, would cause a change similar to that described above for reductions in m_{36}; all of the systems flow variables would increase in value. Lowering either value, X'_{32} or k_{32}, has another effect, however; it lowers the wage income generated by the food distribution subsector for a given unit level of food consumption. This reduction causes a reduction in income and a subsequent reduction in consumption if no other changes are involved.

The net effect of these two opposing responses are given by the results shown in Table 6.3. The reduction of food price, X'_{D_1C}, caused an increase in per unit consumption of food, Y'_{D_1C}, which more than offsets the decrease in per unit consumption of food caused by a decrease in income. Note that the per unit consumption of nonfood decreases as would be expected with a constant per unit price, X'_{D_2C} and lower income, I.

It is extremely interesting to note the wage and nonwage income response pattern. Total wage and nonwage income generated by the production sector increases; with constant wage rates, the increase in wage generation from the food production subsector caused by the increase in demand for food, Y_{P_1D}, more than offsets the reduction in wage generation by the nonfood production subsector caused by a reduction in nonfood demand, Y_{P_2D}. In the distribution subsector, wage generation decreases; a portion of the reduction is caused by the decrease in demand for nonfood and the remainder is caused by the reduction of wage rates to the food distribution subsector even with a higher per unit labor requirement.

The need for a model is clearly demonstrated in this sensitivity test. While the reaction of the model to changes in m_{36} are perhaps directionally predictable, such is not the case in the reaction of the model to a change in either k_{32} or X'_{32}.

Table 6.4 records the values for the specified variables corresponding to five different values for either X'_{33} or k_{33}; the price per unit of food from production to distribution or the unit per unit ratio of food units from production to distribution to food units from distribution to consumption. The reference value of X'_{33} is $1,171.88 and the reference value of k_{33} is 0.416; these are shown in the column labeled Run 3. Each reference value is increased and decreased by 20% in increments of 10%.

Table 6.4--Sensitivity analysis: MOD TWO, k_{33} and X'_{33}

	Run 1	Run 2	Run 3	Run 4	Run 5
$X'_{D_1C}Y'_{D_1C}$	542.76[1]	541.80	540.01	537.33	535.60
$X'_{D_2C}Y'_{D_2C}$	813.90[1]	812.15	808.64	806.89	803.38
Y'_{D_1C}	0.424[2]	0.442	0.461	0.481	0.504
Y'_{D_2C}	0.464[2]	0.463	0.461	0.460	0.458
Y_{P_1D}	248.4[1]	237.1	224.8	211.5	196.9
Y_{P_2D}	292.0[1]	291.2	290.3	289.3	288.2
Y_{CP}	761.3[1]	755.9	750.1	743.7	736.6
Y_{PC}	203.0[1]	201.6	200.0	198.3	196.5
Y_{CD}	144.5[1]	146.5	148.7	151.1	153.8
Y_{DC}	100.5[1]	100.2	99.9	99.6	99.2
I	1809.3[1]	1804.3	1798.7	1792.7	1786.1
X'_{D_1C}	1280.1[3]	1225.8	1171.4	1117.1	1062.7
X'_{D_2C}	1754.1[3]	1754.1	1754.1	1754.1	1754.1
k_{33}	0.500[4]	0.450	0.416	0.375	0.333
X'_{33}	1406.26[3]	1289.07	1171.88	1054.69	937.50

[1]Millions of dollars.

[2]Millions of units.

[3]Dollars.

