THE FEASIBILITY OF USING SIMULATION TO EVALUATE ALTERNATIVE SYSTEMS OF BEEF PRODUCTION IN NORTHEAST BRAZIL

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

JOHN N. LEHKER

1970

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By

John N. Lehker

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Agricultural Economics
1970

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ABSTRACT

THE FEASIBILITY OF USING SIMULATION TO EVALUATE ALTERNATIVE SYSTEMS OF BEEF PRODUCTION IN NORTHEAST BRAZIL

by John N. Lehker

This thesis presents a study of the feasibility of using simulation to analyze the planning of beef production in Northeast Brazil. The model presented focuses on the detailed production relationships of the beef enterprise and other enterprises within the firm which have important economic interrelationships with beef production. The purpose of the model is to develop a conceptual framework which would be useful to agencies who are responsible for rendering technical or financial assistance to the entrepreneur in the process of making investment decisions concerning his beef enterprise.

The model provides for detailed accounting of land use among various combinations of feed production and between feed production and competitive cash crops, competitive meaning a competition between the two for the use of land. The model further translates feed production into costs and revenues resulting from the production of cattle and provides a comparison of the returns from the use of land for feed and cash crop production.

The model also studies the time lag between the time planning decisions are implemented and the time the full benefits of such decisions are realized. By the attention given to this lag the model is able to ascertain the

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economic effects to the firm of not only the land use and herd management alternatives but also of the rate of change from present to future alternatives.

Herd management and sales policies are predetermined by the user and remain more or less fixed throughout the simulation cycle. In order to keep the model stable as the relationship between land and animals change, these policies will be changed once during the simulation cycle when the total herd becomes predominantly modern rather than traditional.

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ACKNOWLEDGMENTS

The research and writing of this thesis was conducted both in Northeast Brazil and at Michigan State University. Its funding was supplied by the Midwestern Universities' Consortium for International Activity and the Brazil Simulation Project. To both organizations the author is gratefully appreciative.

It has been the author's privilege to have been associated with, supported, and guided by three outstanding professors at Michigan State University. To Dr. Harold M. Riley, major professor, and Dr. Marvin L. Hayenga, thesis supervisor, both professors of Agricultural Economics, the author owes many thanks for their patience and guidance. It was with Dr. Thomas J. Manetsch, Associate Professor of Electrical Engineering and System Science and the director of the Brazil Simulation Project, that the author worked most closely in this study. His help was vital to the whole work.

Dr. Dale E. Hathaway and the Department of Agricultural Economics deserve many thanks for their help and financial assistance to the author during his studies at Michigan State University.

The author would like to express his loving thanks to his wife and children whose patience and endurance through this whole episode were decisive to its completion.

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[2]*Ibid*., p

CHAPTER 1

INTRODUCTION

Background

Since the coastal region of Northeast Brazil was found to be well suited for sugar production, it was one of the earliest settled regions of the country. As sugar production increased, a need for plentiful, cheap food became apparent to supply the labor force. Since the coastal region was devoted largely to sugar production, the settlers turned to the interior to produce the demanded food supply.

The interior is subject, periodically, to severe droughts which may last for many years. The drought polygon of Northeast Brazil comprises about one-half the total area of the nine states of the region. It takes up nearly all of seven of the nine states and about half of the state of Bahia. (Figure 1) Only the state of Maranhao is excluded from the polygon.[1] Due to the unevenly distributed and unreliable rainfall in the interior, the area was found to be unsuited to most types of agriculture, particularly cash crops. In years when rainfall is normal, nearly all of it comes in a three or four month period from mid-January to mid-April or May, and the rest of the year the interior receives little or no rainfall.[2]

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[1]Stefan H. Robock, Brazil's Developing Northeast (Washington, D.C.: Brookings Institution, 1963). p. 64.

[2]Ibid., p. 72.

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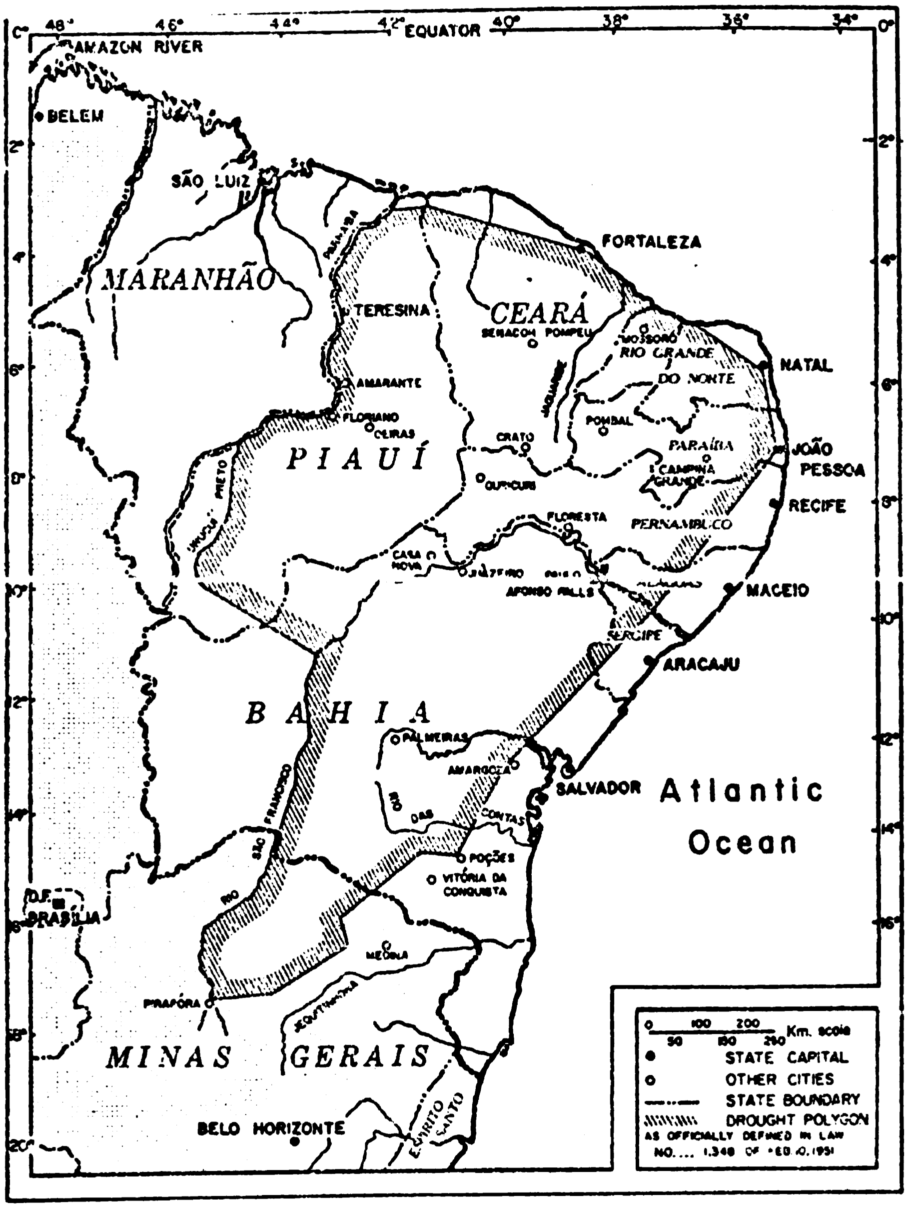
FIGURE I

Northeast Brazil Drought Polygon



Source: Stefan H. Robock, Brazil's Developing Northeast (Washington, D.C.: Brookings Institution, 1963), p. 71.

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When a severe drought occurred in 1958, the estimated size of the cattle herd dropped by as much as 31 per cent in the state of Ceara.[3]

Even though cash crops are unsuited to the interior, it would seem logical to improve suitability through the use of widespread irrigation. However, studies sponsored by the government concluded that the potential for irrigation was very small, encompassing about 1.4 per cent of the land now in cultivation.[4] Because of the interior's unsuitability for cash crops, cattle quickly became an important agricultural product. Currently the production of cattle generates 24 per cent of the total farm income in the Northeast, while agriculture, forestry and fisheries generate 46 per cent of total income in this region.[5]

The Problem

The Northeast is the poorest region in Brazil. The per capita income in 1960 was about 50 per cent of the national average. The mean income per capita for the Northeast was about $140.[6] The distribution of income is also highly skewed; for example, in the city of Fortaleza, about one-half the total population received only about 25 per cent of the total income.[7] This low and skewed income is attended by low levels of caloric intake,

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[3]Anuarios Estatisticos do Brasil (Rio de Janeiro, Brasil: Instituto Brasileiro de Geografia e Estatistica), Vols. 18, 19, 20.

[4]Robock, op. cit., p. 64.

[5]Ibid., pp. 49-55.

[6]Ibid., p. 34.

[7]Suprimento de Generos Alimenticos Para a Cidade de Fortaleza (Fortaleza, Ceara, Brasil: Banco do Nordeste do Brasil S/A, Departamento de Estudos Economicos do Nordeste, December, 1964), pp. 12 ff.

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[9] *Ibid.*,

[10] Robock,

high malnutrition and high infant mortality.[8]

In spite of a high rate of rural to urban migration, two-thirds of the total population of the Northeast still resided in rural areas in 1960. Moreover, the rural-urban income gap is widening, despite the migration and high urban unemployment.[9] Since agriculture is the largest single source of income in the Northeast, the apparent deficiencies suggest that the agricultural sector is not providing sufficient income and employment opportunities.

If the basic problem is low income and insufficient employment, then one intuitive solution is to shift away from labor-saving land and capital intensive means of production toward more labor intensive means. This generally is taken to mean discouraging mechanized and pastoral agriculture and encouraging labor intensive cash crop production. The difficulty here is the previously noted unsuitability of much of the interior for cash crop production. Thus the intuitive solution does not seem to be a feasible way of approaching the problem.

The cattle industry produces 24 per cent of total farm income, making it the second largest single industry in agriculture in the Northeast in terms of income generated.[10] Since cattle production is well suited to the interior

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[8]Donald W. Larson, "A Diagnosis of Product and Factor Market Coordination in the Bean Industry of Northeast Brazil" (unpublished Ph.D. dissertation, Michigan State University, Department of Agricultural Economics, 1968), p. 4.

[9]Ibid., pp. 4 ff.

[10]Robock, op. cit., p. 49.

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relative to other agricultural industries, it would seem to be a logical target for development activity if one wished to improve low incomes. Similarly, if there are improved alternatives to the present beef production system which do not displace the labor the present system uses, then one cannot say, *a priori*, that labor, under such an alternative, would be worse off. Conversely if labor intensive alternatives can be found and implemented, then labor may be better off.

The questions become: (1) Is low productivity in the beef production system a problem? (2) Are there alternatives to the present system which will improve the productivity of land, labor and capital (especially animals)? and (3) Are the alternatives such to increase the use of labor?

The first question may be answered by referring to a study sponsored by the Getulio Vargas Foundation, in which a series of Cobb-Douglas production functions were fitted to data by regions and types of farm specialization. In these functions the dependent variable was total farm income. The estimated coefficients for the Northeast and cattle production are shown in Table I.[11]

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[11]The regression equations used in the study to estimate the values in TABLE I are of the following general type:

$$Y = X_1^{a1} X_2^{a2} X_3^{a3} \ldots X_n^{an}$$

where, for example:

Y=Total farm income
X_1=Area in artificial and natural pasture (Ha.)
X_2=Feed originating from agricultural and.......

The entire equation refers to farms or ranches specialized in beef production in either Ceara or Pernambuco. There is a separate equation for each state.

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TABLE I

COBB-DOUGLAS ESTIMATES FOR ANIMAL PRODUCTION 1962

Variable (X_i)	Coefficient (A_i)	
	Ceara	Pernambuco
Area in artificial and natural pastures	.0007	.0141
Feed originating from agricultural and industrial by-products	.1889	.0212
Vaccines, medicines, and disinfectants	.0786	.0808
Labor	.1204	.0446
Total value of land in permanent crops	.1637	.1050
Total value of buildings, equipment, and work animals	.2734	.4144
Brood cows	-.0058	.0508
Sows	-.0281	.0208
All animals except brood and work animals	-.0266	.0651

Source: Projections of Supply and Demand of the Agricultural Products of Brazil, Vol. 1 (Getulio Vargas Foundation, Brazilian Institute of Economics, Center of Agricultural Studies, 1966), p. 126.

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These data show that increasing the acreage of artificial or natural pasture will be less effective in increasing farm income than other alternatives in Table I. This is true for both regions except for animals in Ceara. The estimated coefficients for Ceara also show that further increases in the size of the cattle herd will reduce farm income.

In general these estimates tend to show that further increases in land or cattle will not increase farm income significantly relative to increases possible from cash crops. The small increases obtainable from pasture means that additional units of pasture would yield very little additional nutrition. Therefore, one may infer that the productivity of current pasture methods is very low. Therefore, the most significant barrier to improved farm income with respect to cattle is the nutrition available.

If the productivity is low, are there any more productive alternatives? One answer can be found by a comparison of estimates of actual productivity with what has been accomplished under controlled conditions. Estimates show that cattle are marketed at four to five years of age; but, under feedlot conditions and high quality feed, cattle from the same general breed have been marketed at eighteen months of age.[12]

Animal scientists at the University of Ceara estimate that market time can be reduced to three years given improvements in nutrition and

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[12]Joint interview conducted with the Faculty and their counterparts from the University of Arizona Project, Escola de Agronomia da Universidade Federal de Ceara, Departmento de Zootecnia, Fortaleza, Ceara, Brazil, September, 1969.

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proper herd management conditions.[13] Proper nutrition and management is an immediate problem which must be solved before consideration can be given to any breeding program to improve the efficiency of the animals themselves. More efficient breeds of animals generally require more and higher quality feed than native breeds as well as better care through management. This latter point is brought up in anticipation of a criticism often leveled at traditional cattle production: that is the limiting factor to improving productivity is breeding. The need for improved nutrition implies that labor intensive home grown feeds, given the unfeasibility of a high supplement ration, are the solution, thus answering the third question.

Objectives

The overall objective of this study was to develop a conceptual framework to study the long run and short run consequences of developmental decisions concerning beef production at the farm or sub-industry level in the Northeast section of Brazil.[14]

Specific objectives were:

1. To develop a model for evaluating alternative means of modernizing beef production in selected areas of Northeast Brazil.

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[13] Ibid.

[14] Industry is defined as all farms or ranches breeding and raising slaughter cattle in the seven states of the Northeast. Seven states refer to the nine states of the region without Bahia and Maranhao.

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2. To formulate and test a computerized simulation procedure for estimating the effects of different systems of beef production.

3. To determine the usefulness of this procedure and specify how it might be further developed into an operational analytical tool for development planning.

A General Review of Simulation, Its Advantages, and Previous Research

For the purposes of this thesis simulation is defined as "a numerical technique for conducting experiments on a digital computer, which involves certain types of mathematical and logical models that describe the behavior of a business or economic system (or some component thereof) over extended periods of real time."[15]

Computer simulation is one of a number of quantitative techniques for analyzing systems models. Simulation has a number of special features which should be of interest to the economist. The technique allows the economist to perform dynamic experiments on an economic system over which there is complete control. Using the technique with the relevant data, the experimenter can test virtually any compatible hypothesis or policy alternative for its impact on the socio-economic environment.[16] Furthermore, this technique has utility to the economist in that it can greatly reduce the number of necessary assumptions concerning the desirability of

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[15] Richard E. Dawson, "Simulation in the Social Sciences," in Simulation in Social Science: Readings, ed. by Harold Guetzkow (Englewood Cliffs, New Jersey: Prentice-Hall, 1967), pp. 1-15.

[16] Thomas R. Webb, "A Systems Model for Market Development Planning: Northeast Brazil" (unpublished Ph.D. dissertation, Michigan State University, 1969), pp. 26 ff.

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goals to be achieved, the normative desirability of one policy over another, and the shape or even the existence of the social welfare function.[17] Using a simulation model (simulator) the researcher can attempt to describe and analyze a larger number of important interrelationships on the system than with other techniques. The policy maker is helped by a simulator in that he can select from among the various alternatives since more information about the political, social and economic consequences of each alternative is available. By using a simulator rather than other models many more dimensions of the problem, economic and non-economic, can be viewed simultaneously and the normative and non-normative consequences of alternative solutions noted.[18]

Simulation in its broadest definition has been a part of man's environment since the beginning of history. Cave drawings, for instance, are simulations of the animals they represent. Simulation has been used in this century in the training of air crews. With the development of high speed computers new applications for the concept were found.[19] The speed of modern computers allows complex problems to be handled in a reasonable amount of time. The business world found application in wedding the computer with the concept of simulation in solving such widely diverse problems as aircraft and electronic circuit design on the one hand to making improvements in their marketing and distribution systems on the other.

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[17]Thomas H. Naylor, "Policy Simulation Experiments with Macroeconometric Models: The State of the Art," American Journal of Agricultural Economics 52 (May, 1970), p. 264.

[18]Glenn L. Johnson, "Discussion of Macro Simulation Models," American Journal of Agricultural Economics 52 (May, 1970), p. 288.

[19]Dawson, op. cit., pp. 1 ff.

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[20] *Ibid.*

[21] Webb,

There are a number of research techniques which are available to the economist which closely approximate simulation. However, in the broader sense, economic models themselves are simulations since they describe some subset of reality and show how that subset behaves internally and how it interacts with its environment.[20] Computer simulation, as distinct from the more general term, simulation, has one advantage over other techniques used by economists. While some relationships can be studied quite adequately by other techniques, computer simulation can study many more such relationships simultaneously. For example, budget studies are capable of analyzing and comparing two or three different combinations of resources, whereas a simulator can study literally hundreds of different combinations. Also, budget studies are capable of determining the profitability of these combinations to the firm; simulators can determine the same information for each of its hundreds of combinations besides the social ramifications of each combination.