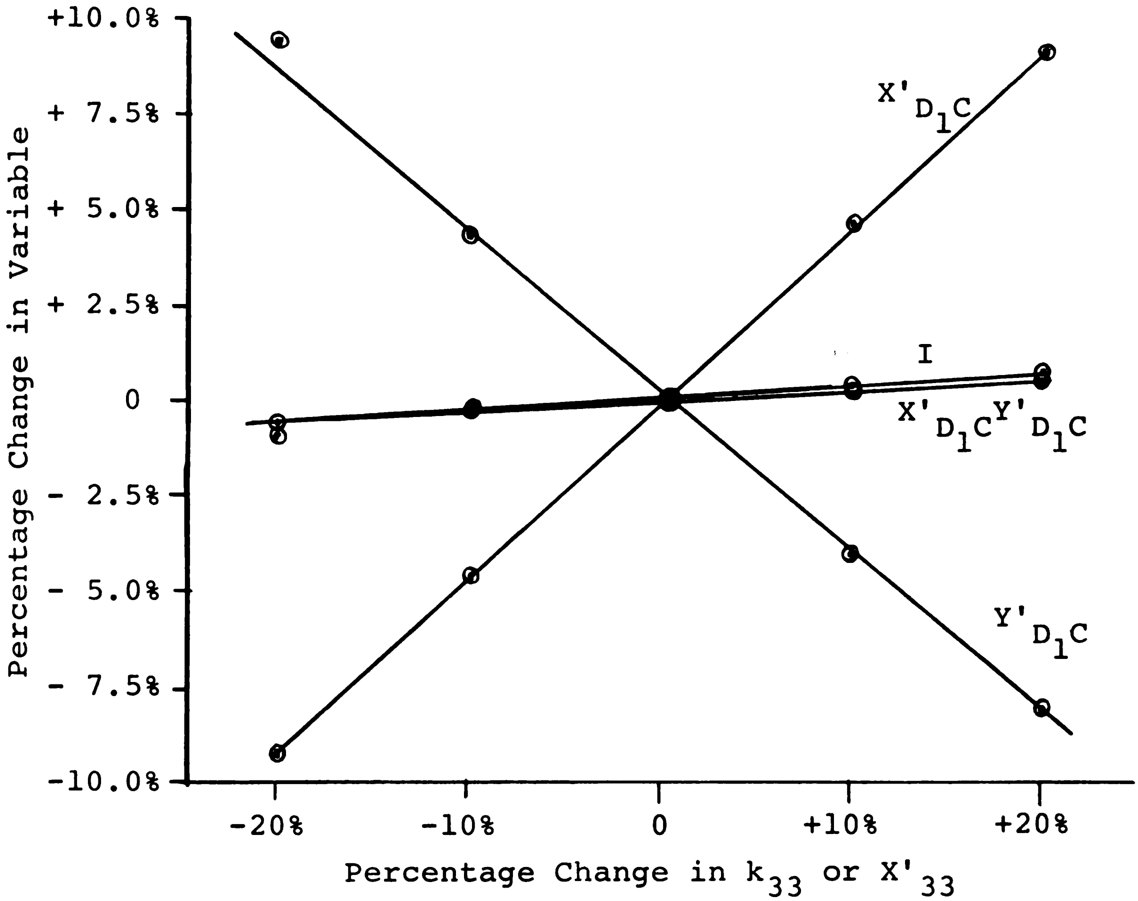
[4]Unit/unit.

When either k_{33} or X'_{33} is lowered, total income and dollar expenditures on food and nonfood decrease. Food consumption on a per unit basis increases while nonfood consumption decreases. This result is analogous to that of the previous test. Three of the four sources of income shown, Y_{CD}, Y_{PC}, Y_{CD}, and Y_{DC}, differ in their directional response to a change in either X'_{33} or k_{33}, however, when compared with their response to a change in either X'_{32} or k_{32}.

Graph 6.3 shows the percentage changes in selected variables for comparison with the previous graphs. The percentage increase in Y'_{D_1C}, for example, is higher for a 20% decrease in X'_{33} or k_{33} than for X'_{32} or k_{32}, or m_{36}.

As in the previous sensitivity run, the two opposing responses to a change in an input price or a technical coefficient are netted out by the model. The interesting difference between the sensitivity runs for X'_{33} and k_{33}, and X'_{32} and k_{32}, is the differences in the magnitudes of the responses and the direction of change in the components of total income.

In response to decreases in both X'_{33} and k_{33}, income generated by the production sector decreases as does nonwage income generated by the distribution sector; wage income generated by the distribution sector increases, but not enough to prevent a decline in total income. In response to decreases in X'_{32} and k_{32}, all income changes, except nonwage income generated by distribution, are in



Graph 6.3 Sensitivity analysis: MOD TWO, k_{33} and X'_{33}

opposite directions. In both tests, a decline in total income occurs.

The reduction in the price of food, X'_{D_1C}, is more dracatic for a change in X'_{33} or k_{33}, than for the same percentage change in X'_{32} or k_{32} since the portion of total imputed cost incurred for internally produced food is higher than that incurred for labor; imputed cost and price is thus more noticeably influenced and the model reacts more noticeably to the change.

Simulation

Three simulation tests are reported below. While these three tests in no way exhaust all of the possible tests they are sufficient to demonstrate the approach.

Table 6.5 records the values of certain system variables corresponding to five different sets of values for k_{33} and k_{34}. The parameter k_{33} is the ratio of unit inputs into the food distribution subsector from the food production subsector to the unit output of the food distribution subsector, and the parameter k_{34} is the ratio of unit inputs into the food distribution subsector from other socio-economic systems to the unit output of the food distribution subsector. The parameter k_{33} was altered in a sensitivity test in the previous section.

The sum of k_{33} and k_{34} is held constant for the five sets of parameter values recorded in Table 6.5. The recorded values for Run 1 are approximately equal to the reference values as used in the sensitivity runs; they have been rounded for ease of reporting.

As the ratio of k_{33} is decreased relative to k_{34}, Run 1 to Run 5, or as more units of input to the food distribution subsector are required from external sources relative to internal, the values of the system flow variables decrease. Per unit food and nonfood consumption decrease as does total income and dollars spent on food and nonfood.