Within economic development there has been a growing interest in the use of computer simulation to study the problems of development. Most of this interest has been focused on the study of macro-level problems. In a macro-simulation development study the area of interest is the whole economy or some large subsector of it. Two good examples of macro-development simulators are Webb's Systems Model for Market Development Planning: Northeast Brazil[21] and a study conducted by the Consortium for the Study

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[20]Ibid.

[21]Webb, loc. cit.

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In his model Webb structured a simulation of the overall marketing relationship between the city of Recife and the surrounding region. The model's structure provides a detailed description of the production, distribution and consumption sectors which emphasizes the flows of goods, services, and incomes with the market.[23]

The Nigerian Model, as implied by its title, is a subset of a larger model constructed around the Nigerian rural economy. The model is a macro study in that no discrete production unit can be isolated in the model and the outputs of the model are aggregated values. Likewise the alternatives studied are general policy alternatives and do not reflect alternatives open to the individual farmer except to the degree that he chooses to participate in the alternative systems.

The use of simulation in studying general policy alternatives is the crux of the neglected area in simulation studies of developing economies. Essentially all simulation work has been aimed at helping high level policy makers arrive at optimum decisions for development strategy. Very little work has been done at the farm level. Yet there is a clear need for this type of simulation study. Overall policy decisions must be implemented by individuals and agencies who must translate such decisions

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[22]Glenn L. Johnson, et al., A Simulation Model of the Nigerian Rural Economy: Phase I — The Northern Nigerian Beef Industry, Report to the Agency for International Development (East Lansing: Michigan State University, April 26, 1968).

[23]Webb, op. cit., Abstract.

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into concrete actions. But in the process of doing so these agencies must, in turn, develop their own policies in order to carry out their instructions rationally. Such agencies, for example, must develop policies to allocate funds and personnel among individual farmers, production alternatives and subsectors and do so in conformity to the local socio-economic conditions. Simultaneously these agencies must, or should, take into consideration the externalities their decisions will impose upon such other areas as labor, input and commodity markets, and consumers. They also need to understand and anticipate the constraints upon the individual farmer which limit his ability to behave in the manner desired by the agency. Thus there is clearly a need for simulation studies to aid the lower level policy maker in understanding the nature of the system about which he must make his decisions.

There have been a number of studies aimed at applying the simulation technique to the agricultural firm. All of these have been confined to studies of more developed countries (MDCs). One good example of this type of study is a simulator constructed by Hinman and Hutton. In this study a general simulation model for four firms was constructed based on the generally accepted theory of firm behavior. The objective of this model is "to provide a means of studying management problems using the simulation approach."[24] The objective of studies such as this has been exclusively to help the individual farm manager meet his individual goals.

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[24]H. R. Hinman and R. F. Hutton, A General Simulation Model for Farm Firms, USDA, Agricultural Economics Research, Vol. 22, no. 3 (July, 1970), p. 1.

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These studies are therefore basically farm management simulators designed to analyze what are clearly important problems for developed agriculture and to varying degrees, for underdeveloped agriculture as well. These studies do not approach the basic problem of structural and technological limitations which are imposed upon underdeveloped agriculture or suprafirm goals which should be taken into account by policy makers.

In addition to these limitations on the applicability of present agricultural micro simulators to less developed countries (LDCs) there is a more fundamental limitation. One cannot justify the study of the firm as an isolated unit of production with given states of technology and given ownership.

The range of ownership is much broader in LDCs than in MDCs. More developed economies are well established institutionally and the structure of agriculture is well integrated with the rest of the economy. While radical change is possible in agriculture the process at best can be considered slow and evolutionary in nature. This is not so in LDCs. The political system in most LDCs is perpetually in a state of flux. As long as change in the political systems is possible then changes in the patterns of agricultural organization and ownership are also possible and, indeed, inevitable should a revolutionary change in the political system take place. But even barring political change, the concept of development planning implies directed change and this in turn implies that alternative organizational patterns as a policy goal are not ruled out.

The model developed in this thesis is an attempt to provide government agencies responsible for implementing the national policies (and to a lesser degree

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a lesser degree the farmer) with the means of studying alternative production methods given any state of technology or the means of studying different technology and production alternatives simultaneously. It should be noted that size and method of ownership are independent of the model. Although the "entrepreneur" and the "firm" are referred to frequently in the study, these terms are for convenience and make no real reference to specific organizations or ownership. The model developed here attempts to consider the externalities imposed by the firm on certain other sectors.

The approach used in this study is in some respects very close to that used by Hinman and Hutton. It is not the purpose of the model developed in this thesis to study the day to day management of the enterprise. Instead it looks at the planning phase of the management function. Its purpose is to study consequences, over a period of years, of planning decisions on the enterprise's profits, on labor, on government costs and returns, and the supply of primary products (i.e. meat) through changes in the firm's contributions to total product, taxes, and employment.

The model in this study borrowed an important component from the Nigerian Model. The Nigerian Model has built into it a good framework for determining the demographic situation of the cattle herd. This component was used with slight modifications in the model to be presented here.

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Northeast. This consisted of searching out all known reference materials available at Michigan State University[25] and conducting interviews with individuals at the University who had firsthand knowledge of the cattle industry in the Northeast,[26] or had firsthand knowledge of complementary crop production relationships in the Northeast.[27] At the same time additional information, not currently available, was requested from the Superintendancy for Development of the Northeast (SUDENE) and the Bank of Northeast Brazil (BNB/ETENE). The information thus obtained allowed the author to define the boundaries of the system to be studied more sharply, and formulate additional data requirements not, at that time, available.

At the beginning of September 1969 a three week field trip was taken to Northeast Brazil. Two cities were visited, Fortaleza and Recife, and a brief, one day trip was made to a number of cattle production enterprises to gain some firsthand impressions about their modes of operation. In Fortaleza the author was able to conduct interviews with knowledgeable persons from the Bank of Northeast Brazil,[28] the School of Agronomy of the

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[25]These materials are listed with an asterisk in the Bibliography for the readers' convenience.

[26]Lawrence A. Johnson, Associate Professor of Dairy Science, East Lansing: Michigan State University, a series of personal communications throughout 1969.

[27]Thomas J. Manetsch, Associate Professor of Electrical Engineering and System Science, East Lansing: Michigan State University, a series of personal communications from September, 1968—June, 1970.

[28]Eduardo Bezerra, and others, a series of personal communications at Banco de Nordeste de Brasil, S/A Departamento de Estudos Economicos de Nordeste, September, 1969.

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University of Ceara,[29] the University of Arizona Project to the School of Agronomy,[30] and the Rural Extension Service for the State of Ceara (ANCAR-CEARA).[31] In Recife interviews were conducted with agricultural officials from U.S.A.I.D.,[32] FAO,[33] the Superintendencia do Desenvolvimento do Nordeste,[34] and the Institute of Agronomic Experiments (IPA).[35] The purpose of these interviews was to gain a more detailed knowledge of cattle production relationships in the Northeast, fill in gaps in the data available in published form and confirm important data values already obtained.

The model was constructed using Fortran computer language compatible with Michigan State University's Control Data Corporation 3600 Computer.

The major problem with the data was that little of it was the result of careful, rigorous experimentation or controlled survey research. The

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[29]Faculty..., loc. cit.

[30]Raymond Anderson and Charles Hanes, Livestock Specialists, University of Arizona Project to the School of Agronomy, University of Ceara, personal interviews, September, 1969.

[31]Clinton Saboia Valente, Engenheiro-Agronomo, Fortaleza, Ceara, Brasil: Service De Extensao Rural de Ceara, personal interview, September, 1969.

[32]Dr. Henry Mike Kilpatrick, Agronomist, U.S. Agency for International Development/Ibec Research Institute, and Dr. Roy Carvalheira Wanderley, Chefe de Zootecnia, IPEANE, personal communications, September, 1969. Elbert B. Bowen, and others, Food and Agricultural Officer, Division of Agriculture and Rural Development, U.S.A.I.D., a series of personal communications, September, 1969.

[33]Cleveland James Allen, FAO Animal Production Officer, Recife, Brazil, personal communication, September, 1969.

[34]Technical Staff, Superintendancy for Development of the Northeast, Division of Agriculture and Supply, Recife, Brazil, a series of personal interviews, September, 1969.

[35]Kilpatrick, loc. cit.

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bulk of the data was well informed opinion or the results of case studies of different kinds of farming operations. Except for that obtained through interviews, none of the information was in the form required for the modeling technique. Thus, most of the parameters and variables used in the model have been extrapolated from the original data.

One advantage in using this kind of data is that the range of information concerning the overall system is much broader than for other data collection techniques where the data to be collected are in a form compatible with the proposed model. The data collected in the manner described here contained a good deal of information concerning the structure of the system as well as its input-output parameters and therefore could be used to guide the model builder in constructing the model.

The basic approach used in the model was to measure the resulting revenue, costs, employment, and wage bill given any combination of proposed alternatives for herd management and land utilization.

In this model the basic unit of study is a single, large hypothetical ranch constructed by aggregating the data concerning land, labor, and animals from several real ranches studied by Dickerman from the University of Arizona Project.[36] This procedure may be questionable, especially from an econometric point of view, but since the Dickerman Report provided no usable input-output data, it is not an important objection. Information

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[36]Alan B. Dickerman, The Economic Structure and Analysis of a Ranching System in Northeast Brazil (Fortaleza, Ceara, Brazil: University of Arizona in cooperation with U.S.A.I.D. and the Federal University of Ceara, 1968).

obtained from Dickerman included an estimate of the number of animals which should be combined with the appropriate amount of land in a realistic combination, and a determination of the number of people necessary to tend the postulated amount of land and animals. Actual input-output data were obtained from various other sources and compared, as closely as possible, to the production relationship described in Dickerman's report. In this paper this hypothetical ranch will be referred to as "the firm."

Conceptually there are three broad categories of production functions under which the firm may be operating. These three are classed according to the three major climatic zones of the Northeast. These zones are (1) the dry interior or sertao, (2) the transition zone or agreste, and (3) the humid coastal belt.

For each of these three categories there are two additional possibilities. One is a high capital-labor ratio and the other is a low capital-labor ratio. In reality there are not two such alternatives but an infinite number: the theoretical boundaries being zero to infinity. If hypothetically there are two possibilities with respect to capital/labor, then there are thus far six possible production functions.

For every one of these six production functions there are two more possibilities. These are: (1) the firm is also specialized in the production of milk or, (2) it is specialized in the production of beef. Again this is really a range of specialization options for the firm, but if one assumes that the firm is completely specialized in one or the other then there are twelve possible production possibilities available to the firm. Since th

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firm. Since the focus of this study is on beef production, only six of the twelve will be considered.

Specific alternatives, specific sources of land and potential returns in yields and cash for the firm will be discussed. However, this should not be construed to mean that these are the only sources, alternatives, or potentialities that the model can be made to analyze. For example, when annual cotton is referred to an an alternative to irrigated forages, by changing parameters one may consider cocoa-nuts or bananas or sugar cane or any other such crops as alternatives to irrigated forages. Since the primary purpose of this study was to build a framework and only secondarily to study actual alternatives <u>per se</u>, all the possible alternatives will not be considered here.

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CHAPTER II

THE BASIC MODEL

Introduction

The model performs as follows: Given land being presently utilized according to an arbitrary formula and a herd of cattle being fed at a specified arbitrary level of nutrition and composed of a selected number of males and females with a given age distribution, decisions can then be made with respect to improving the nutrition level of the cattle. These decisions may involve removing land from present utilization and applying it to different uses which will yield more nutrition per unit of land for the cattle enterprise. Decisions can be made with respect to the management of the herd and level of additional supplemental feeding which may be desired. Once these decisions have been made they are instituted for a number of years. At the expiration of this time the results can be compared to the same number of years in which the present practices (i.e. no decisions to change) were affecting the herd.

Two simulation cycles must be made with this model. In the first cycle no modernizing decisions are made. The traditional production process takes place for a given number of years. During this simulation cycle, economic and environmental variables external to the firm behave in a prescribed way. This means that relative prices and outputs change without any influence by the firm.

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and herd management alternatives are made. Then the second cycle is simulated on the computer with all economic and environmental variables not controlled by management behaving in exactly the same manner as in the first cycle (i.e. retaining the same values).

The model is divided into two general sectors. The first sector is animal nutrition and also cash crops. It is here that the process of land reallocation takes place in order to change the nutritional levels available to the second sector.

The second sector is herd management. In this sector herd management decisions change the level and kinds of veterinary care and supplemental feed received by the animals in the herd.

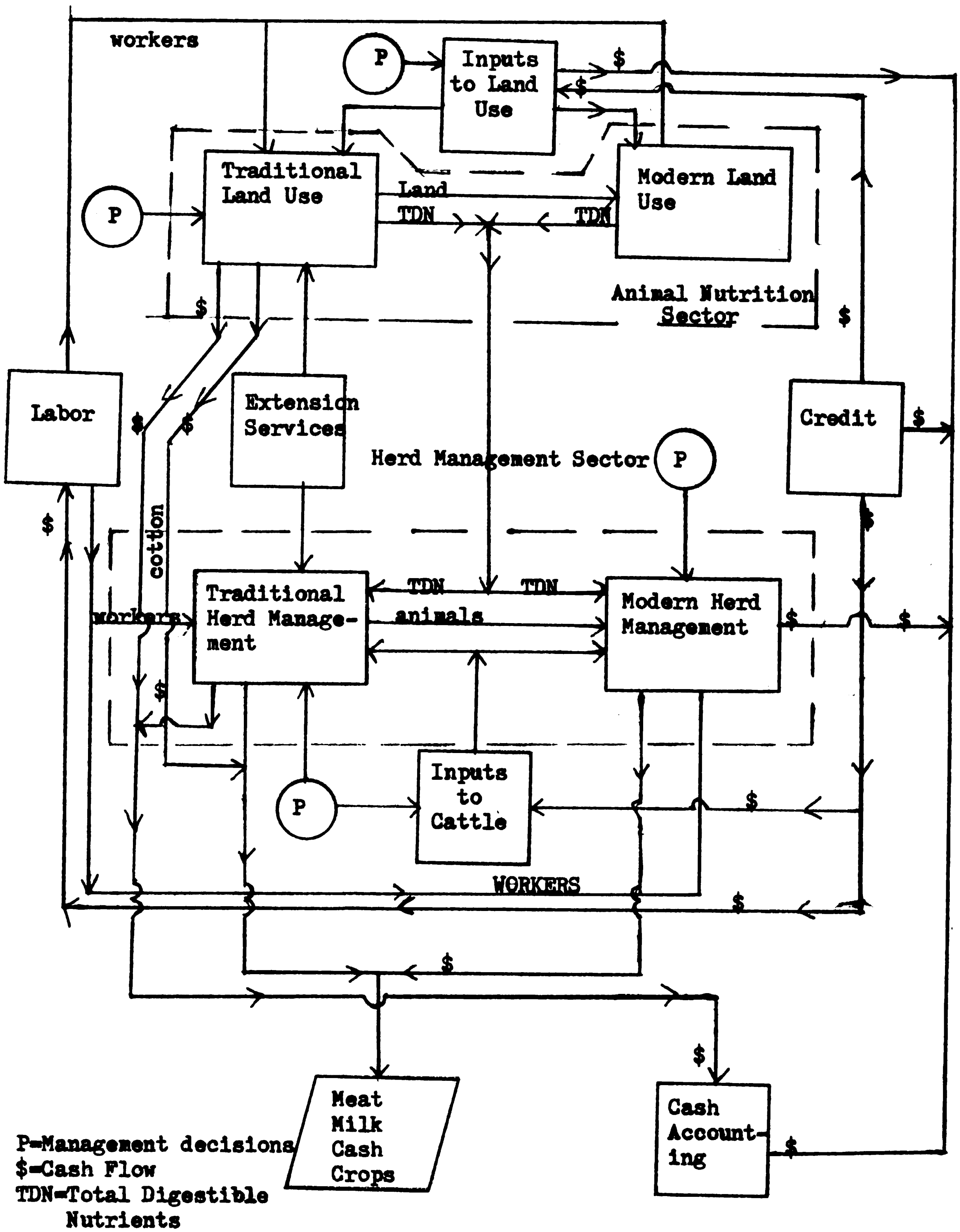
The basic system structure is shown in Figure II. Inputs to land use include not only the operating inputs, such as seed, and fertilizer, but also modernizing inputs such as brush killer and fencing. The actual inputs to the cattle nutrition sector are not differentiated in the model but are accounted for on a cost per hectare basis.

Labor consists of vaqueiros, sharecroppers, and all hired labor. The units of labor are defined to be man-days of labor. Each individual laborer is assumed capable of supplying 250 man-days of labor per year to the system described in the model. Further differentiation of the man-day into hours can only be approximated since most of the available data was in the man-day form. Also, hired labor is generally paid on a per day basis or what may be reduced to such a basis if paid in larger units of time.

Legend: P=Ma
S=Ca
TDN=

FIGURE II

Basic System



Legend: P=Management decisions
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In this model extension services, like credit, are assumed available at whatever levels are required by the modernization scheme being implemented. The implementation of any given modernization scheme in cattle or land use generates a demand for a given number of man-days of extension services per animal or per hectare for each unit actually in the process of modernization, i.e., being "transferred" from traditional to modern production.

An individual extension agent is assumed capable of delivering 200 man-days of service to the system. The cost of this service includes not only the wages of the agent but also the cost of materials, transportation, and, roughly, his share of the bureaucratic structure of the extension service which is consumed per day. Every man-day of extension service is considered identical to every other man-day in cost, only the number of man-days consumed per unit varies according to the innovation being implemented.