Table 6.5--Simulation I: MOD TWO

	Run 1	Run 2	Run 3	Run 4	Run 5
$X_{D_1C}Y_{D_1C}$	543.0[1]	540.6	539.5	538.3	537.11
$X_{D_2C}Y_{D_2C}$	813.9[1]	812.2	810.4	806.9	805.1
Y'_{D_1C}	0.462[2]	0.460	0.459	0.458	0.457
Y'_{D_2C}	0.464[2]	0.463	0.462	0.460	0.459
Y_{P_1D}	238.0[1]	232.0	226.1	220.1	214.3
Y_{P_2D}	291.8[1]	291.1	290.4	289.7	289.0
Y_{CP}	756.6[1]	753.6	750.6	747.7	744.7
Y_{PC}	201.8[1]	201.0	200.2	199.4	198.6
Y_{CD}	149.3[1]	148.9	148.6	148.2	147.9
Y_{DC}	100.4[1]	100.2	100.0	99.7	99.5
I	1808.1[1]	1803.7	1799.4	1795.0	1790.7
X'_{D_1C}	1175.4	1175.3	1175.3	1175.3	1175.3
X'_{D_2C}	1754.1[3]	1754.1	1754.1	1754.1	1754.1
k_{33}	0.44[4]	0.43	0.42	0.41	0.40
k_{34}	0.34[4]	0.36	0.37	0.38	0.39

[1]Millions of dollars.

[2]Millions of units.

[3]Dollars.

[4]Unit/unit.

The conditions reported in Table 6.5 differ from those reported in Table 6.4 although in both cases the value of k_{33} is being altered. The differences are both interesting and easily explained. In Table 6.5 the price of food from distribution to consumption, X'_{D_1C}, is fairly constant. As reported in Table 6.4, altering k_{33} alone causes the price of food to change; this is due to a change in imputed cost.

In the above simulation run, the price remains fairly constant because the total number of input units required is held constant, the sum of k_{33} and k_{34}, and because the prices per unit of these inputs are approximately equal. Under these two conditions, the imputed cost and thus the selling price is fairly constant. If the price per unit of k_{33} had been higher than the price per unit of k_{34} and the sum of the two technical coefficients had been held constant, the imputed price and thus the value of X'_{D_1C} would have increased, causing different results than those shown in Table 6.5' the results would be certainly different in magnitude and possibly even different in direction.

In the first simulation run, the reaction of the model to one aspect of a technical coefficient change, a price change, is offset and the other aspect, the increased physical throughput response, is recorded. This explains the decreases in all system flow variables as the value of k_{33} was decreased relative to k_{34}. This simulation describes quite effectively the complexity of response of relatively simple changes in parameter values. Had the relative prices of X'_{33} and X'_{34} been different, or the technical coefficient parameters had been altered in a different manner, a difference in either the magnitude or directions of change for the system variables may have occurred. The model, of course, is used to compute both direction and magnitude.

The second simulation run conducted alters four of the eight parameters associated with the food distribution subsector. The values of five sets of the four altered parameters and the corresponding values of the identified variables are recorded in Table 6.6. The value of the margin, m_{36} is reduced from the value appearing in Run 1 in 1% increments; the value of the technical coefficient for labor is reduced in 1% increments, and the sum of the technical coefficients k_{33} and k_{34} is held equal to 0.486 while the value of k_{33} is increased relative to k_{34} in increments of 0.0005. The four remaining parameters associated with the food distribution subsector, including all input prices, are held constant. The value of all other parameters in the system are also held constant.

There is very little additionally that can be said in a methodological sense about the response of the model as recorded in Table 6.6 to the changes in the four parameter values that has not already been stated. Each parameter

Table 6.6--Simulation II: MOD TWO

	Run 1	Run 2	Run 3	Run 4	Run 5
$X'_{D_1C}Y'_{D_1C}$	539.5[1]	539.4	539.4	539.3	539.3
$X'_{D_2C}Y'_{D_2C}$	808.6[1]	808.6	808.6	808.6	808.6
Y'_{D_1C}	0.461[2]	0.462	0.463	0.464	0.465
Y'_{D_2C}	0.461[2]	0.461	0.461	0.461	0.461
Y_{P_1D}	224.8[1]	225.5	226.3	227.1	227.9
Y_{P_2D}	290.2[1]	290.2	290.2	290.2	290.2
Y_{CP}	750.0[1]	750.4	750.7	751.0	751.4
Y_{PC}	200.0[1]	200.1	200.2	200.3	200.4
Y_{CD}	148.7[1]	148.2	147.7	147.2	146.8
Y_{DC}	99.9[1]	99.9	99.9	99.9	99.9
I	1798.5[1]	1798.5	1798.5	1798.4	1798.4
X'_{D_1C}	1170.3[3]	1167.6	1165.0	1162.3	1159.7
X'_{D_2C}	1754.1[3]	1754.1	1754.1	1754.1	1754.1
k_{32}	0.52[4]	0.5148	0.5096	0.5044	0.4992
k_{33}	0.370[4]	0.3695	0.369	0.3685	0.368
m_{36}	0.114[5]	0.11286	0.11172	0.11058	0.10944

[1]Millions of dollars.

[2]Millions of units.

[3]Dollars.

[4]Unit/Unit.

[5]Unitless.

change made has been studied individually and the directional response of the system variable values as recorded in Table 6.6 is certainly consistent with the previous tests. There is almost negligible change in many of the system variable values, such as income, but the percentage changes in parameter values are small in comparison to the percentage changes made in previous tests.

The third and final simulation conducted uses the same changes in the four parameters altered in the second simulation with one change; income distribution is altered within the consumption sector.

This simulation is designed to demonstrate how changes in other sectors of the system can be made simultaneously with changes in the distribution sector in order to see what modification these changes may impose upon the results of changes in distribution parameters alone.

The income distribution changes, as shown in Table 6.7 with the results of the simulation, are made to cause a shift in the percentage of income to the middle income bracket from the lower income bracket; the percentage of income to the high income group is held constant. The low income group's percentage of total income is reduced in 5% increments and this increment added to the percentage of total income held by the middle income group.

By comparing Tables 6.6 and 6.7, a number of differences, both in the direction and magnitude of the change

Table 6.7--Simulation III: MOD TWO

	Run 1	Run 2	Run 3	Run 4	Run 5
$X'_{D_1C}Y'_{D_1C}$	539.5[1]	534.8	530.1	524.2	519.5
$X'_{D_2C}Y'_{D_2C}$	808.6[1]	810.4	812.1	813.9	815.7
Y'_{D_1C}	0.461[2]	0.458	0.455	0.451	0.448
Y'_{D_2C}	0.461[2]	0.462	0.463	0.464	0.465
Y_{P_1D}	224.8[1]	223.5	222.2	220.9	219.6
Y_{P_2D}	290.2[1]	290.8	291.4	291.9	292.5
Y_{CP}	750.0[1]	749.7	749.4	749.1	748.8
Y_{PC}	200.0	199.9	199.8	199.8	199.7
Y_{CD}	148.7[1]	147.8	147.0	146.2	145.4
Y_{DC}	99.9[1]	99.6	99.4	99.1	98.9
I	1798.5[1]	1797.1	1795.6	1794.2	1792.7
X'_{D_1C}	1170.3[3]	1167.6	1165.0	1162.3	1159.7
X'_{D_2C}	1754.1[3]	1754.1	1754.1	1754.1	1754.1
k_{32}	0.052[4]	0.05148	0.05096	0.05044	0.04992
k_{33}	0.416[4]	0.4165	0.417	0.4175	0.418
k_{34}	0.370[4]	0.3695	0.369	0.3685	0.368
m_{36}	0.114[5]	0.11286	0.11172	0.11058	0.10944
d_1	0.30[5]	0.275	0.25	0.225	0.20
d_2	0.40[5]	0.425	0.45	0.475	0.50

[1]Millions of dollars. [3]Dollars. [5]Unitless.

[2]Millions of units. [4]Unit/unit.

of the variables, are noted; the introduction of income distribution shifts alters the response of the system to the changes made in the food distribution subsector parameters. It should be expected, of course, that the model would respond differently when an income redistribution effect is introduced along with the other parameter changes; the question is how differently it would respond.

The explanation of the response pattern alteration recorded is informative. Changing the income distribution parameters affects the percentage relationship between total dollars spent on food and nonfood and total income; equations 6.25 and 6.26 are used to describe this relationship. In this simulation, shifting the percentage of total income to the middle income group, which spends less on the average for food and more on the average for nonfood than the low income group, alters the responses of the consumption sector, in total, to any change in either its income or the prices it faces for food or nonfood from the distribution sector.

When the income distribution shift is introduced, per unit consumption of food decreases and per unit consumption of nonfood increases; this is occurring even though the price per unit of food decreases and the price per unit of nonfood remains constant. All of the four internal sources of income, wage and nonwage, from production and distribution, decrease.

The shift toward nonfood consumption is explained, of course, by the increased percentage of total income which is spent on nonfood items. Total income decreases in magnitude.

The change in the direction of many of the response patterns when an income redistribution effect is overlayed on the changes in the food distribution subsector parameters indicates the relative strength of this effect.

The three simulation runs recorded above do not begin to exhaust the sets of conditions which could be tested using MOD TWO. All of the parameters of the distribution sector were not altered nor were all of the parameters of the consumption or production sectors or the values of the terminal variables. The major responses and the reasons or explanations of why MOD TWO responded as it did, have, however, been covered in the sensitivity and simulation tests.

Conclusions

The sensitivity and simulation tests conducted above demonstrated how an operational systems model can be used to study the response of the economic system to changes within the distribution sector.