Credit is divided into two categories, long run and short run credit. Short run credit is assumed to be used solely for buying supplementary feed. This credit must be repaid within one year at the same rate of interest as long run credit (18 per cent in this model). Long run credit is assumed to be used solely for land modernization. No other operating costs or expenditures are allowed to be financed in this manner in the model. Likewise all land modernization expenditures are assumed to be fully financed through this means, both inputs and labor. The cost of credit, which will be discussed later is defined in the model as the difference between that rate of return which is actually earned and that which would ne

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which would need to be earned for the credit agency to break even. The cost of credit can therefore be negative and would be counted as a profit in the model. In the model this value is plus 2 per cent.

Inputs to cattle are all operating inputs. There are two such inputs in this model. One is a package of veterinary services which consists of a variety of vaccinations for the control of disease and the labor required to administer them. These services are accounted for in the model as a "standard dose" per animal. All labor and medicine costs are assumed absorbed in the cost of the "standard dose." The service agency is assumed to be on a break even basis. Therefore this is not accounted for in the government account.

The Traditional Firm

The firm which is used as the basis of comparison in the model is a hypothetical ranch which is large and specialized in the production of cattle and cotton. For the purposes of the model the size of the ranch is of no importance since constant economies of scale are assumed. The range of limits for size under this assumption is indeterminant. Another feature of the model ranch is the assumption that cotton and cattle are the only two productive enterprises which in any way interact with one another. Food production for on-ranch consumption, other production, and work animals are in no way involved in the problem, that is they are assumed not to exist. Work animals exist only to the degree necessary to perform their tasks on the cotton and cattle enterprises. They create no operating costs, only a fixed cost as an item of capital. If included, work animals would make up

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would make up approximately 3 per cent of the animals on the ranch.

The characteristics of this firm are presented in Table II. This table is divided into two parts. The first part is entitled Initial Values. The values presented under this heading are values which are either fixed for the duration of the simulation cycle or will change as the simulation proceeds. These latter values are the costs and prices in the base year before the influence of inflation or changing market conditions take effect. The second part of the table is entitled Equilibrium Values. These are the interacting variables whose values depend upon the initial values and the management policies under which the model traditional firm is operating.

The Animal Nutrition Sector

Only three sources of animal nutrition for the traditional firm exist in this sector, native pasture, supplemental feed, and crop residue. The first is native pasture, that untended natural range land normally grazed or available for grazing on the ranch or group of ranches in the model. There are no direct inputs to this source of feed. The second is from supplemental feed which is used during the dry season to mitigate the effects of this season. The third is from crop residue; in this case perennial cotton and associated grass which are generally grazed toward the end of the dry season after the cotton has been harvested. For the sake of simplicity, the traditional supplemental feed is assumed to be the same type as that for the modern herd, cottonseed or bean cake, the difference being quantity rather than quality. The nutritional value of

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TABLE II

CHARACTERISTICS OF THE TRADITIONAL FIRM

A. Initial Values

Description	Unit	Value
Land in Native Pasture	ha.	70,360
Land in Perennial Cotton	ha.	1,400
Land in Annual Cotton	ha.	70
Laborers	approx. no.	80
Yield of Meat per Carcass	kg.	150
Total Value of Fixed Investment	NCR$	3,641,500.0
Total Quantity of Cotton Supplied per Year/Level	kg.	308,000
Rate of Inflation	%	20
Interest Rate on Credit	%	18
Cost of Credit to Government	%	2
Average Value of Traditional Animals	NCR$	135.0
Price of Beef per Head	NCR$	160.0
Price of Cotton per Kilo	NCR$	0.50
Yield of Perennial Cotton per Hectare	kg.	200.
Yield of Annual Cotton per Hectare	kg.	300.
Wage Rate per Day	NCR$	3.00
Sales Tax Rate	%	18
Sharecroppers' Share of Cotton	%	50
Vaqueiros' Share of Cattle	5	20
Length of Short Run Credit	yr.	1
Length of Long Run Credit	yr.	5

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Description	Unit	Value
Supplemental Feed per Animal per Year	lbs.	25
Percentage of the Herd Receiving Vaccinations per Year	%	20
Cost of Supplement per Kilogram	NCR$	0.041
Cost of Vaccinations per Dose	NCR$	1.60
Grazing Rate per Animal	ha.	12.5

B. Equilibrium Values

Description	Unit	Value
Grazing Rate per Animal	ha.	10.0
Herd Size	animals	5700
Extraction Ratio (Males & Females)	%	7.7
Sex Ratio (Males & Females)	number	.57
Sales of Animals per Year	number	440
Percentage That Are Females	%	33
Birth Rate (Females Calving per Year)	%	28
Death Rate (Males & Females)	%	9
TDNA (TDN Available per Animal-Year)	lbs.	2100

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the cotton residue is assumed to be the same as for native pasture because grasses are grown in association with cotton; the feed value of cotton and the amount of forage and cotton actually grazed is not well known.

Land areas for which irrigation is feasible are assumed to be in continuous cash cropping because of higher fertility and better water conditions. The model assumes this to be annual cotton managed so that any crop residue is returned to the soil. The model also assumes that no irrigation is presently practiced on the ranch in the model. Land for which there is a potential for irrigation is assumed to have one alternative to its present use, i.e., irrigated forage grass. Other alternatives are beyond the scope of the model. This is for cash crop alternatives to the present cash crops. The model is capable of handling alternatives to forages for feed production under irrigation.

Since perennial cotton production is a relatively labor intensive operation, it was decided that the alternative to perennial cotton should also be labor intensive. Therefore sorghum became the sole alternative to tree cotton.

The greatest portion of the land is untended, unimproved native pasture. From this source will come the majority of the land to be modernized. The first alternative is improved native pasture; that is, native pasture which has been fenced off, debrushed, fertilized, and allowed to grow for one season without being pastured. This practice allows the native annual grasses to become established and, through proper grazing management, perform in much the same way as perennial grasses.

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Improved native pasture is the cheapest and also the least productive of the alternatives to establish and tend.

The second alternative is artificial pasture. The establishment and cultural practices are the same as for improved native pasture except perennial grasses are sown.

The third alternative is forage grasses. For the purposes of this model elephant grass is chosen because it grows well as long as it is not grazed. The establishment practices are similar to the first two alternatives with the added cost of cutting for silage several times in the growing season.

The final alternative for native pasture is sorghum. Here the relevant cultural practices are similar to forages except the cycle is one or possibly two years rather than five. The labor requirement is therefore correspondingly higher.

The complete animal nutrition sector is shown in Figure III.

The level of mechanization is assumed to include horse-drawn implements, hand-harvesting, and gasoline or diesel-operated stationary forage choppers.

Table III shows the modernization and operating costs plus yields for the land alternatives just discussed. These values alone do not show the costs of operating the innovations for one year since all the acreage in any innovation is not replanted every year.

FIGURE III

Nutritional Sector

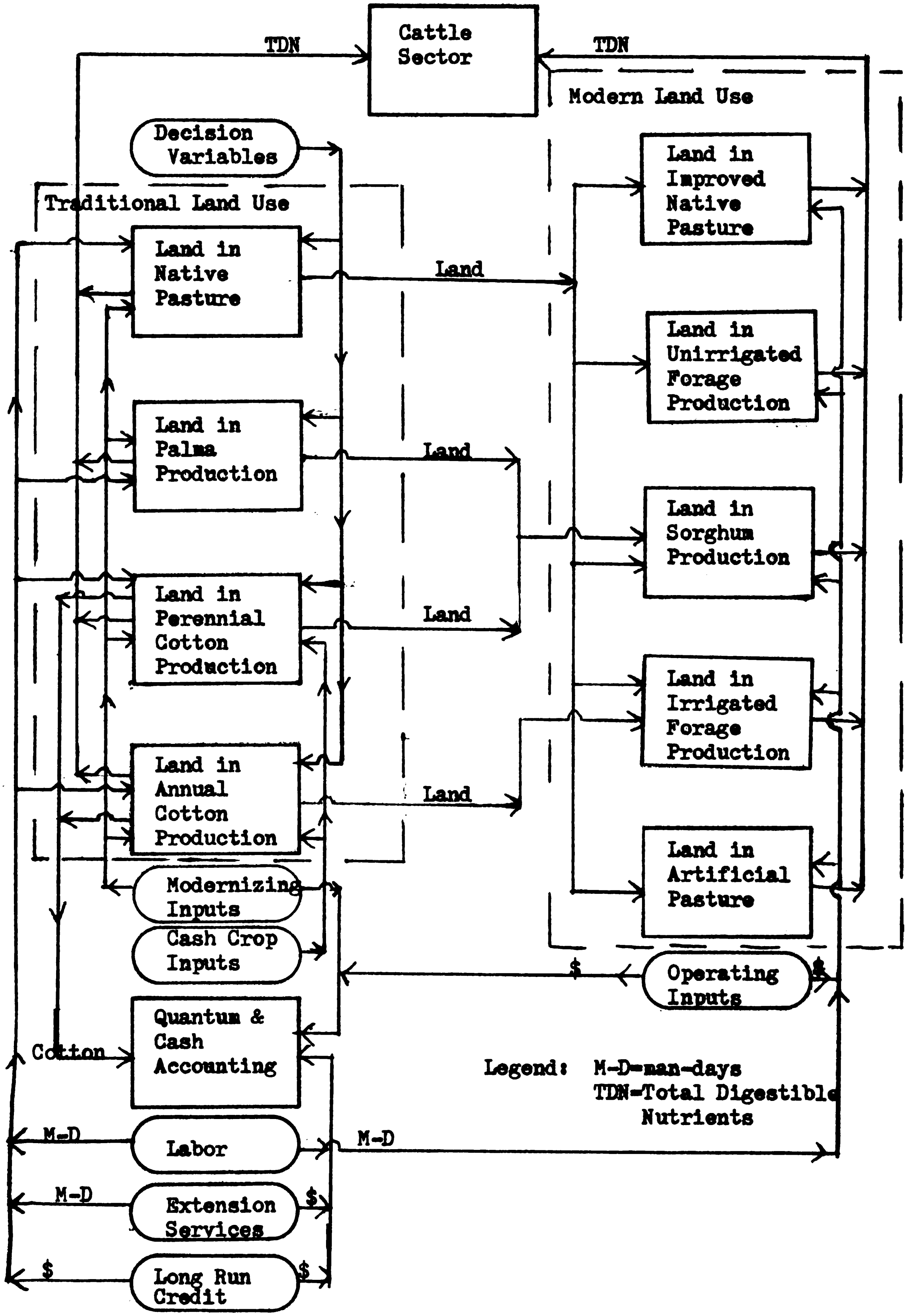


TABLE III

LAND ALTERNATIVE COSTS PER HECTARE

Alternatives	Input Costs		Labor Requirements			Yields	
	Initial	Operating	Initial	Planting	Harvesting	TDN	Cotton
	NCR$		man-days			1000 lbs.	kg./yr.
Sorghum	35	23	63	13	12.5	13.5[b]	n/a
Artificial Pasture	35	35	58	8	n/a	18.25	n/a
Improved Native Pasture	1	1	49	4	n/a	2.2	n/a
Irrigated Forages	220	35	100	10	4	53.5[b]	n/a
Forages	35	35	58	10	3	16.6[b]	n/a
Tree Cotton	n/a[a]	.5	n/a	58	2	.16	200
Annual Cotton	n/a	.75	n/a	10	2	n/a	300
Native Pasture	n/a	n/a	n/a	n/a	n/a	.16	n/a

[a]Not applicable

[b]This value is a function of the number of cuttings per year.

The Herd Management Sector

This sector is divided into three types of herds: Modern, Transitional, and Traditional. The traditional herd is characterized by lower birth rates, higher death rates and slower gain. The modern herd has higher birth rates, lower death rates and faster gain. The transitional herd is included in the management sector to account for the period of time between placing the herd under modern management practices and observing results approximating the modern herd. Because of this, the transitional herd is defined to be receiving modern management and nutrition but to be still producing at the traditional level, that is, on the traditional birth and death rate curves. This measure is used as a proxy for slow gain in productivity. The herd will receive the benefits of modern nutrition and therefore be more productive than the traditional herd, but will not experience the much greater productivity of the modern herd at the same nutritional level (see Chapter III).

Since the herd management decisions are in a sense independent of the nutritional decisions, the decision with respect to the rate animals come under modern management will be a parameter that is not influenced by any other factor. One advantage of this is that for short duration nutritional modernization projects, the herd management may be made to precede the nutritional decision in such a way that as the increased TDN becomes available, there will be increased productivity among the animal population to take full advantage of the increased nutrition. It must be recognized that this does not strictly conform to reality in that improved nutrition and improved management will reinforce each other so that the gains from both will probably be greater than either alone. However, it is the object of this model to build in as much flexibility as possible for the decision maker. The way the model is now constituted the decision maker will be able to explore alternatives of his own creation and not of the model maker. This desire for increased flexibility exacts its price in that the model parameters and variables must be given carefully considered initial values and pre-balanced by the user to prevent irrationality and unrealistic results from occurring as the simulation cycle proceeds.

The herd management sector consists of inputs from the nutritional sector, supplemental feeding, government-supplied veterinary services, extension services and short run credit for one year duration in order to pay for supplemental feeding. The outputs from the sector are meat and milk or cheese depending upon the location of the herd. The cattle also provide additions or subtractions from the capital accumulation of the owner depending upon whether the herd is increasing or decreasing. The herd management sector is shown in Figure IV.

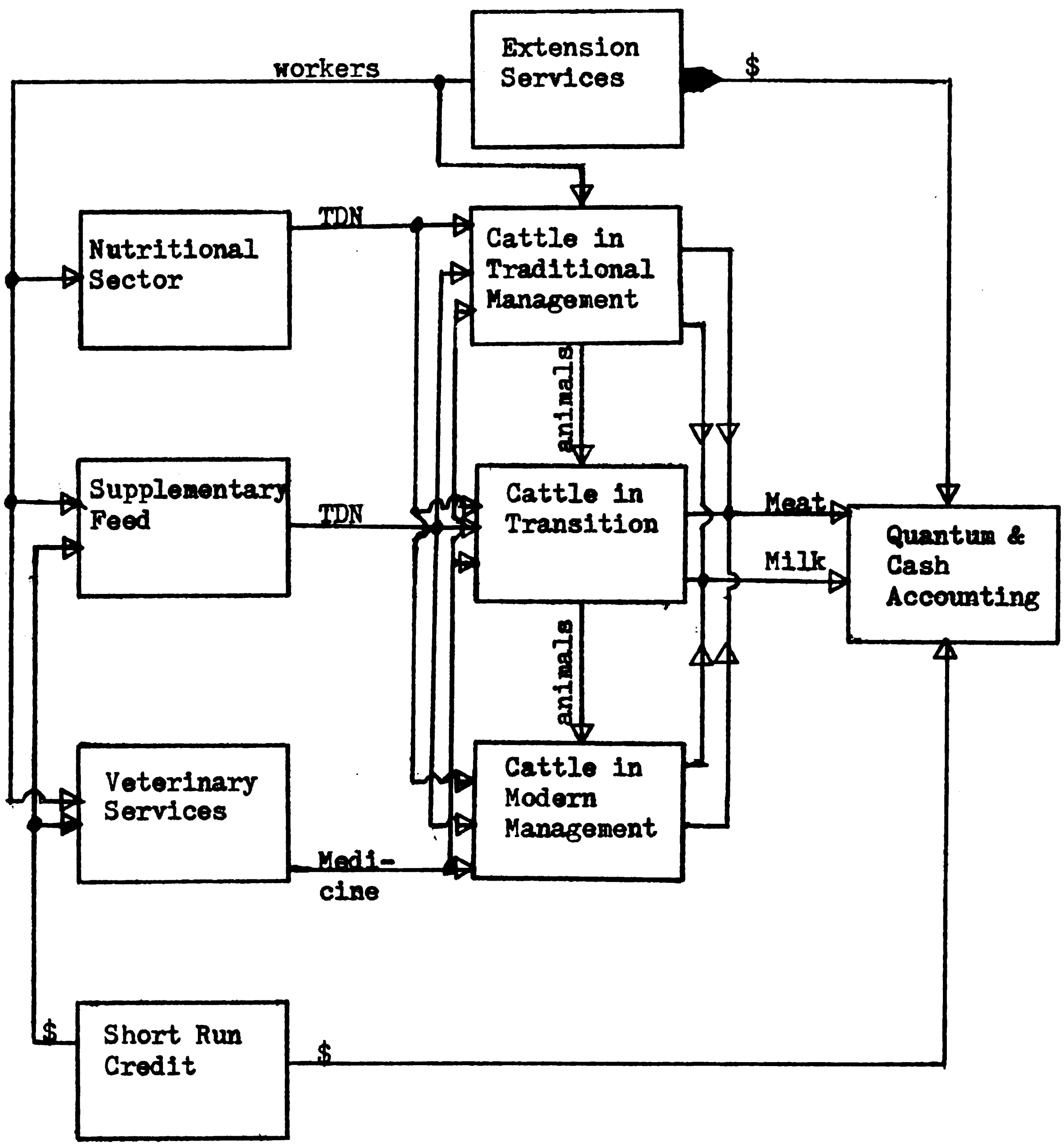
The Overall Model

There are four major policy variables that drive the system (Figure V). These are:

1. Herd modernization policies concerning:
    a. The rate animals are to come under modern management techniques;
    b. The level of supplemental feeding to be received by the modern and traditionally managed animals.