The specific sensitivity and simulation tests described above were chosen to address certain issues raised in Chapter II concerning the nature of an economic system's response to changes within the distribution sector. As stated in that chapter, the result of marketing changes cannot be considered only in terms of their effect on one sector, such as the consumption sector, without consideration of the reactions of other sectors, such as the production sector. The interrelationship between the distribution sector and both the consumption and production sectors, and also the relationship between the consumption and production sectors need to be considered.

The interrelated response of the economic sectors defined in MOD TWO are clearly demonstrated in the above tests; a change in the parameter values of the distribution sector resulted in responses explainable only in terms of the interrelatedness of the defined economic system.

Perhaps the most informative single test of MOD TWO is the alteration of the value of a technical coefficient in the distribution sector; all other tests conducted reflect more complex variations on the response patterns uncovered by this test.

To understand the response of the system to a change in a technical coefficient requires that the interrelatedness of the system be recognized. As the model is constructed, a technical coefficient change in the distribution sector affects the price of the output and also the input requirements per unit of output. These two alterations cause the model to respond in different ways.

A reduction in price per unit of an output of the distribution sector causes the three consumer subsectors to respond by consuming more units of the output for any level of income. Increasing unit consumption increases income because of the tie between income and physical output through labor requirements. Thus, the price decrease, initiated by a technical coefficient decrease, sets a rather complex response pattern in motion.

The other consequence of a technical coefficient change, a reduction of input unit requirements per unit of output, causes an equally complex response but in another direction. Reducing unit throughput causes reductions in labor requirements, and thus income, and thus demand.

The final result of a technical coefficient change in terms of the direction of change and the magnitude of change of each system variable is virtually impossible to predict; the tests reported above demonstrate this fact. When other changes in parameter values are made simultaneously with changes in a technical coefficient parameter, the final results become more difficult to predict although the basic response patterns involved are similar.

CHAPTER VII

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

Summary

Evaluating the economic consequences of a change or reform within the marketing system of a developing country was viewed as a problem where the application of systems theory could provide both assistance and increased understanding through the development of mathematical simulation tools.

A review of the literature on the tole of marketing in economic development clearly indicated the need to view the economic system as a set of interrelated economic sectors. A review of both input-output and national income models determined that the distribution sector of the economic sector was not treated as an interrelated sector; certain features of these models were found to be valuable however.

After explaining the methodology of systems theory in qualitative terms and relating the methodology to the problems of modeling a socio-economic system, two systems models were developed.

Both system models, identified as MOD ONE and MOD TWO, were developed from a set of explicit assumptions concerning the behavior of and relationships between three basic economic sectors; production, distribution and consumption. Parameters defined in both models were estimated from data concerning the economic conditions in Puerto Rico in 1963. Computer programs were written to solve for the values of the systems variables given different sets of values for the parameters and terminal variables. Tests of the models demonstrating the response of the system, as measured by the direction and magnitude of change in certain system variables, to changes in parameter values associated primarily with the food distribution subsector of the distribution sector were conducted and explained.

Conclusions

Two basic issues must be clearly separated to arrive at conclusions concerning the usefulness of the modeling effort in the context of the objective of the thesis. The accuracy of the models to describe the economic system and estimate the response of that economic system to changes within the distribution sector is one basic issue. The ability of the modeling technique, as demonstrated in the two models presented, to address the complexities of the measurement problem is the other basic issue.

The first issue, the accuracy of the model to describe the system and its response to change, is most difficult to evaluate. The behavioral assumptions are stated explicitly; the correctness of each assumption influences, of course, the correctness of the model. Aside from concern for the accuracy of the assumptions used to build the model, the accuracy of the parameter values must also be considered. The tests conducted on MOD TWO demonstrate how the values used for a parameter influence the results of the model. Data problems are severe and the need to estimate variable values and balance data taken from several sources is reported.

The issue of the accuracy of the models is vital to anyone concerned with either the practical problems of application, such as long range economic planning, or with the problems of evaluating the role of marketing in economic development. This issue is recognized as being highly important and the end objective toward which this effort is directed: this issue is not, however, the overriding one in the context of the objectives of this thesis.

The issue which is of prime concern in this thesis is the ability of the modeling technique to provide a framework for developing more meaningful and useful simulation tools for evaluating the role of marketing in economic development. At issue is the ability of this approach to provide a framework with sufficient flexibility to make alternative assumptions with relative ease yet provide a stable framework to work within.

The "step" between MOD ONE and MOD TWO is presented as a demonstration of the ease with which alterations can be made within a basic modeling framework. Changes were made in MOD ONE in measurement unit definition and in the basic assumptions made concerning the behavior of the distribution sector and the consumption sector. Even with these changes, a great deal of previous work, including the model of the production sector and part of the consumption sector and the basic parameter data, were available for reuse.