FIGURE IV

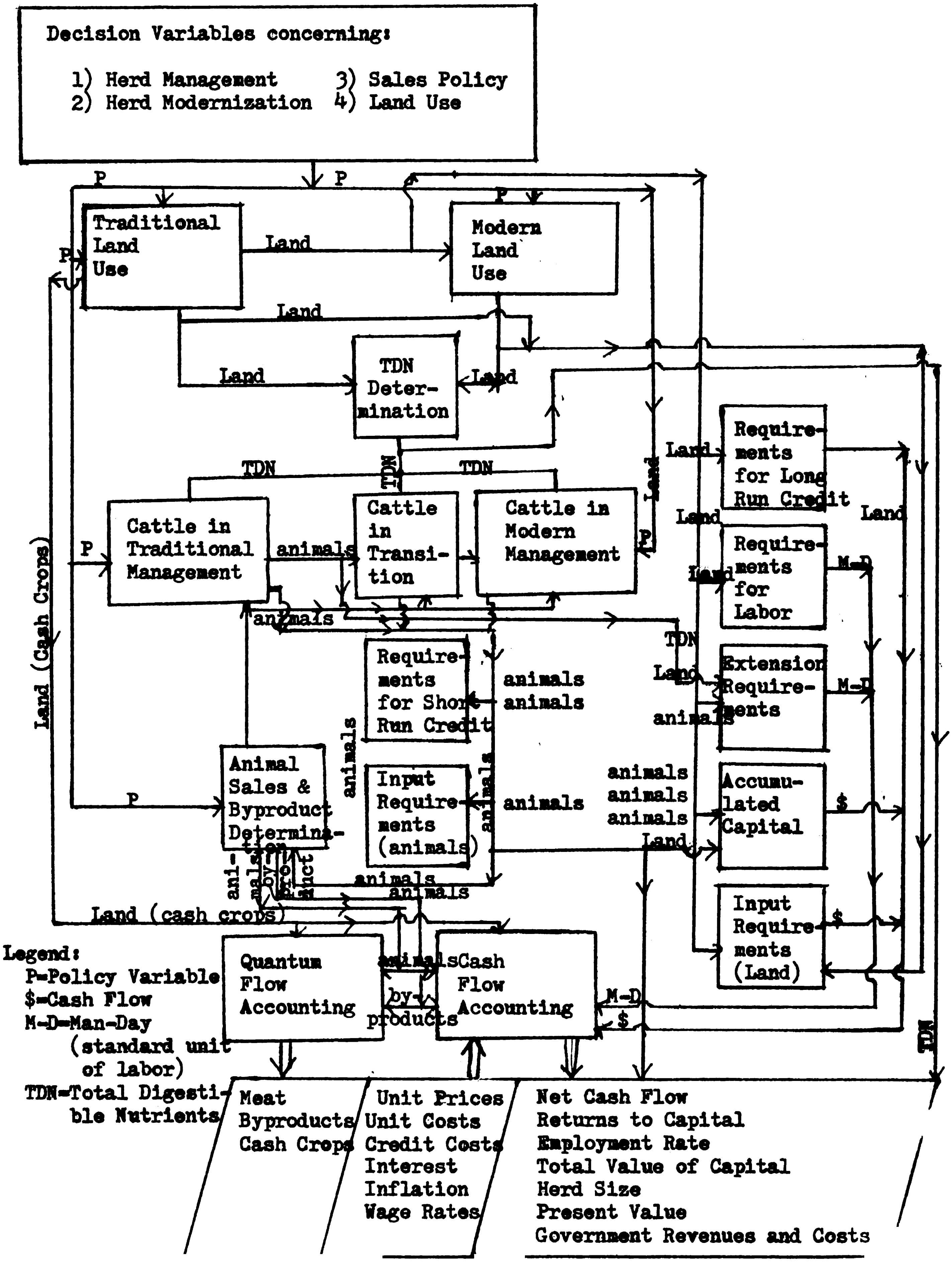
Herd Management Sector



Legend: TDN=Total Digestible Nutrients
$=Cash Flow

FIGURE V

The Overall Model



2. Sales policies with respect to modern, traditional, and transitional herds concerning:
    a. The sex ratio the policy maker wishes to maintain;
    b. The rate at which the herd size is to be changed;
    c. The rate at which animals will be sold in accordance with modern or traditional sales policies.[37]
3. Nutritional modernization concerning hectares and combinations of:
    a. Sorghum
    b. Forages
    c. Improved native pasture
    d. Irrigated forages
    e. Artificial pasture
4. The management of the nutritional sector with respect to:
    a. The rate at which land is to be reallocated among the various alternatives;
    b. The rate at which the various alternatives are to be depreciated out and replaced;
    c. The amount of storage necessary for the forages being planted for silage.

The major parameters taken to be fixed with respect to decisions are:

1. The prices of products and inputs.
2. The rates of inflation.
3. The costs of credit to the government assuming there is a degree of subsidy from this activity.

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[37]There is only one sales policy with respect to the three herds concerning nutritional levels to balance out the herd demands for feed.

4. The interest rate: both returns to alternative investments not in the cattle sector and the cost of debt to the entrepreneur.

5. The wage rate.

6. The costs of government services not absorbed by the entrepreneur.

7. The technical input, labor, and output coefficients.

The major parameters which may be influenced by the decision maker but not controlled by him as an on-going management decision are:

1. The capital-labor ratio;

2. By products of beef production whose returns are yielded to the firm, i.e., a decision between cheese and milk.

3. The initial matrix of land, modern and traditional nutrients, and cattle production;

4. The level of irrigation initially being used.

The major outputs from the model in any time period are:

1. Cash profits per year

2. Cash returns to capital

3. Levels of employment of labor

4. Total capital accumulated

5. The size of the herd

6. The present value at time (t=0) of all returns

7. Total tax revenue

8. Total government costs

9. Private debt balance

10. Meat supplies

11. By product supplies

12. Quantity of cash crops supplied

CHAPTER III

THE DETAILED MODEL

Introduction

The modelling technique used in this thesis is essentially an economic-engineering approach. An alternative technique to analyze a similar problem was used by Dixon in his comparative budget studies of production methods used in cattle breeding herds in the Argentine Pampa.[38] The main difference between Dixon's procedure and this one is that Dixon was able to obtain enterprise combinations and input-output data from actual ranch records for both modern and traditional practices. All data were obtained from ranches with resources in a combination similar to the budgeted one. In the present study this was not possible; instead, data were only available from diverse sources. In this case the input-output data had to be synthesized from these data. The attempt, then has been to meld information from diverse sources into a meaningful structural framework approximating that of the beef enterprises found on ranches and farms in the Northeast.

The engineering approach and its attendant building block concept seems to lend themselves well to the required flexibility of a model purported to be applicable in any given cattle enterprise in the region. Also it was discovered early in the modelling phase that there were many

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[38]J. J. G. Dixon, "An Economic Analysis of Range Improvement in the Cattle Breeding Area of Buenos Aires Province," (unpublished Ph.D. dissertation, Michigan State University, 1969).

points of correspondence in the way seemingly dissimilar computations could be performed. This discovery made possible greater simplification of the model structure than would otherwise have been possible.

The modelling procedure used was to select from whatever sources were available the present combinations of land use, herd size, birth rates, and death rates. These data came mainly from a budget study by Alan B. Dickerman who was at the time of the study a member of the University of Arizona Project in Brazil.[39] Alternatives to the present production process were selected on the basis of (1) what was actually observed by the University of Ceara personnel on the more progressive ranches and (2) what were thought to be potentially useful innovations by these and other personnel.[40] The alternatives considered were restricted to the two major areas of study, nutrition and herd management. Physical input-output relationships for each alternative were then selected from whatever sources were available, hence the building block concept. In some cases input-output relationships for one alternative had to be synthesized from more than one data source. Where possible the input-output relationships once accepted were confirmed in full or in part from additional sources. In certain cases the differences between the accepted relationships and those to which they were compared were sufficiently dissimilar to require serious reconstruction of the relationships to resolve the differences as much as possible.

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[39]Dickerman, loc. cit.

[40]Kilpatrick, Faculty and Counterparts of Escola de Agronomia da Universidade Federal de Ceara, Anderson, and Hanes.

Input and output prices were determined from a third group of sources. These plus fixed costs were then applied directly to the input-output relationships to derive the resulting revenue-cost relationships.

The Demographic Subroutine: The Determination of Herd Size and Productivity

This subroutine is essentially the same as that incorporated in the Nigerian Macro Model II.[41] Here the entire subroutine will be described and dissimilarities will be noted.

```
 1 BR=TABLIE(VALB,SMALLB,DIFFB,KF,TDNA)
 2 DR=TABLIE(VALD,SMALLD,DIFFD,KD,TDNA)
 3 RB=PF*BR/(PF+PM)
31 ERP=RB-DR
32 ERPF=RB-DR*C44
```

Equations 1 and 2 are identical to Macro Model II. Equations 3 and 31 are equivalent to that found in Macro Model II and Equation 32 has been added. The purpose of these equations is to determine the initial unlagged birth and death rates where:

BR: The percentage of females calving per year (% of PF).

DR: The percentage of the total population dying per year (% of PF+PM).

TABLIE(VALB,SMALLB,DIFFB,KF,TDNA): A table look up function in which the computer essentially reads the BR value directly from a graph (see Figures VI and VII).

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[41] Johnson, *et al.*, *op. cit.*, pp. 17 ff.

On the graph TDNA is the independent argument and BR the dependent argument.[42]

RB: A dummy variable to redefine the births as a percentage of the total herd.

PF: Population of females (K animals).[43]

PM: Population of males (K animals).

ERP: The unlagged extraction ratio of males. This is the percentage of excess births over deaths.[44]

ERPF: Unlagged extraction ratio of the females.

C44: A parameter which allows for a differential death rate for the females.[45]

It is important to note the value C44 takes and in which equation it is added. If used in equation 32 then it will have the net effect of shifting the total death curve upward, thus causing distortion. If used in equation 31, C44 would be less than one and would have the effect of shifting the whole curve downward, again causing distortion. Therefore, caution should be exercised when using this parameter so that its value does not become too large (or too small). If DF is greater than DM

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[42]Robert W. Llewellyn, Fordyne: An Industrial Dynamics Simulator (Raleigh, North Carolina: Typing Service, 1965), pp. 423 ff.

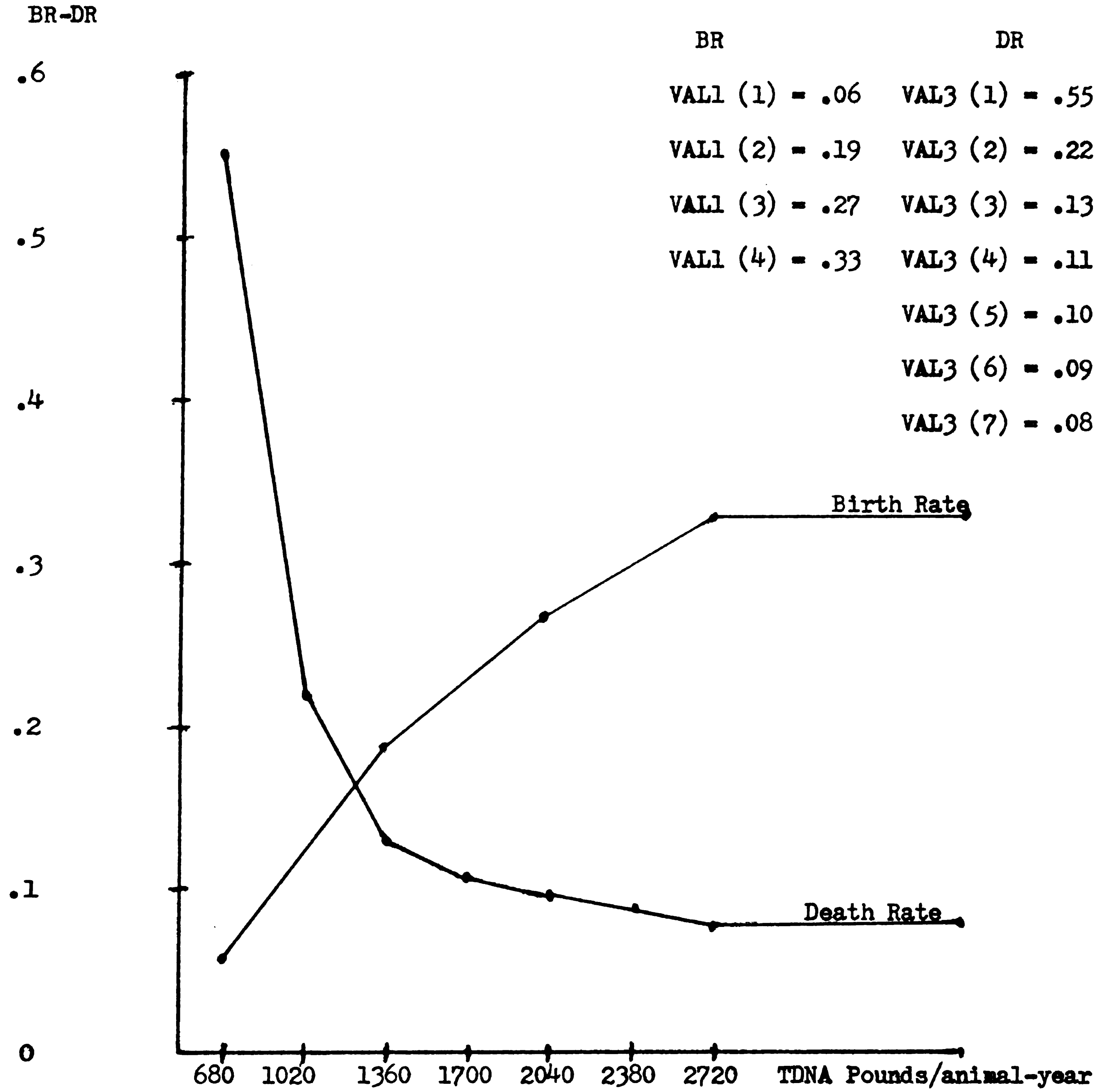
[43]K indicates thousands.

[44]Note that 3 and 31 would be combined in the Nigerian Model to form the following equation: ERP=PF*BR/(PF+PM)-DR. This equation assumed that the death rates of the males and females are identical which may not be true. Therefore the model presented here separates the two and makes allowances for separate death rates as was suggested by further work on the Nigerian Model, Manetsch, loc. cit.

[45]Note that this parameter would be about 1.7 for the Nigerian Model. Ibid.

FIGURE VI

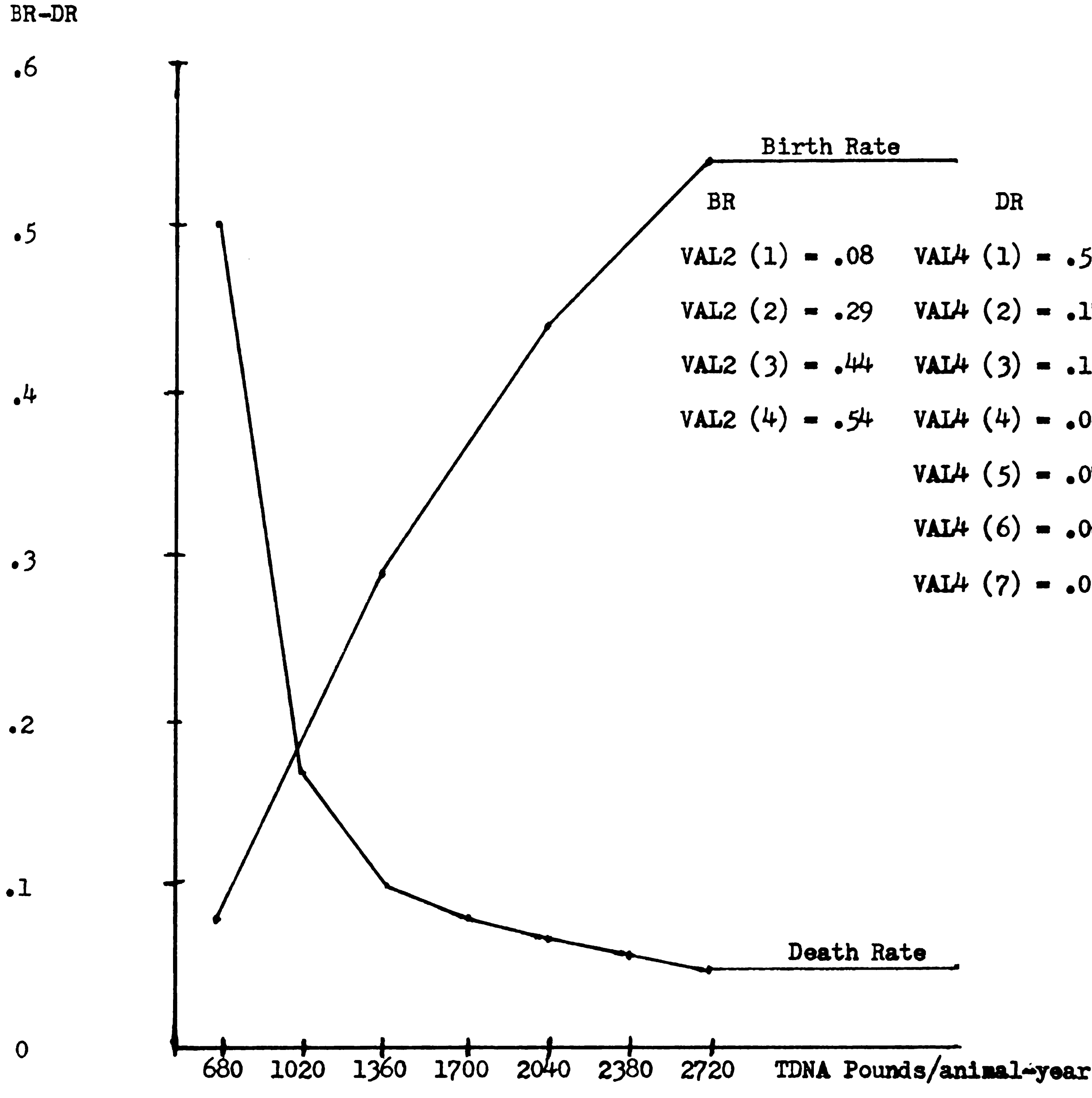
Traditional Birth and Death Rate Curves



Source: A Simulation Model of the Nigerian Agricultural Economy: Phase I - The Northern Nigerian Beef Industry, pp. 20-21.