Aside from providing a flexible mechanical framework, the results of the tests of MOD TWO are felt to have provided a clearer picture of the intricacy of the measurement problem actually being faced. The response pattern of MOD TWO to changes in the "margin," the "technical coefficients," the "input prices," and even the income distribution parameters, described what is involved. The multiplicity of responses to relatively simple alterations, such as a change in a single technical coefficient, are shown.

Measurement term definition, data collection, and parameter evaluation problems, important aspects of any modeling effort, were explicitly considered and initial solutions presented.

The methodological approach offered by the application of systems theory seems worth pursuing further as one tool to assist in the evaluation of the role of marketing in economic development.

Recommendations

Four areas are suggested for further research efforts. First, it is suggested that improvements be made in the model itself. The assumptions made about the behavior of the defined sectors of the model need to be improved; in the same vein, the sectors of the model need to be treated in a more disaggregated form.

Second, it is suggested that the data collection and measurement problems be addressed in greater detail. A systems model, such as MOD TWO, needs information on the actual flow pattern of goods. Current information sources report little on actual flow paths nor is data presented in both unit and price per unit terms. Further research into the types of measurement definitions usable for the flow and propensity variables needs to be conducted.

Third, the problem of the valuation of the costs incurred in a specific parameter change or set of parameter changes needs to be considered. The cost of altering certain parameters must certainly be viewed as part of the problem in evaluating the results of a marketing change.

Fourth, it is suggested that future models developed be more directly usable by those in a decision making capacity. This would involve, perhaps, greater ease in altering parameter values and interpreting results.

NOTES

CHAPTER I

1. A review of the literature on the role of marketing is contained in Chapter II.

2. "A Comparative Study of Food Marketing Systems in Latin American Countries," project title of contract number AID/csd-786 between The United States Department of State, Agency for International Development and Michigan State University.

3. "Latin American Market Planning Project Contract," project title of contract number AID/la-364 between the United States Department of State, Agency for International Development and Michigan State University.

4. "A Comparative Study of Food Marketing Systems in Latin American Countries," contract, p. 2.

5. <u>Ibid.</u>, p. 2.

6. <u>Ibid.</u>, p. 2.

7. For a review of the economic growth of Puerto Rico see, <u>The Role of Food Marketing in the Economic Development of Puerto Rico</u>: Seminar Summary, ed. Robert Nason (East Lansing, Latin American Studies Center, Michigan State University), 1966.

8. <u>Ibid</u>., Chapter VII, "Modeling and Simulation," pp. 81-99. In addition, the discussion in Chapter III of this thesis discusses shortcomings of input-output and national income models with respect to measuring the impact of marketing reforms.

9. The term "systems theory" is used to define a specific methodology which is described in Chapter IV of this thesis.

CHAPTER II

1. Gardner Ackley, *Macroeconomic Theory*, (New York: The Macmillan Company, 1961), p. 505.

2. *Ibid.*, p. 506.

3. *Ibid.*, p. 506.

4. *Ibid.*, p. 506.

5. *Ibid.*, p. 506.

6. Henry J. Bruton, "Contemporary Theorizing on Economic Growth," *Theories of Economic Growth*, Hoselitz, et al. (The Free Press of Glencoe, 1960), p. 242.

7. Moses Abromvitz, "Economics of Growth," *A Survey of Contemporary Economics*, Vol. II, p. 177.

8. Reed Moyer, *Marketing in Economic Development*, Occasional Paper No. 1 (East Lansing, Institute for International Business Studies, Michigan State University, 1965), p. 5.

9. *Ibid.*, p. 3.

10. Charles P. Kindleberger, *Economic Development* (New York: McGraw-Hill Book Company, Inc., 1958), p. 107.

11. Report of the Definitions Committee, *Journal of Marketing*, XII, 2 (1948), p. 202.

12. Moyer, p. 5.

13. Moyer, p. 12-13.

14. Peter F. Drucker, "Marketing and Economic Development," *Journal of Marketing*, Vol. 22 (January, 1958), p. 252.

15. Kelly Max Harrison, *Agricultural Market Coordination in the Economic Development of Puerto Rico*, (PH.D. Thesis), Michigan State University, East Lansing, 1966, p. 283.

16. J. C. Abbott, "The Role of Marketing in the Development of Backward Agricultural Economies," *Journal of Farm Economics*, Vol. XLIV (May, 1962) pp. 249-262.

17. George L. Meyren, "Market Organization and Economic Development," *Journal of Farm Economics*, Vol. 416 (December, 1959), pp. 1300-1315.

18. Harrison, pp. 31-75.

19. Richard H. Holton and John.K. Galbraith, Marketing Efficiency in Puerto Rico, (Cambridge, Mass.: Harvard University Press, 1955).

20. W. W. Rostow, "The Concepts of a National Market and Economic Growth," American Marketing Association. (Winter, 1965), p. 13.

21. W. W. Rostow, View from the Seventh Floor, (New York: Harper & Row, 1964), p. 136.

22. W. W. Rostow, "The Concepts of a National Market and Economic Growth," American Marketing Association, (Winter, 1965), pp. 14-15.