FIGURE VII

Modern Birth-Death Rate Curves



Source: A Simulation Model of the Nigerian Agricultural Economy: Phase I - The Northern Nigerian Beef Industry, pp. 20-21.

by some large factor then a weighted average should be used in order to average out the potential distortion. A more accurate but more time consuming method would be to use separate death curves for males and females.

Equations four through twelve determine the actual animals born per year.

4 A1=BR*PF

5 A1P=A1P+(DT/.3)*(A1-A1P)

6 .,....,9.,..........

10 A2=A2+(DT/BRDEL)*(A1-A2)

11 BF=.5*A2

12 BM=BF

A1: A variable which redefines the birth rate from a percentage into a rate of animals. This is an unlagged variable (K animals/year).

A1P: The proposed lagged birth rate in which it is explicitly assumed that the current birth rate is a function of past events (K animals/year).

Equations 6 through 9 determine the birth rate delay (BRDEL) of equation 10. In this case if the long run proposed birth variable is less than the unlagged current births then the birth rate delay will be increased and vice versa.

A2: The actual lagged births in the current time period (K animals/year).

Equations eleven and twelve reflect the obvious fact that one half the animals born will be females (BF) and one half males (BM). DT is the basic time unit of the model one DT=.1 of a year.

The next series of equations compute the deaths of animals per year.

121 DRF=C44*DR[46]

13 A3=PF*DRF

14 DF=DF+(DT/D3)*(A3-DF)

15 A4=PM*DR

16 DM=DM+(DT/D4)*(A4-DM)

DRF: The death rate of the females.

A3: A dummy variable which redefines the unlagged female death rate into an unlagged rate of animals (K animals/year).

DF: The lagged current time period death rate. As in previous equations this explicitly assumes that current death rates are a function of past events.

A4: Same as A3 but for males.

DM: Same as DF but for males.

The following equations compute the extraction ratio for males and females and augment the level of males and females.[47]

17 ER=ER+(DT/D5)*(ERP-ER)

171 ERF=ERF+(DT/D5)*(ERPF-ERF)

---

[46]Note: Equation 121 does not exist in the Nigerian Model.

[47]Note: Equation 171 and statement 172 do not exist in the Nigerian Model.

```
172 IF(KKK.EQ.O.) GO TO 20
 18 PF=PF+DT*(BF-DF-SF-RFT)
 19 PM=PM+DT*(BM-DM-SM-RMT)
```

ER: The lagged extraction ratio showing the current percentage of males which may be extracted from a stable herd without changing the herd size.

ERF: Same as ER but for females.

PF: Population of females. Equation 18 is a level equation in which SF (rate females are sold), DF, BF, and RFT (rate females are transferred into or out of the herd) are rates used to calculate the net change from the year at current rates and the incremental addition for the herd is made (K animals).

PM: Population of the males, the argument is identical with that above.

IF(...: This statement is a switch function designed to omit equations 18 and 19 at this time for the transitional herd which will be calculated elsewhere.

Equations 20, 21, and 22 compute the amount and gross returns from the herd by-product if the herd is specialized in beef or the main product if the herd is specialized in milk.

```
20 QM=PF*PFCA*YMA*TABLIE(VAL5,1360.,1360.,1,TDNA)
21 QCH=QM*TCFFC
22 YC=QCH*PRC
```

QM:

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QM: The quantity of milk produced by the total herd (K kg/yr.).

PFCA: The proportion of females lactating (%).

YMA: The average yield of milk per animal (kg).

TABLIE(...: Another table look up function where an upper limit of milk is the dependent argument and TDNA is the independent argument.

QCH: A conversion variable which may be redefined as cheese or left as milk, or some other milk product as desired (K kg/yr.).

TCFFC: A technical coefficient to convert rates of milk into rates of some other milk product.

YC: Total revenue from QCH (in K NCR$/yr.).

PRC: The price of QCH in NCR$/kg.

The Cash Crop Subroutine (Subroutine Crop)

This subroutine is used in calculating revenues, costs, quantities of output, and labor inputs for cash crops. As currently used in association with perennial and annual cotton, it may be expanded to any number of cash crops.

Equations 1, 2, 3, and 42 compute the total quantity of the crop produced per year, the gross return, tax return, and sharecroppers' share.

```
1 TOTC=HECT*YIELD
2 A=TOTC*PRICE*EXP(RFFP*TDT)
3 B=A*TAX
42 C=(A-B)*SHAR
```

TOTC: The total quantity of the cash crop produced (K kg/yr.).

HECT: The amount of land in the crop (K ha).

Yield: The average yield of the crop (Kg/ha-yr.)

This is a constant value and therefore is the long run average.

A: Gross return from the crop (K NCR$/yr.).

PRICE: Price of the crop (NCR$/kg.).

EXP(RFFP*TDT): This is an exponential function defined to be equivalent to e^{it} where RFFP is the rate of inflation of farm products (in general) and TDT is time defined in tenths of years. In every iteration of the model, TDT is augmented by DT, i.e. TDT=TDT+DT. Initially, TDT is set to zero. This formulation allows the model to compound the inflation through time. Note also by changing RFFP relative to other inflationary parameters, the model user is able to change classes and/or specific relative prices continuously over time.

B: Tax revenue (K NCR$/yr.)

TAX: The tax rate.

C: Net return after taxes and reduction of sharecroppers' share accruing to the owner (K NCR$/yr.)

SHAR: The inverse of the sharecroppers' share, i.e., if the sharecroppers' share is a% then SHAR=1-.a

Equations 5, 6, 7, and 8 compute the returns to the sharecroppers; the total cost to the entrepreneur, and the amount of employment generated per year from this cash crop. Labor is calculated in man-days per year (M-D/yr.) where a man-day is defined as an eight hour day. One man employed for one year is defined as able to generate 300 man-days of labor per year.

5 WB3

6 D-H

7 PTC

8 EMP

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5 WB3D=(A-B)-C

6 D=HECT*RPR

7 PTCD=D*(CTOI*EXP(RFLTI*TDT))

8 EMPL=D*WP+TOTC*WH

WB3D: The sharecroppers' share (K NCR$/yr.)

PTCD: The costs incurred by the owner from replanting the crop. Note that the model as formulated assumes no cash costs are incurred from harvesting or marketing the cash crop.[48]

D: K Ha/yr. being replanted.

RPR: The rate the crop is replanted (for annual cotton this value is 1).

CTOI: Costs of inputs for planting per hectare (NCR$/ha.).

RFLTI: The rate of input inflation.

EMPL: The rate of employment per year from the cash crop. This includes sharecropper labor as well as hired labor. (K M-D/yr.)

WP: Labor requirements for planting (M-D/ha.).

WH: Labor requirements for harvesting (M-D/ha.).

"Subroutine Plast"

This subroutine may be considered in one of two ways. First it may be regarded as the costs and employment possibilities of reestablishing the land production alternatives as they complete their useful life cycle and require replanting. This is the actual meaning of this subroutine.

[48]This assumption, while simplifying, is unrealistic and should be changed.

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1 A=HE

2 B=HE

3 C=HE

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CPR:

4 D=C*

5 E=C*

6 PTC=

7 EMPI

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An alternative consideration is to regard this subroutine as determining the amount of reinvestment necessary in the nutrient sector in any time period.

The seven equations comprising this subroutine are as follows:

1 A=HECT*RPR*WP

2 B=HECT*RPR*CTOIP*EXP(RFLTI*TDT)

3 C=HECT*CPR

A: A variable to calculate the labor requirement for replanting (K M-D/yr).

HECT, RPR, WP WH, RFLTI, TDT are identical to those in SUBROUTINE CROP.

B: The cash costs of replanting the alternative under consideration (K NCR$/yr.).

CTOIP: The cost of inputs for replanting (NCR$/ha).

C: A variable denoting the amount of land in the alternative which will be harvested in any one year (K Ha/yr.).[49]

CPR: The number of cuttings to be accomplished in any one year. For grazed crops this value will be zero. The yield of the crop will be dependent in part upon this value.

4 D=C*WH

5 E=C*CTOIH*EXP(RFLTI*TDT)

6 PTC=PTC+(E+B)

7 EMPL=EMPL+A+D

These four equations compute the labor requirement for harvesting,

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[49]This reflects the necessity of cutting forage crops.

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WI:

costs of harvesting, total costs of operating the alternative for one year and total labor requirement for one year. The variables are:

D: Labor requirements for harvesting (K M-D/yr.).

E: Costs of harvesting (K NCR$/yr.).

CTOIH: Cost of harvesting inputs (NCR$/ha).

PTC: Total cost to the entrepreneur (K NCR$/yr.).

EMPL: Total employment (K M-D/yr.).

"Subroutine Bod"

This is the final subroutine to be discussed in detail in this thesis. This subroutine consists of three equations and performs the function of calculating the initial costs, labor, and extension requirements of setting up the land alternatives.

```
11 RPTC=RHECT*CTOI*EXP(RFLTI*TDT)
 2 REMP=RHECT*WI
 3 REXTC=RHECT*EXTC
```

RPTC: The rate of addition to total private cost from establishment of this alternative (K NCR$/yr.).

RHECT: The rate land is put into production of the alternative in question (K Ha/yr.).

CTOI: The costs of establishing the alternative (NCR$/ha).

REMP: The rate of addition to total employment from the establishment of this alternative (K M-D/yr.).

WI: The labor requirements for establishing the alternative (M-D/ha).

REXTC:

EXTC:

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REXTC: The rate of addition to the extension load from the establishment of the alternative (K M-D/yr.).

EXTC: The per unit extension requirements for the alternative (M-D/ha).

With respect to extension and extension costs, it is assumed that the total government extension costs may be translated directly into labor requirements. Thus, once the labor requirements are determined, the total costs to the extension service may be determined directly from this value.

Other Subroutines and Functions

Two other subroutines are used in the model for the sole purpose of calculating distributed delays. These are the DELAY and DELDT subroutines. Both are essentially the same but the DELDT routine allows a much smaller delay with a given DT value.[50]

A table look up function, FUNCTION TABLIE, is also used in conjunction with the Demographic Subroutine.[51]

The Structural Equations

Statements 992 through 997 set up a mechanism to control the policy decisions. The basic policy decision with respect to nutrition is setting a land target. That is, regardless of the combinations of alternatives selected, the decision maker must select the number of hectares he thinks reasonable to include in the modern sector. This is not to imply that

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[50]For discussion see Llewellyn.

[51]*Ibid*.

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such a land target must be selected independent of the knowledge of (1) the combination and relative size of the alternatives or, (2) the size of the herd. However, in order to keep the model simple and allow the innovational process to be stopped at the appropriate time, the land target concept was selected. The land target is important because of the existence of a large amount of land and a relatively small number of cattle. The model must be capable of ceasing the innovative process to avoid producing nutrition at a level which is far above that necessary for the number of head in the model.

Included in the nutritional decisions is the selection of combinations and relative weights of the alternatives to be used. Since there are differential costs and benefits to these alternatives, these decisions must also be made with respect to the overall system and the land target.[52] Another group of parameters are used to select the rates at which the land is transferred from the traditional to the modern sector. These rates are vital in determining the degree of stability of the model. If these rates are too low, the cattle population, depending upon the sales policies and rate of management modernization, will cause the herd to decline absolutely over time. If too high, subject to the management and sales policies, the yearly returns will decline for a variable period allowing the herd to build up. This increase in herd size to the detriment of the revenue component will result in any case from the lack of a buying function. There is, therefore, an optimum rate of increase in herd size which will optimize the long run returns to the entrepreneur.

Statements 994 through 997 make provision for stopping the transfer

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[52]C68 is a parameter determining the land target in K ha.

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of cattle to the modern sector. This mechanism depends upon the desired TDN level of the modern herd. This is a "target" or parameter value. When the nutrition available exceeds a limit above the target level, then the transfer mechanism is started at a parametric rate. As the herd is transferred to the modern sector, and coupled with the sales policy, the rate of growth of TDN over and above the TDN target in the traditional herd will be slowed. Depending upon the rate at which the land is transferred, this growth may continue until the land target is reached or until the modern herd is of sufficient size to insure that the total TDN per animal (in the model GTDNA), modern and traditional, becomes less than the lower limit around the desired TDN per animal (DTDN). At this point the transfer of animals will stop until the GTDNA again exceeds the upper limit. With proper management of the model only the first of these limits need be exceeded. If it is desired to keep the herd constant, then land transfer rates, animal transfer rates, and sales policies may be adjusted in order to just exhaust the traditional herd as the land target is met.

Statements and equations 1000 through 1014 are used to call the crop subroutine as often as necessary to cover all cash crops. In this model it is called twice, for perennial cotton and annual cotton.

```
1012 PTC=PTHC+PCTC
1013 PTR=PCTR+PTRC
1014 WB3=WB3C+WB3H
```

PTR: The total revenues after taxes and share payment, accruing to the entrepreneur (K NCR$/yr.).

PCTR,PTRC

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PCTR,PTRC: Same as PTR but for the perennial and annual cotton sectors respectively.

WB3: Sharecroppers revenues after taxes (K NCR$/yr.).[53]

Equations 1012 through 1014 are necessarily separate and distinct from the subroutines so that the model can be generalized to an n-dimensional cash crop sector. The cash crops must be calculated in every time period since the amount of land available to these cropping alternatives is subject to change with time.

Equations 1100 through 1170 compute the total TDN available in any time period from the modern nutritional sector.

1100 TDNINP=YINP*HINP

1110 TDNAP=YAP*HAP

1120 TDNS=YS*HS

1130 TDNIP=YIP*HIP

1140 TDNF=YF*HF

1170 TDNM=TDNINP+TDNAP+TDNS+TDNIP+TDNF

In equation 1100:

TDNINP: The total TDN available from improved native pasture (K lbs./yr.).

YINP: The yield of TDN of improved native pasture (lbs./ha).

HINP: The total land in improved native pasture (K Ha).

Equation 1110 refers to artificial pasture.

Equation 1120 refers to sorghum.

Equation 1130 refers to irrigated forages.

Equation 1140 refers to non-irrigated forages.

Equation 1170 computes the total TDN from the modern nutritional sector

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[53]The C and H subscripts denote WB3 for perennial and annual cotton respectively.

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1202 TMU

1204 PTC-

1220 TCU-

1222 PTC

1223 EMP

1224 SRC

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5 THI

in K lbs./yr. (TDNM).

Equations 1202 through 1224 compute the impact of supplemental feeding and veterinary care on costs and employment.

1202 TMU=THT*C60+C5*(THM+THD)

1204 PTC=PTC+TMU*CM*EXP(RFI*TDT)

1220 TCU=CPHT*THT+CPH*(THM+THD)

1222 PTC=PTC+TCU*CC*EXP(RFI*TDT)

1223 EMP=EMP+TCU*WDC

1224 SRCC=TCU*C8*(CC*EXP(RFI*TDT))

TMU: Total animal doses administered of a predefined combination of drugs (K doses/yr.).

THT, THM, THD: Total population of the traditional, modern, and transitional herds respectively.[54]

C60: A parameter determining the percentage of animals treated in the traditional sector.

C5: A parameter determining the number of animals treated in the modern sector (%).

CM: The cost of veterinary services per aggregated dose in the base year.

TCU: The total amount of supplemental feed used per year (K lbs./yr.).

CPHT: A parameter determining the pounds per head per year of supplement fed in the traditional sector.

CPH: Same as CPHT but for the modern sector.

RFI: The rate of inflation of inputs.

WDC: The labor required to handle and distribute the supplemental

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[54]THT=PFT+PMT.

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SRCC:

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1270 TDNN

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feed (M-D/lb.).[55]

SRCC: Credit requirements for feeding supplemental feed. Because the government suffers a net loss in handling the credit, a credit subsidy is assumed.[56] This is credit for one year duration (K NCR$/yr.).

C8: A parameter reflecting the percentage of the total supplemental feed bill that is lost to the government. It is assumed in this model that the whole cost is financed through a short term loan.

CC: The cost of the supplemental feed per pound in the base year (T=0).

The following equations compute the TDN available from the traditional sector.

```
1270 TDNNP=YNP*RCON*HNP
1280 TDNP=YP*HP
1160 TDNC=YTC*HC
1290 TDNT=TDNNP+TDNP+TDNC
```

TDNNP: Total available TDN from native pasture (K lbs./yr.)

TDNP: The same, but for palma. Palma, a crop of some small impact

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[55]Note that labor requirements for veterinary services are assumed to be absorbed in the cost since it is assumed that this labor is accomplished by veterinary personnel.

[56]This loss is the difference between the rate of interest and service charges on the one side and the rate of actual costs per unit time in real terms to the government.

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as a feed source, is approximately 92 per cent water and 8 per cent dry matter. At one time there was serious consideration of palma as a nutritive source, especially in dry areas; however it seems to be losing its popularity and the data did not indicate any in the area of the Northeast from which the data were taken. Palma was, therefore, included at a zero hectare level.

TDNC: The same but from the residue from tree cotton (perennial).

RCON: A variable reflecting the degree of over grazing. This is a function of pasture land and herd size, defined below.

```
1240 GRT=HNP/((THT+THD+THM)*(TDNT/(TDNT+TDNM)))
1250 RCON=RCON+DT*C6*(GRT-GRE)
```

GRT: Grazing rate in the traditional sector (Ha/animal).

RCON: An exponential average of the difference in traditional grazing rate versus an equilibrium grazing rate: If GRT-GRE=0, then the limit as time approaches infinity of the range condition is one.

C6: A parameter reflecting the impact in any time period of the disequilibrium on the total value.

From the definition of GRT and the corresponding independence of the herd innovations from pasture innovations, it is easy to see that $GRT \neq f(THT)$ only. Therefore it becomes necessary in equation 1240 to make GRT=f(THT,THD,THM, percentage of total nutrition from traditional sources). In the manner shown in 1240, GRT will remain a reflection of actual grazing conditions in the traditional feed sector. It has been explicitly assumed that the modern pasture practices incorporated in the package of innovations will reflect proper grazing rates for the modern feed sector. It can also be expected, as pressure is taken off the traditional sector, that the yield of the native pasture will improve.

GTDNA=(TDNT+TDNM)/(THT+THD+THM)

TDNAT=GTDNA+TDNAKT

TDNAM+GTDNA=TDNAK

The above three equations determine the availability of TDN for the three herd components. As previously explained, the transitional herd is managed according to modern requirements with traditional results. Therefore there needs to be only two availability variables for the three herds.

GTDNA is the total TDN per animal available from the two sources of farm produced feed. TDNAKT is the TDN per animal arising from supplemental feeding in the traditional herd. TDNAK is the same but for the modern herd. These last two parameters are calculated in the initial phase of the model using the following two equations:

(1) TDNAKT=CPHT-TDNK

(2) TDNAK=CPH*TDNK

Where TDNK is a parameter whose value depends on the percentage value by weight of the TDN in the supplemental feed used. GTDNA,TDNAT, and TDNAM are in pounds per animal-year.

Equations 1292 through 1340 compute the amount of land to be taken out of traditional land use. These are rates in K Ha/yr.

1292 RLLHC=C10-HHC

1293 RLLC=C12*HC

1340 RLL

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1340 RLLNP=C14*HNP

RLLHC: Rate land leaves annual cotton.

RLLC: Rate land leaves perennial cotton.

RLLNP: Rate land leaves native pasture.

C10,12,14: Policy variables discussed previously concerning the rate at which these alternatives are taken out of their current use.

Equations 1350 through 1371 allocate the land taken out of native pasture to the four alternatives according to the way in which the decision maker has prescribed.

1350 RLDF=C15*RLLNP

1360 RLDINP=C16*RLLNP

1370 RLDAP=C17*RLLNP

1371 RLDNS=C7*RLLNP

The dependent argument in each equation is the rate native pasture is to be modernized for use as non-irrigated forages, improved native pasture, artificial pasture and sorghum, respectively.[57]

Statements 1390 through 1440 route the value of the variable representing the amount of land removed from traditional use through a series of distributed delays. Statement 1390 will be analyzed as an example.

1390 CALL DELAY(RLLHC,RLAIP,CROIP,DEL1,DT,K1)

This statement calls the SUBROUTINE DELAY. In the case shown, the

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[57]Note that the parameters are such that C15+C16+C17+C7 must equal 1.

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input to the subroutine is RLLHC, the rate land leaves annual cotton, and the output is RLAIP, the rate land is added to irrigated forages.

CROIP: A multi-dimensioned variable initialized at zero and containing the intermediate values throughout the delay of the land in the delay.

DEL1: The length of the delay in years.

K1: The order of the delay.

The Subroutine DELDT is also used in much the same manner: as a substitute for DELAY in statements 1420 and 1440 where the value of the delay falls below A, where A=2*DT*K.[58] In this case the delay will become unstable.

The delays, as used here, represent the time difference between the introduction and completion of work on an innovation. A completed innovation may mean either that a new innovational phase may begin or that the innovation is prepared to yield its intended services. Allowing a new innovational phase to begin does not imply a mere reallocation of resources used in the innovational process; but that the completion of the preceding innovation was a prerequisite to the second innovation regardless of resources available for the completion of the innovation. The use of a distributed delay allows one to predetermine the nature of the completion of the innovation process, given the nature of the input.

Equations 1442 through 1640 compute the incremental additions and subtractions to land that are forthcoming from the distributed delays.

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[58]Llewellyn, op. cit.

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1442 HHC

1460 HIP

1562 HC=

1600 HNP

1610 HF=

1620 HINP

1630 HAP=

1640 HS=H

Where: RLA

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These equations are among the few level equations in the model. With respect to rate equations, the results of the model must be considered to be instantaneous reports of the condition of the system at the time and not the reports of level conditions resulting from activities over a previous time period.

1442 HHC=HHC-DT*RLAIP

1460 HIP=HIP+DT*RLAIP

1562 HC=HC-DT*RLLC

1600 HNP=HNP-DT*RLLNP

1610 HF=HF+DT+R:AF

1620 HINP=HINP+DT*RLAINP

1630 HAP=HAP+DT*RLAAP

1640 HS=HS+DT*(RLAS+RLLP+RLLC)

Where: RLAIP: The output of delay 1390. This is the rate of addition of land to irrigated forages (K Ha/yr.).

RLAF: The output of delay 1410. The rate land is added to forage (non-irrigated) production.

RLAINP: The output from delay 1420. The rate land is added to native pasture.

RLAAP: The output from delay 1630. The rate land is added to artificial pasture.

RLAS: From delay 1440. Rate land is added to sorghum.

Equations 1442, 1562, and 1600 represent traditional land use as it is reduced by innovative decisions. Note that annual cotton is assumed to be removed from production after the expiration of the delays. The great amount of work necessary to establish irrigation which implies a significantly greater time period when it would not be feasible to try and establish forage production and therefore cotton production will continue. There will, however, be a time period for the establishment of forage when it will be necessary to stop production of cotton. This is not reflected in the model and some corresponding double counting results. It will probably be feasible in later models create a delay reflecting this establishment time lag. For tree cotton and native pasture this reduction in acreage takes place when the land is fed into the delay. The land must be taken out of current production once innovation has started. There is a degree of distortion here also, since grazing may continue on native pasture during a portion of the innovative period. The magnitude, however, is not now known but probably will not be large.

Equation 1640 refers to the addition of land to sorghum. Only one source of this addition flows through a delay. The others from palma and tree cotton are assumed to be fed directly into sorghum production. This is possible from these cropped lands since fencing and brushing need not be accomplished. However, this does ignore the time needed to establish sorghum production. This, however, is a seasonal variable and is probably not relevant. Cotton will probably be taken immediately out of production after it is harvested in November. It would not be feasible to establish sorghum until at least January, the normal planting time. Therefore no conflict should result.

Statements and equations 1652 through 1681 deal exclusively with animal transfers from traditional to modern production and the demography of the tra

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1660 RFTT

1661 RMTT

RFTT:

RMTT:

of the transitional herd.

The animals which are transferred from the traditional to the modern sector must be fed into a distributed delay to account for the time necessary for these animals to come up to the full potential of the modern herd. During the time that they are in the delay, however, they will continue to produce at some intermediate level. This menas that births, deaths, and sales will result. It was, therefore, necessary to include a separate demographic calculation for this herd. Using the Nigerian Data for the birth rates and death rates, it was decided that the animals would be kept on the traditional birth-death curves in this subroutine (see Figures VI and VII) but feeding, herd management, and sales policy would closely correspond to the modern herd. Within the subroutine itself, feeding and management are identical to that of the modern herd. With respect to meat yields and milk production, these animals are assumed to produce at the traditional level; however, these two parameters could easily take on an intermediate value.

Statement 1652 calls the demographic subroutine for the transitional herd. Note that only in this call of the subroutine are the population levels not calculated. Also note that this subroutine occurs at a different place in the model than the other two.

```
1660 RFTT=PFT*C70
1661 RMTT=PMT*C71
```

RFTT: Rate females are transferred from the traditional sector (K animals/yr.).

RMTT: Same as RFTT but for males.

C70,71: Policy parameters preselected by the decision maker with respect to the percentage of the females and males respectively, to be transferred in the first year.

The use of these separate parameters allows the decision maker a choice with respect to the sex composition of the modern herd vis-a-vis the traditional herd.

Equations 1668 through 1677 are a specialized distributed delay fabricated because of the necessity of adjusting the transitional herd size while it is within a delay.

1668 ANETF=BFD-DFD-SFD

1669 ANETM=BMD-DMD-SMD

ANETF,M: These are the net changes in the herd size as would be calculated within the Demographic Subroutine (K animals/yr.).

DF(M)D, BF(M)D, SF(M)D: These are death of females (males), birth of females (males) and sales of females (males) for the transitional herd. The first two are computed in the subroutine, the last in the sales function.

These two variables are the change factors which are added into the delay.

1670 R1F=R1F+DT/DEL12*(RFTT-R1f)

1672 R2F=R1F+ANETF

1674 R3F=R3f+DT/DEL12*(R2F-R3F)

1676 RFAM=RFAM+DT/DEL12*(R3F-RFAM)

These four equations are the delay itself. It is composed of three exponential averages where DEL12=1/3 of the total delay. This representation shows only the female component of the delay; the male component is identical with the proper suffix change. R1,2,3F are intermediate variables. RFAM is the negative of the variable which will be added to the modern females as a transfer component.

```
1680 PFD=PFD+DT*(RFTT-RFAM+ANETF)
1681 PMD=PMD+DT*(RMTT-RMAM+ANETM)
```

These equations determine the level of the transitional herd. Note that ANETF(M) must be added here also since PF(M)D is the level of animals in the delay. The necessity of adding ANETF(M) in the delay itself was to insure that the variable would have the proper impact on the output of the delay.

Equations 1682-4 compute the sex ratio of the three herds.

The following equations and statements determine the extension component from herd management practices and compute the amount of storage required, its costs, and extension and employment components of it. The storage is that which is necessary for silage.

```
1686 RXH=EH*(RFTT+RMTT)
     CAPT=(TDNS+TDNIP+TDNF)*C9
     IF(STOR-CAPT) 1687,1759,1759
1687 RPCAPT=(CAPT-STOR)*C13*CBS*EXP(RFI*TDT)
     STOR=STOR+DT*(CAPT-STOR)*C13
     RXCAP=(CAPT-STOR)*C13*ECB
     RECAP=(CAPT-STOR)*C13*WCB
     GO TO 1760
```

1759 RECAP=0

RXCAP=0

RPCAP=0

1760 ....

RXH: Rate of extension workers devoted to herd modernization (K M-D/yr.).

CAPT: The storage capacity required for silage (K pounds).

EH: The extension workers required per animal (M-D/animal).

C9: A parameter determining the percentage of the total forage production that is to be stored.

STOR: Storage capacity actually in existence (K pounds).

IF(...: This statement determines whether or not additional storage facilities will have to be erected.

RPCAPT: The rate private cost is increased by execution of the additional storage capacity.

C13: A parameter to convert levels to a flow and accelerate the construction to less than one year (C13 is greater than or equal to 1).

CBS: The cost of building the storage (NCR$/lb.).

RXCAP: The rate of addition to extension work from the building of the storage capacity.

ECB: Extension workers required per pound of storage capacity built (Man-Days).

RECAP: Rate of addition to employment from storage building.

WCB: Labor requirements per pound of storage capacity built.

Statements 1760 through 1800 call SUBROUTINE BOD to compute the extension, cost, and labor requirement of the land allocation alternatives.

Statement 1760 which deals with converting annual cotton to irrigated forages will be cited below as an example.

```
CALL BOD(RLLHC,RFI,CMIP,EIP,WIIP,REIP,RXIP,RPIP,TDT)
```

The inputs to the subroutine are:

RLLHC: Rate land leaves annual cotton.[59]

RFI: Rate of inflation of inputs.

CMIP: Cost in the base period of the inputs for innovating. (NCR$/ha)

EIP: Extension requirements.

WIIP: Labor requirements.

The outputs from the subroutine are:

REIP: Rate of addition to employment.

RXIP: Rate of addition to extension.

RPIP: Rate of addition to cost.

The statement following 1760 refers to sorghum; 1780 refers to forage; 1790 to improved native pasture; and 1800 to artificial pasture.

Equations 1860 and 1880 compute the employment and cost component respectively for land modernization.

```
1860 EMPM=REIP+..........
1880 PTCM=RPIP+...+EMPM*WR*EXP(RFL*TDT)
```

Where:

EMPM: The rate of employment for land modernization.

PTCM: The rate of private cost for land modernization.

RFL: The rate of inflation of wages.

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[59]This comes from Equation 1292 and is the direct result of a policy decision.

The independent arguments are the first and third variables listed in the BOD subroutine call statement.

WR: The wage rate (NCR$/m-d)

The private debt component of the model and credit costs are constructed to achieve termination of the debt five years after the innovations have become completed. The innovations are the only component of the whole process to receive long term credit. Long term credit is the only component explicitly carried as debt. Short run credit is absorbed in the cash expenses category. One possible improvement in this might be to include reinvestment in the debt category and therefore continue debt throughout the model.

Equations 1891 through 1898 compute additions and reductions from debt and interest charges.

```
1891 RNT=RINT*PTD
1892 RPD=PRP*PTD+RNT
1893 IF(RPD.GE.DPD)GO TO 1895
1894 PTCC=DPD
     GO TO 1897
1895 PTCC=RPD
     DPD=RPD
1897 PTD=PTD+DT*(PTCM+RNT-PTCC)
1898 IF(PTD.LE.0.) PTD=0.
     CCM=PTD*C8
```

RNT: The interest component of the total debt (K NCR$/yr.).

RINT: Rate of interest

PTD: Private debt (K NCR$)

RRP: The rate of repayment of the debt (in this model 5 years implies RRP=.2)

RPD: The rate of actual cash payments per year on the debt (K NCR$/yr.).

DPD: A dummy variable that assumes the greatest value of the debt payment to insure that private debt will not continue more than five years beyond its peak value.

PTCC: The cash component to private cost as a result of debt retirement.

CCM: The cost of credit for modernization. The net subsidy from the credit granting agency.

C8: A parameter determining the net subsidy in percentage terms.

Note that in Equation 1897, RNT is added to the debt. This is necessary since PTCC implicitly contains this value. In the last five years of the debt life, however, the component in PTCC will be greater than RNT. This will then induce some distortion which can easily be dealt with in future models by including an equation after 1894 of the type: RNT=RPD*DPD. The distortion in this model will be slight.

One problem with retiring the debt within 1/RRP of the peak value of the debt is that there is no allowance for reduced debt expenditures. Therefore, any future model should take this into account. The actual effect of DPD however is to keep repayments constant at the peak value of RPD. This will not quite pay off PTD within five years since after the peak small increments will normally be added. One further distortion can occur. For the final debt period when PTCC RNT is greater than PTD plus the incremental addition then more will be paid back than was owed.

Equations 1900 and 1950 redefine extension requirements from man-days per year to NCR$ per year:

1900 EXTM=RXIP+RXDF+RXDINP+RXDAP+RXCAP+RXH+RXS

1950 WE=WED*EXTM

WE: Total cost of extension (K NCR$/yr.).

WED: Cost of extension per man day (NCR$/m-d).

The next equation recomputes the value of the capital of the enterprise as this value is changed solely by changes in the cattle sector. This value neither depends upon nor reflects the herd size. This is a level equation.

VALCAP=VALCAP+DT*(VALCAP*(RFG-DIST)+PTCM)

VALCAP: Value of the capital.

RFG: General rate of inflation.

DIST: Rate of depreciation of capital.[60]

The following equations are the sales component of the model.

SFT1=C24*PFT

This equation represents the minimum sales of females which can take place in the traditional sector. This portion of the sales function represents the culls which are beyond the reproductive stage and must be sold

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[60](RFG-DIST) as used in a simulated integral of this type approximates e^i as used in the rate equations.

in any event. This equation is duplicated for the other two herds with different parameters reflecting the breeding population as a percentage of the total stock of females. The reproductive life probably does not vary greatly and therefore these parameters really reflect the per cent of the females that are reproducers more than actual breeding life. As one approaches modernity, the parameter value declines—reflecting greater productivity.

ALPH1=(SRT-SRDT)*PFT*C62

ALPH1 computes an adjustment for the traditional herd. This adjustment is a net change in the males to be sold to keep the total traditional herd at a "desired" sex ratio (SRDT).[61] The desired sex ratio in the traditional herd is an observed value based on actual herd composition. It is not strictly a policy parameter but for the purposes of this model, is treated as such. C62 is an accelerator parameter used to speed or retard the correct mechanism ALPH1.

Identical equations exist for determining the correction mechanism for the transition and modern herds. The idea of a desired sex ratio is not legitimate in these equations although it is used. This value is indeterminant. It is a function of whether or not the herd is increasing or decreasing, the relative age composition, male and female death rates, the productivity in terms of births of the producing females and the length of the life, from birth to sale. To summarize, the sex ratio is basically a function of herd management and sales policies. It was parameterized in this model to simplify the extraction of animals from the herd

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[61]*Sex Ratio=SR=PM/PF.

since marketing factors are not known. An estimate of the modern sex ratio has been based on the Nigerian data. The sex ratio will not be of great importance to the total herd in the model since the sex ratio only affects males and not productive females. In later generations of the model a better method of determining the male component of the sales function should be found.

```
1965 IF(C69*PFM-PFT) 1966,1966,1967
1966 BETA=-C1*(TDNAT-DTDNAT)/DTDNAT
     GO TO 1990
1967 BETA=-C1*(TDNAT-TTDNAT)/TTDNAT
1990 SFT=(BFT-DFT)*EXP(BETA)
```

The above equations are a portion of the sales function as the model is now constituted. The lack of reality and the rigidity this sales configuration induces in the model far outweighs the stability it concurrently produces in the model.