23. Dr. Slater is also Co-Director of the "Comparative Study of Food Marketing Systems in Latin American Countries" project with Dr. Harold Riley of Michigan State University.

24. Charles C. Slater, "International Regional Development," address delivered January 12, 1967, at Travelers Research Center, Incorporated. For supplementary articles by Dr. Slater see "Some Current Studies in the Role of Market Processes in the Development of Latin America," (Lafayette: May 13, 1966) and "The Role of Food Marketing in Latin American Economic Development," American Marketing Association, (Fall, 1965).

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1. G. Hadley, Linear Programming, (Reading, Mass: Addison-Wesley Publishing Company, Inc., 1962), p. 487.

2. Richard Stone, A Programme for Growth-3, Input-Output Relationships, (Cambridge: The M.I.T. Press, 1962), pp. 2-5.

3. Ibid., p. 4.

4. UN ECAFE 1960, Chapter V has a brief discussion of the problems associated with the use of input-output.

5. O. Morgenstern, ed., Economic Activity Analysis (New York: Wiley, 1954).

6. The Junta De Planificacion of Puerto Rice developed input-output model which is used to predict economic growth trends. See "Models de Crecimiento Economics," Informe Técnico No. 3, Junta De Planificacion, Estado Libre Asociädo De Puerto Rico, 1966.

7. Hadley, pp. 490-492.

8. Hadley, pp. 499-501.

9. An alternative method of closing the system is used in the models developed in this thesis.

10. Hadley, pp. 505-508.

11. H. M. Wagner, "A Linear Programming Solution to Dynamic Leontief Type Models," *Management Science*, 3, 3, 1957, 234-254.

12. Stone.

13. Stone, pp. 11-14.

14. Stone, pp. 24-30.

15. Statistical Office of the United Nations, *International Standard Industrial Classifications of All Economic Activities*, New York, 1958, (Statistical Papers, Series M, No. 4, Rev. 1).

16. Joseph L. Tryon, unpublished working paper, 1966.

17. Gardner Ackley, *Macroeconomic Theory*, (New York: The Macmillan Company, 1961), p. 517.

18. For more detail see Evsey D. Domar, "The Problem of Capital Accumulation," *American Economic Review*, 37 December, 1948), pp. 777-794.

19. Ackley, pp. 518-520.

20. A. H. Hansen and R. V. Clemence, eds., *Reading in Business Cycles and National Income*, (New York: Norton, 1953), pp. 200-219.

21. Ackley, p. 529.

22. Ackley, p. 506.

23. UN ECAFE 1960, pp. 81-86.

24. Simulmatics Corporation, *Dynamic Models for Simulating the Venezuelan Economy*, (Cambridge: The Simulmatics Corporation, 1966), pp. 41-49.

25. Ibid., pp. 49-97.

26. L. R. Klein, "The Social Science Research Council Econometric Model of the United States," Econometric Analysis for National Economic Planning, (London: Butterworths, 1964), pp. 129-169.

27. Ibid., p. 170.

28. Ibid., p. 139, p. 148, p. 154.

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1. Kenneth Boulding, "General Systems Theory: The Skeleton of Science," General Systems, Vol. 1, 1956, p. 17.

2. James Miller, A. B. Blalock, "Toward a Clarification of System Analysis in the Social Science," Philosophy of Sciences, Vol. 26, 1959, p. 54.

3. H. E. Koenig and W. A. Blackwell, Electro-Mechanical System Theory, (McGraw-Hill, New York, 1961).

4. J. S. Fram and H. E. Koenig, "Application of Matrices to System Analysis," I.E.E.E. Spectrum, (May, 1964), pp. 18-27.

5. H. K. Kesavan and P. H. Roe, Networks and Systems, (University of Waterloo Press, Waterloo, Onterio, 1963).

6. H. E. Koenig, Y. Tokad, and H. K. Kesavan, "Analysis of Discrete Physical Systems (bound notes)," (Department of Electrical Engineering, Michigan State University, 1964).

7. M. G. Keeney, H. E. Koenig, and R. Zamach, "State Space Models of Educational Institutions," Organization for Economic Cooperation and Development, Proceedings of the Second International Conference, Paris, January, 25-27, 1967.

8. J. R. Ellis, "Outdoor Recreation Planning in Michigan by a Systems Analysis Approach; Technical Report No. 1," State Resource Planning Program, Michigan Department of Commerce, May, 1966.

9. H. E. Koenig, A. Hilmerson, and L. Yuan, "Modern System Theory in Agricultural Industry--An Example," American Society of Agricultural Engineering (submitted for publication October, 1967).

10. F. H. Mossman, and R. J. Gonzales, "Investigation of the Application of System Theory to the Capital Budgeting Problem," Working Report No. 1 (Michigan State University, East Lansing, October, 1966).