The arithmetic IF statement in 1965 is used to determine the sales policy with respect to the traditional herd. Since the source of feed is independent of herd management, and it is desirable to tailor the sales policy to make full use of available nutrition, a differential of the above type is necessary. As the available TDN increases, more becomes available to the traditional as well as to the modern herd. In order to manage the nutrition gain properly it will be necessary to switch sales management from a traditional to a more modern method as the traditional herd becomes a less significant part of the total herd. The BETA variable implies that as available feed exceeds a recognized level of TDN, the sales rate will be slowed to build up the herd. As total TDN becomes significantly larger, the traditional herd will essentially stop selling altogether. Therefore, it becomes necessary to increase the management level to prevent this. It is logical that this management variable should be changed when the modern herd reaches some proportional level of magnitude comparable with the traditional herd. Therefore C69 is the parameter determining this level of magnitude.

DTDNAT: The traditional management level of TDN (lbs./animal yr.).

TTDNAT: The more modern level of TDN.

C1: A scale parameter.

BFT,DFT: Birth and death of females per year (K animals/yr.).

Equation 1990 was found to have the greatest stability of all those tried. While not strictly correct, since it does not reflect maturity on the part of females, it, nevertheless, is good for stabilizing the herd because of the uncertainties of a fluctuating herd size. The original idea was to make sales of females subject to the female extraction ratio. However, as the herd declined in size the extraction ratio had the tendency to increase the sales rate greatly, and thus an unrealistic situation developed where there were a great number of sales early in the run and then sales tapered off later on to an unrealistic level.

```
2000 SFD=(BFD-DFD)*EXP(-C41*(TDNAM-DTDNAM)/DTDNAM)
2001 SMD=ERD*PMD*C42+ALPH2
     IF(SFD.LT.SFD1) SFD=SFD1
```

These equations determine the sales function of the transitional herd.

The modern herd sales function is identical with different parameters. The traditional males sales function is also identical. This female sales function does not have the incidence of fallacies that the traditional one does. Herd management is reflected in a constant manner and is not subject to change in an arbitrary manner.

Equation 2000 is essentially the same as 1990 with DTDNAM the modern herd management level of TDN per animal. The effect of this policy when available TDN is less than the management level is that sales will increase above the instantaneous extraction ratio (BF*DF), continuing until herd density and/or available TDN return the system to equilibrium.

Equation 2001 depends upon the averaged extraction ratio for males, ERD. Because of the correction mechanism (ALPH2) the sales of males are partially a function of the female sales rate, this variable works satisfactorily. The logical IF statement insures that the sales do not fall below the salvage rate of old animals.

Equation 2060 computes the quantity of meat supplied

```
2060 QMS=(SFT+SMT)*YMT+(SFD+SMD)*YMD+(SFM+SMM)*YMM
```

QMS: Quantity of meat supplied.

SF,SM: Sales of females and males (K animals/yr.).

YM: Yield of meat per animal (Kg/animal).

Statements 2070 and 2080 call the Demographic Subroutine for the modern and traditional herd respectively.

The following equation updates the land in modern production for comparison with the land "Target" on which the land allocation decisions are made (see page 55).

2097 TML=HINP+HAP+HIP+HF+HS.

Statement 2110 calls SUBROUTINE PLAST in turn for each of the modern land alternatives. This subroutine computes the reinvestment necessary for each alternative, in terms of the per cent of the total area to be replanted per year. It also computes the operating expenses of the alternatives in terms of harvesting costs. The statement for sorghum will be analyzed below.

CALL PLAST(HS,CS,RS,WPS,CIS,RFI,WHS,CHS,PTC,EMP,TDT)

Inputs to the subroutine are:

HS: Hectares of sorghum (K ha).

CS: Number of cuttings or times the area is harvested per year.

RS: Rate sorghum is replanted.

WPS: Workers to plant sorghum.

CIS: Cost of inputs for planting sorghum per hectare.

WHS: Labor to harvest sorghum.

CHS: Input costs for harvesting sorghum.

Outputs:

PTC: Private total cost (An input as well as an output).

EMP: Total labor use (An input and an output).

The implicit total costs of replanting are the rate of reinvestment in this subroutine.

The following equations augment the private cost variable and employment variable with the debt component and management or tending requirements and costs for the cattle herd.

PTC=PTC+PTCC

EMP=EMP+TDT*WCCT+(THM+THD)*WCCM

PTC=PTC+THT*CFCT+(THM+THD)*CFCM

WCCT,WCCM: The traditional and modern labor requirements for routine care of the animals. (M-D/animal).

CFCT,CFCM: The traditional and modern out-of-pocket costs for routine care of the animals.

2120 GRC=(SFT+SMT+SFD+SMD+SFM+SMM) *PBH*EXP(RFFP*(TDT*.5)) +PTRCH.

GRC: Gross return from the cattle sector.

PBH: The price of beef per head.

RFFP: Rate of inflation of farm products.

PTRCH: Gross revenue from milk or cheese.

2130 TRC=GRC*TAX

TRC: Tax return from cattle.

TAX: Tax rate.

2131 TR=TXRC+TXRH+TRC

TR: Total tax revenue (K NCR$/yr.).

TXRC,TXRH: Tax revenue from tree and annual cotton respectively.

Equations 2140 and 2150 compute the owners' and vaqueiros' revenues from the cattle sector respectively:

2140 PRC=(GRC-TRC)*(1.-SCS)

2150 WB2=(GRC-TRC)-PRC

Equations 2160 and 2170 compute the cash costs of hired labor. WCS is the total amount of labor supplied by the vaqueiros (K M-D/yr.).

2160 EMP1=EMP+EMPM-WCS

2170 WB1=EMP1*WR*EXP(RFL*(TDT-.5))

Where WB1 is the total cash labor bill at the average wage rate for the year.

2180 WB=WB1+WB2+WB3

WB then is the total returns to labor.

Equation 2201 computes the government profit that is the excess of tax revenue over extension and credit costs.

2201 GP=TR-CCM-EXTM-SRCC

The total value of all capital is computed by equation 2240.

2240 VALC=THT*PAT+THM*PAM+THD*PAD+VALCAP+VALLND*EXP(RFLND*TDT)

VALC: Total capital value (K NCR$).

PAT,M,D: Average animal value of the separate herds (NCR$/animal).

VALLND: Initial value of land, buildings, in the base period.

RFLND: Rate at which this value inflates.

The next three equations finish up the accounting process by determining the cash profit, return to capital and present value in year T=0 of the expected future returns.

PROFIT=PR-PTC

RETCAP=PROFIT/VALC

TPRFT=TPRFT+PROFIT/((1.+RINT+RFG)**T)

where:

PROFIT: The cash profit in K NCR$/yr.

RETCAP: The percentage cash profit is of the total value of the capital.

TPRFT: The discounted future returns.

CHAPTER IV

MODEL TESTING

Introduction

The model was tested in two parts. First a combination of alternatives was selected to test the more important features of the model. These features were:

(1) allocation of land in annual cotton to irrigated forages,

(2) allocation of land in perennial cotton to irrigated forages,

(3) the allocation of native pasture among all four potential alternatives.

The exact combinations, initially, reflect the author's experience with the model in the building phase.

In this first phase a simulation run was made; then the outputs and last year combinations of resources were analyzed to compare relative efficiency and payoff, especially with respect to TDNA, and cash flow to the entrepreneur. The results of this analysis were then used to adjust the alternative combinations to attempt to improve both resource use efficiency, as reflected by TDNA, and the flow of profits to the entrepreneur.[62] Another simulation run was made and the procedures were the same. The

[62]TDNA (pounds of TDN/animal-year) is one measure of technical efficiency in nutrition with respect to this model. From Figures VI and VII one can see that at TDNA levels above 2720 pounds per animal-year, birth rates stop increasing and death rates stop declining.

number of simulation cycles thus run were seven, this number being arbitrarily selected. Each subsequent simulation run did not necessarily result in improved conditions as defined in the previous paragraph.

The second part of the testing concerned testing the model's sensitivity to changes in the parameters. For this test the best of the seven alternative combinations, or options were selected. The chosen option was then used as the basic simulation run for the sensitivity testing. The sensitivity testing procedure is described in "The Sensitivity Tests" section of this chapter.

The model was constructed in such a way that as modernization alternatives were put into operation, there no longer was a traditional sector which could be isolated from the total model. This implies that in order to compare the outputs from the modern sector with those of the traditional sector, it is necessary to run the model in the absence of any modernization. This means that the decision parameters for modernization will remain at a "zero level" and all other parameters will remain the same as for the modernization run. That the traditional sector cannot be isolated is primarily due to the possibility that no traditional herd will be left at the end of the simulation period. This possibility exists as a result of the model's being constructed on a sub-industry basis.

Testing Criteria

In testing the alternatives to modernization two classes of criteria were selected. The first, termed the "superior" class, attempts to judge all the alternatives according to their ability to meet all of a list of socially desirable objectives the model is capable of directly influencing and reporting, e.g., any alternative's ability to increase the returns to farmers and increase employment rates.

The second class, termed the "inferior" class, attempts to do the same as the superior class but for a greatly reduced list of social objectives. In this case the objectives are considered the minimum that must be met in order for the alternatives to be considered viable because the real world decision concerning the alternatives will be made by a private rather than a public decision maker. These classes and the variables in them are listed below.

1. SUPERIOR CLASS
   a. $TPRFT > TPRFT_o$[63]
   b. $EMP > EMP_o$
   c. $WB > WB_o$
   d. $GP > GP_o$
   e. $OMS > OMS_o$
   f. $PROFIT > PROFIT_o$[64]
2. INFERIOR CLASS
   a. $TPRFT > TPRFT_o$

63This should read: "The variable TPRFT for the last reporting period of the simulation run with the alternative included must be greater than the variable TPRFT for the last reporting period in the "Zero Level" run.

64For this variable the values must be compared in each reporting period.

b. $PROFIT > 0$

c. $QMS > QMS_o$

The inferior class, by absence of employment and government returns, reflects the possibility that a modernizing alternative which passes these criteria only will make government and/or labor worse off in terms of returns to the two sectors. This means that some of the goals of society, on the one hadn, represented by government and labor, and the entrepreneur on the other, may partially conflict. In order for a particular alternative to be profitable, labor may be forced to accept a smaller share of the return, and/or government may have to subsidize the modernization process more heavily; but the process will yield government no additional revenues for the added expenditure.

Tests of Alternatives

The options to be tested were more or less arbitrarily selected. Guidelines to selecting the options were: (1) Previous experience with the model with respect to which options would probably have the highest payoff. (2) The parameter values, both yields and costs, with respect to opportunity costs, cash costs, and expected returns.[65] (3) A desire to test all the important options, and (4) A desire not to greatly upset the system of production as would have happened if, for example, all native pasture had been placed in the production of sorghum (implying a much higher labor requirement). (5) An intuitive understanding of a realistic combination of options

[65]Opportunity costs refer to both cash crops and nutrition foregone.

given the major constraint of the model.[66] In sum constructing the model was a long and difficult process; many problems were encountered and often these could be traced to improper combinations of alternatives. These improprieties had to be corrected before further structural problems could be identified. By this process, a reasonable combination of options began to emerge, and Option A resulted.

After the testing of the options was completed a fault in the accounting mechanism for labor was found. The model was increasing the rate of employment reported in the read out by a large non-constant factor. This was also reflected in the returns to labor but did not influence the returns to the farmer. Therefore the effects of the various options on labor and the wage bill are marginally certain at best and cannot be assumed to be a valid comparison.

Each subsequent option was the result of analyzing the preceding option and determining the probable cause for its failure to meet the criteria. This is the fundamental reason for the clear dichotomy between the first three options and the last four which will be discussed later. The options are defined below.

1. Option A

   The land target, i.e., the amount of land to be placed in modern production alternatives, was set at 1000 hectares. Annual cotton land is reallocated at 10 per cent per year of the remaining land in annual cotton. Perennial cotton is reallocated

[66]This constraint is that there are too few animals to take advantage of any relatively great increase in nutrition.

at 5 per cent per year. Native pasture is reallocated at 2 per cent per year. Cattle are to be brought under modern herd management at the rate of 70 per cent per year of animals remaining under traditional management. Ten per cent of all land reallocated from native pasture will go to sorghum; the rest is evenly divided among the other alternatives for native pasture.

2. Option B

   This option has the same features as Option A except the land target has been reduced to 500 hectares.

3. Option C

   The land target is set at 100 hectares. All innovations are to come from native pasture only. Native pasture is reallocated at 2 per cent per year with 10 per cent devoted to sorghum. Cattle are transferred to modern management at 40 per cent per year.

4. Option D

   The same features as Option C are found here except the land target has been increased to 500 hectares.

5. Option E

   The same features as Option C characterize Option E except the land target is 250 hectares.

6. Option F

   The same features as are present in Option E characterize Option F except cattle are transferred at 60 per cent per year.

7. Option G

The land target is set at 1000 hectares; cattle are transferred at 40 per cent per year; and native pasture is reallocated at .5 per cent per year with 10 per cent going to sorghum.

The results of these tests show that all seven options fail the superior class of criteria. Options A through C fail the inferior class as well. Options D through G pass the inferior test. The major problem with all tests was that yearly profits tend to drop off for a period of years early in the innovative process. This may indicate that either credit terms are too high or the repayment period too short to make repayments profitable or that sales policy has been mismanaged or that cost parameters are sufficiently unrealistic to be meaningful. Assuming sales policy and parameter values to be correct, then terms or length of credit appear to be a significant barrier to modernization. Both types of credit difficulties when approached from an income point of view appear roughly identical, since both are subtractions from yearly net income. When one considers the fact that the response of the cattle enterprise to modernization is rather slight in the early years and only slowly becomes more productive, then credit that is only partially subsidized can be a serious limit on the rate of modernization. There are at least three partial solutions to this problem: (1) More fully subsidize credit by reducing interest rates further; (2) Extend the repayment period; (3) Defer repayment for a given number of years until the cattle enterprise becomes more productive.

The dichotomy between the sets of Options A-C and D-G hinged on the present value of future returns. The slow gain in productivity of the cattle enterprise means that high returns to modernization will be deferred for a greater number of years than would be the case if much faster increases in productivity were possible. Since the early returns in the simulation cycle are weighted more heavily than later returns in calculating present value, one could expect that heavy expenditures coupled with small gains in revenues would greatly outweigh even higher net profits in later years given a high discount rate. The tests in fact show that while net profits are higher in later years for all options as compared with the "zero level" run, the present value of Options A-C are less than the zero level run.

From this present value problem it would seem that there exists a limit on the rate of innovation. In order to keep early returns from dropping so low that the present value of future returns is less than the present value of doing nothing, expenditures must be reduced. This then translates into limiting the rate of modernization in the absence of significant changes in inflation and/or interest rates.

An associated problem is the effect on revenue from reallocating cash crop land to feed producing alternatives. The loss of revenue resulting from this land use does not seem to be made up by improved productivity in the cattle sector as would be expected. The cash crop alternative seems to have some validity if the price of the crop should change relative to cattle. In this case a threshold may result which would make exploitation of the alternative possible. In the meantime the alternative is not viable especially with respect to the sertao. Valente[67] has suggested that in the coastal zone, the productivity of irrigated pasture

[67]Valente, loc. cit.

may be sufficiently high to make this alternative vialbe, if the enterprise is specialized in milk production rather than beef.

The second series of tests to be conducted on the model concerns the stability of the model in the face of changes in certain parameters. Since it was desirable to test the model in the face of a viable alternative, this battery of tests was administered second. For this test Option G was selected with one exception: Cattle were transferred at 60 per cent rather than 40 per cent per year.

In summary there seem to be two significant and clearly indicated barriers to innovation. One is the credit arrangements which reduce short run profits. The second barrier is the rate of discount which makes "cheap money" returns in later years insufficient to justify "good money" expenditures in early years of the simulation. This bears a relationship to the credit problem. If repayment could be deferred for several years, these expenditures, with the proper interest rate, would also become less "expensive" and would be partially offset by higher revenues.

The Sensitivity Tests

The sensitivity tests were run to determine the influence of parameter changes on the outputs reported by the model. Any parameter whose value is changed from that of the initial conditions and significantly changes the outputs of the model is critical. Therefore, the accuracy of that parameter is relatively more important to the operation of the model than others not having such an effect.

The sensitivity tests were run according to the following procedures. First, certain parameters were selected because of the uncertainty of the values assigned to them. Secondly, these parameters were grouped in three categories according to the degree of suspected error. These classes were ± 10 per cent, +30 per cent, and +50 per cent.

Using the SENSINC Subroutine (10),[68] these three classes were each run repetitively; each parameter, in turn, being incremented by the percentage value of its class. Upon completion of each simulation run, the incremented parameter was then reset to its original value. The results are shown in the following four tables.

In Tables IV through VII the horizontal rows represent discrete simulation runs of twenty years duration for each run. The parameter listed at the beginning of each horizontal row is the parameter which was incremented by the value corresponding to the table heading. The first simulation run in each table represents the model with no parameters incremented. The variables listed at the head of each vertical column are the variables from the model used to determine the effect of changes in parameters on the model stability. These variables correspond to the values below them. These values are the values the variables at the head of their respective columns attained at the end of the twentieth year of simulation when the parameter at the head of the corresponding rows was incremented by the amount indicated.

The results of these tests tend to show that the most important classes of parameters are those dealing with relative or what may be termed absolute

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[68]Gloria Page, a paper describing a testing procedure for use on the Nigerian Model, Macro Model II, (Michigan State University). (undated.)