11. F. H. Mossman and R. J. Gonzales, "Systems Experiments in Decision Making," Working Report No. 2 (Michigan State University, East Lansing, Mcy, 1967).

12. H. E. Koenig, "Mathematical Models of Social Economic Systems--An Example," Proceedings, 1964 System Science Conference of I.E.E.E., Philadelphia.

13. H. E. Koenig, Y. Tokad, and H. K. Kesavan.

14. Unbound class notes.

15. Conversations and research working papers.

16. H. E. Koenig, Y. Tokad, and H. K. Kesavan, pp. 1-26.

17. _Ibid_., pp. 149-155.

18. Unbound class notes.

19. H. E. Koenig, Y. Tokad, and H. K. Kesavan, pp. 162-163.

20. _Ibid_., pp. 244-263.

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1. U. S. Bureau of the Census in cooperation with the Puerto Rico Planning Board, _1963 Census of Business, Puerto Rico_, BC63-FR. U.S. Government Printing Office, Washington, D. C., 1965.

2. U. S. Bureau of the Census in cooperation with the Puerto Rico Planning Board, _1963 Census of Manufacturers: 1963_, Puerto Rico, MC63-PR, U. S. Government Printing Office, Washington, D. C., 1965.

3. Puerto Rico Planning Board, _Ingreso Y Producto, Puerto Rico, 1964_. Junta De Planificacion, Puerto Rico Planning Board, Commonwealth of Puerto Rico, 1965.

4. Department of Labor, Puerto Rico, _Ingresco Y Gastos De Las Familias_, Puerto Rico 1963, Bureau of Labor Statistics, Department of Labor, Commonwealth of Puerto Rico, 1967.

5. Bureau of Economic and Social Analyzing, 1963 External Trade Statistics, Bureau of Economic and Social Analysis, Puerto Rico Planning Board, Commonwealth of Puerto Rico.

6. Ingreso Y Producto, p. 50.

7. Ibid., p. 50.

8. Ibid., p. 50.

9. 1963 External Trade Statistics, pp. 1-72 and 76-166. The individual codes are too numerous to list. Both Table 1, reporting imports from the United States to Puerto Rico, and Table 2, reporting imports to Puerto Rico from foreign countries must be considered.

10. Ingreso Y Gastos De Las Familias, p. 111.

11. Ibid., p. 5. The income groups of less than $1,000, $1,000 to $1,999, and $2,000 to $2,999 were defined as "low"; income groups of $3,000 to $3,999, $4,000 to $4,999, and $5,000 to $7,499 were defined as "medium"; the income group of $7,500 and over was defined as "high."

12. Ibid., p. 5. The dollar value of expenditures was obtained as the product of the percentage of average total expenditure and the reported average total expenditures.

13. Ingreso Y Producto, p. 31.

14. Ibid., p. 27.

15. 1963 Census of Business, p. 28.

16. Ibid., p. 29.

17. Ibid., p. 18.

18. Ibid., p. 18.

19. 1963 Census of Manufacturers, p. 38. The sum of the appropriate industry data under the column header "Domestic Consumers."

20. The value of $1,241.5 million is equal to the total values of sales as reported on the same pages in the sources footnoted in 17, 18, and 19 above.

21. Ingresos Y Gastoe De Las Familias, p. 31. Income is "average income" times "total number of families" and the food and nonfood expenditure values were obtained by summing reported expenditures by income group.

22. Ingreso Y Producto, p. 25.

23. Ibid., p. 27.

24. 1963 Census of Business, p. 12. The sum of annual payroll to wholesale trade and retail trade.

25. 1963 Census of Manufacturers, p. 48.

26. Ibid., p. 48.

27. Commonwealth of Puerto Rico, Department of Agriculture and Commerce, Facts and Figures on Puerto Rico's Agriculture, 1963.

28. Ibid.

29. 1963 External Trade Statistics. These commodities are identified in Tables 4, 5, and 8.

30. Ingreso Y. Producto, p. 27.

31. 1963 Census of Business, p. 18.

32. 1963 Census of Manufacturers, p. 48.

33. 1963 External Trade Statistics.

34. 1963 Census of Manufacturers, p. 440.

35. 1963 External Trade Statistics.

36. 1963 Census of Manufacturers, p. 440.

37. Commonwealth of Puerto Rico, Department of Agriculture and Commerce, Facts and Figures on Puerto Rico's Agriculture, 1967.

38. 1959-60 Input-Output Table, Puerto Rico Planning Board, Commonwealth of Puerto Rico.

39. Ingreso Y Producto, p. 25.

40. 1963 Census of Manufacturers, p. 22.

41. 1963 Census of Business, p. 13.

42. Ingreso Y Producto, p. 25.

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1. Ingresos Y Gastos De Las Familias, Puerto Rico, 1963, p. 5.

2. 1963 Census of Business, p. 12.

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