TABLE IV

PARAMETERS INCREMENTED MINUS 10 PER CENT

OUTPUT VARIABLE	THM	QMS	RETCAP	WB	EMP	PROFIT	VALCAP	TPRFT	GP
PARAMETER									
UNINCRE'D	11.9E0	5.2E2	5.4E-2	7.5E3	2.6E1	1.6E4	2.4E4	7.4E2	6.1E3
C3	11.7E0	5.1E2	5.3E-2	7.4E3	"[b]	"	"	"	5.9E3
C4	11.9E0	5.2E2	5.4E-2	"	"	"	"	7.3E2	6.0E3
GRE	12.4E0	5.5E2	5.6E-2	7.7E3	"	"	"	7.9E2	6.3E3
C44	11.9E0	5.3E2	5.6E-2	7.6E3	"	"	"	7.6E2	6.2E2
C20	"	5.2E2	5.8E-2	7.5E3	"	"	"	7.4E2	6.1E2
WIDF	"	"	5.5E-2	"	"	"	2.3E4	"	"
WIDINP	"	"	"	"	"	"	"	"	"

[a]All values are expressed as "E" values. This means that 11.9E0 = 11.9, 11.9E1 = 119.0, etc. The numbers reflect the values the variables assumed at the end of the simulation cycle when the parameter at the beginning of the row was incremented by the percentage indicated at the head of the table.

[b]The value of the output variable did not change appreciably from that value directly above it.

TABLE V

PARAMETERS INCREMENTED PLUS 10 PER CENT

OUTPUT VARIABLE	THM	QMS	RETCAP	WB	EMP	PROFIT	VALCAP	TPRFT	GP
PARAMETER									
UNINCRE'D	11.9E0	5.2E2	5.5E-2	8.3E3	3.2E1	1.6E4	2.4E4	7.4E2	6.1E3
C3	12.1E0	5.3E2	"	8.4E3	"	"	"	"	"
C4	11.9E0	5.2E2	"	8.3E3	"	"	"	7.5E2	"
GRE	11.5E0	5.0E2	5.3E-2	8.1E3	"	1.5E4	"	7.0E2	5.9E3
C44	11.9E0	5.1E2	5.4E-2	8.2E3	"	"	"	7.2E2	"
C20	"	5.2E2	5.1E-2	8.3E3	"	1.6E4	"	7.4E2	6.1E3
WIDF	"	"	5.4E-2	"	"	"	2.5E4	"	"
WIDINP	"	"	"	"	"	"	"	"	"

TABLE VI

PARAMETERS INCREMENTED PLUS 30 PER CENT

OUTPUT VARIABLE PARAMETER	THM	QMS	RETCAP	WB	EMP	PROFIT	VALCAP	TPRFT	GP
UNINCRE'D	11.6E0	5.1E2	5.4E-2	8.3E3	3.2E1	1.6E4	2.4E4	7.4E2	6.0E3
C5	"	"	5.3E-2	8.2E3	"	1.5E4	"	7.3E2	"
WHS	"	"	5.4E-2	8.4E3	3.3E1	1.6E4	"	7.4E2	"
WHF	"	"	"	"	"	"	"	"	"
WIDAP	"	"	"	8.2E3	3.2E1	"	"	"	"
CMDINP	"	"	"	"	"	"	"	"	"
CMDAP	"	"	"	"	"	"	"	"	"
CMS	"	"	"	"	"	"	"	"	"
YC	"	"	5.7E-2	9.1E3	"	"	"	8.6E2	6.4E3

TABLE VI — Continued

OUTPUT VARIABLE	THM	QMS	RETCAP	WB	EMP	PROFIT	VALCAP	TPRFT	GP
YHC	11.6E0	5.1E2	5.4E-2	8.3E3	3.2E1	1.6E4	2.4E4	7.5E2	6.0E3
WPC	"	"	"	8.2E3	3.7E1	"	"	7.4E2	"
YAP	12.4E0	5.4E2	5.5E-2	8.4E3	3.2E1	"	"	"	6.2E3
YF	"	"	"	8.5E3	"	"	"	"	"
YINP	11.7E0	5.1E2	5.4E-2	8.3E3	"	"	"	"	6.0E3
YS	11.9E0	5.2E2	5.5E-2	"	"	"	"	"	"
PBH	11.6E0	5.1E2	7.1E-2	9.5E3	"	2.0E4	"	9.5E2	7.3E3
PC	"	"	5.7E-2	9.2E3	"	1.6E4	"	8.6E2	6.4E3
PHC	"	"	5.4E-2	8.3E3	"	"	"	7.5E2	6.0E3

TABLE VII

PARAMETERS INCREMENTED PLUS 50 PER CENT

OUTPUT VARIABLE	THM	QMS	RETCAP	WB	EMP	PROFIT	VALCAP	TPRFT	GP
PARAMETER									
UNINCRE'D	11.6E0	5.2E2	5.4E-2	7.5E3	2.6E1	1.6E4	2.4E4	7.4E2	6.1E3
RFC	11.9E0	"	2.8E-2	"	"	"	"	"	"
RFFP	"	"	48.E-2	54.5E3	"	13.8E4	"	27.4E2	43.4E3
RFG	"	"	3.9E-2	7.5E3	"	1.6E4	13.6E4	4.2E2	6.1E3
RFI	"	"	-4.5E-2	"	"	-1.3E4	2.5E4	1.8E2	5.7E3
RFIND	"	"	1.0E-2	"	"	1.6E4	2.4E4	7.4E2	6.1E3
RINT	"	"	5.5E-2	"	"	"	"	4.1E2	"
CIS	"	"	"	"	"	"	"	7.3E2	"
CIAP	"	"	"	"	"	"	"	"	"
CIF	"	"	"	"	"	"	"	"	"
WPF	"	"	"	"	2.7E1	"	"	7.4E2	"

prices, estimates of yields, and the grazing rate.

With respect to prices, the parameters defined as rates of inflation are actually rates of inflation only if all parameters so defined have the same value. If given different values then they represent differential price trends. From the results it can be seen that the values of these parameters will greatly influence the outcome of the model and therefore special attention must be paid to determining their actual values in future research. When these parameters are used as experimental variables to test for the effects of changing market conditions, the experimenter will have to be very cautious about the results because of the impact these variables have on the system.

The initial prices of beef and cotton also seem to have a significant effect on the outcome of the simulation. These factors will have to be given carefully investigated initial values. Since any error in these parameters will be enlarged as the simulation process proceeds, these factors are as important as the inflation parameters.

Yield estimates of land alternatives seem also to be important but of slightly less importance than the initial prices. Their importance stems from their being direct inputs to the cattle herd.

The equilibrium grazing rate parameter seems to have a rather destabilizing effect on the system, which is because of its significant influence on the herd nutrition in the long run. This parameter must be more fully investigated in future research not only with respect to its value but also with respect to its actual influence in a real situation on the nutrition available to the herd.

The other parameters shown in the tables have some destabilizing influences on the model but these influences are, in general, less than those previously mentioned. Nevertheless close attention should be paid to estimating these values also.

Suggested Areas of Future Investigations

On the basis of the results three areas are suggested for more intensive investigation.

First, the equilibrium grazing rate is very important for overall system stability. This variable will affect the future results of the model by the degree to which the native pasture improves as the herd pressure is reduced. Also, there is a real question as to how much the nutritive value of native pasture can be expected to improve through this alone. The range condition mechanism is on the whole suspect because of these effects.

The second area concerns the yields to be expected from the modern land alternatives. These yields will obviously have a great deal of effect upon the costs and herd sizes permissible within the system, and, therefore, the total capital accumulation and cash profit. Since yields will vary from area to area and will be a function of the expenditures on inputs, careful investigation must be made with respect to any locality to ascertain the interrelationship between these two factors, yields and input costs.

A third area is relative price trends. In the long run the directions the trends take, both relatively and absolutely, will determine the decision to innovate or not to innovate. In the long run these variables are not only difficult to estimate, but there is also the possibility that the level of aggregation will have a distorting effect as the factors and commodities within any category group assume different relative prices. This implies that substitutions will take place thus altering the production function as it is described in this model.

A fourth area that needs more intensive investigation concerns the birth-death curves around which this model is built. These curves are as initially reported in the Nigerian Macro Model II.[69] For lack of more appropriate data to this situation, the curves are assumed a fair approximation of what one could expect in the Brazilian case. The similarity of climatic conditions between Northern Nigeria and the Sertao and the similarity of native breed types is significant. However, these curves should be more closely investigated to determine what the values should actually be. There are several quantitative methods which could be used. The main problem is to estimate values for the birth-death curves against TDN intake under actual conditions found in the Northeast. The inclusion of the transitional herd in this model also introduces a question as to the wisdom of differentiating the demography of this herd. Similarly, there arises a question with respect to the wisdom of assuming independence between feed production and herd management. It is probably correct to say that the effects of improved nutrition and improved management yield higher gains when considered together than when considered

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[69]Johnson, et al., op. cit.

separately—a multiplicative effect versus an additive effect because the two separate sectors are expected to complement each other. With careful model management this difficulty can be controlled within limits. However, this assumed independence also produces a degree of distortion by the limitations placed on the land innovational process.

In summary, while the above mentioned areas of further research are the most important with respect to the stability and usefulness of the model, it must not be overlooked that essentially all the parameters are subject to revision. There are six different conditions under which the model will have to be parameterized. Consequently, an entire library of parameters will have to be obtained to use the model generally. Also there are ranges of conditions among these six that will necessitate the discovery of good approximations for the parameters.

CHAPTER V

SUMMARY AND CONCLUSIONS

Introduction

The overall objective was to develop a conceptual framework to study the long run and short run consequences of developmental decisions concerning beef production at the farm or sub-industry level in the Northeast section of Brazil.

Specific objectives were:

1. To develop a model for evaluating alternative means of modernizing beef production in selected areas of Northeast Brazil.
2. To formulate and test a computerized simulation procedure for estimating the effect of different systems of beef production.
3. To determine the usefulness of this procedure and specify how it might be further developed into an operational analytical tool for development planning.

The model is of use chiefly in making evaluations of alternative combinations of land use and herd management practices at the firm level. This evaluation need not be restricted to the Sertao but may be used in virtually any region of the Northeast assuming the parameters for the region are available. It may be used also in evaluating an aggregation of several ranches using similar production techniques and located in the same geographical area. At higher levels, however, care must be taken to ascertain the impact the ranches have on the local assembly market and the local factor market since the model assumes a perfectly competitive production sector with respect to impact on market prices.

The model is designed to report the rate of cash flow, employment, supplies, government revenue and expenditures, and levels of land by land utilization and herd size.

The model itself does not optimize but merely tells the user what the effects of his decisions will be on the cattle production enterprise of any given ranch or set of ranches.

The model cannot determine prices or supply responses over time. The price at the farm level for beef products and inputs must be given. The model can predict the consequences of allocation decisions on the firm itself given changing relative prices over time. As the model is now constituted the rates of price changes must remain constant. However, with minor redesign the pricing mechanism can be made to perform in any desired manner so long as the performance preferred is independent of the model itself. In other words price must remain an exogenous variable if major redesign is to be avoided.

What Has Been Accomplished

This study has produced a method potentially useful in calculating the consequences of a given set of production relationships and the corresponding decisions on the part of management concerning these relationships. The consequences of this interaction between management and the production relationships may be observed for both short and long periods.

Specifically the study has created what is potentially a decision-making aid for an entrepreneur, credit lending agency, extension agency or development planner with respect to cattle production. It is a mechanism to calculate costs, revenues and employment levels in each of a given number of years given specific decisions and specific economic trends in the form of prices.

A second potential use is in determining the impact on the individual enterprises of government intervention in the production and marketing systems. Specifically it will measure the impact of successful government efforts at changing subsidies, manipulating prices in the commodity or factor markets. An example of its usefulness is the tentative conclusion discussed later concerning the inadequacy of the system for a rapid rate of profitable modernization. A most important area of research in the long run, given the present state of knowledge, will be to study the economic impact of successful research aimed at adapting foreign technology to the region, especially biological technology.

There is a third potential use of the model as a mechanism to study the economic impact of natural or other uncontrollable phenomena on individual enterprises. Examples of this are: (1) a sudden decrease in herd size due to natural disaster; (2) undesirable price trends in one or more factors without a corresponding change in commodity prices.

What More Needs To Be Accomplished

There is a high priority on the sales function in future work in the model. As it is presently constructed, with price given, the sales function attempts to study the technological decisions the entrepreneur must entertain in order to establish a balance between present and future returns when making decisions concerning whether or not to sell, and the amount and kind to sell. This basic approach to the marketing problem should be retained. However, the present sales function is too divorced from the market forces to be considered realistic. Another criticism of the current sales function is that it is very inflexible. To be useful it should allow greater freedom concerning the assumptions of selling behavior than is now possible. The sales function should be extensively redesigned to take into account this needed flexibility and to conform more significantly with reality.

A second area of further work is in the market for feeder calves, cattle, and breeding stock. Although this market is neglected in this model, it is fairly well developed in the Northeast. The reason for neglect is that the simple demographic subroutine is incapable of handling the large changes in age composition which would result from a rational cattle buying decision. The result of neglecting this factor market for cattle is that both the supply function and the profitable rate of innovation are distorted. As more and more nutrition becomes available, a larger herd size is needed to utilize the additional nutrition. In the absence of the ability to buy new animals, the only other alternative is to retain additional females from the mature animals ready for sale. Since the potential productivity of the herd is lagged, fewer animals will be sold, thereby reducing revenues. But, the costs of innovations are increasing total cost. Alternatively, if neither reduction in revenues nor large increases in costs are desirable, then the entrepreneur must select a properly reduced rate of innovation in order to keep supplies flowing at a constant rate while allowing the herd to grow. Herd size sales will increase more slowly, but there will be no wasted nutritional resources and no interim reduction in revenues. Increased costs, however, are unavoidable, but may be partially mitigated by increased revenues.

On the other hand, with capability of buying additional animals, gains can be realized more quickly and herd size can increase much more rapidly. The constraint of the rate and magnitude, then, is shifted to availability and terms of credit and the effect on the present value in the long run.

One solution to the inadequacy of the Demographic Subroutine to handle this function might be to use a more detailed subroutine such as that suggested in the Nigerian Macro Model II.[70] The suggested subroutine is capable of handling animals by age groups and determining separate nutrition requirements, births and deaths. In sum, it keeps age composition separate and explicit allowing birth, death and nutritional calculations to be made on any age group.

Conclusions Concerning the Industry

Since the data cannot be considered very reliable because of the method of generation, these conclusions are by necessity general and superficial in nature. Before meaningful conclusions can be drawn, more rigorously generated data will have to be obtained. Parameters will then

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[70] *Ibid.*, Appendix I.

have to be more carefully estimated and the model subject to more extensive testing with respect to the actual input-output relationships. This means that rigorously constructed surveys will have to be made of "typical" ranching operations in both the modern and traditional sectors both to generate the data and to compare with the results of the model.

The results of the tests of the alternatives suggest that it may not be profitable to transfer cotton land to cattle production. It further suggests that, in the Sertao at least, cattle may not be able, in the short run, to compete with cash crops in general. In the long run this may not be true because of the greater ability of the cattle sector to survive periods of stress. This result is tentative; further study should be done on this using more reliable data.

The ability to import feeder cattle from outside the region appears important in taking advantage of gains in the quantity of feed realized from improved land use. This point has been discussed in the section, "What More Needs To Be Accomplished," in this chapter.

In the long run most of the options studied in the model resulted in higher profits to the rancher; however, in the short run profits were less than those in the traditional sector during the innovational process. This means that yearly cash returns less yearly cash expenses were lower in the modern sector than in the traditional sector during the innovational period.

Assuming the correctness of the parameters during the innovation period and a few succeeding years, either revenues were too low or costs too high, vis-à-vis the traditional sector. If returns were too low, then the absence of additional sources of cattle could explain this lower profit. However, if costs were too high, then the credit system may be at fault. In the process of innovation the greater the rate of innovation the less the short run profit rate. However, since all costs to the process were paid with the use of long run credit, it is not unrealistic to believe that the repayment period was too short. To lengthen the repayment period would require increased interest rates for the credit agency to break even due to inflation. Increased interest rates may either increase long run total cost or offer no change to the rancher. Therefore it may be necessary to increase the length of the repayment period with no change in interest rates in order to mitigate either partially or fully the reduced profits during the innovational process. Another alternative might be a direct cash subsidy to the rancher rather than the more indirect credit approach. This analysis is meaningful whether or not inflation rates remain substantial.

Given an actual wage rate of NCR$3.00 per day in 1968 prices, the modern sector will increase the amount of labor utilized, but the modern cattle production sector appears to be a less lucrative alternative than cash crops for labor. This may or may not be true since experience with the Brazilian Cotton Simulation Model suggests the opposite.[71] The difference appears to hinge upon the estimation of relative prices for cattle and cotton and their trends over time. However, in the long run there appears to be a substantial increase in employment, assuming no labor saving technology.

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[71]T. J. Manetsch, Computer Simulation Analysis of a Program for Modernizing Cotton Production in Northeast Brazil (East Lansing: Michigan State University, Division of Engineering Research, August, 1968).

Suggested Areas of Further Investigation Using This Basic Model

In addition to the uses for which this model was intended, there are at least two other areas which may be investigated using a properly parameterized model of this basic structure.

The first area is to study the long run consequences of the drought upon the enterprise and labor. A comparison between one zero level run and another zero level run in which in a given year a drastic reduction in herd size and nutrition available can be made to determine these consequences. Two factors may be determined. First, what is the magnitude of the economic loss to the region in terms of lost opportunity for profits over a period of twenty or thirty years? Second, what policies could be established to reduce the adverse effect of the drought on the entrepreneur, his laborers, and the region?

The second high priority area of study is the consequences of changes in the terms of long term and short term credit.

The model, by itself, will not determine the influence upon investment of alternative credit arrangements. The influence on the returns to the investor, however, will be reported by the model and investment rate changes can be made from that point to determine the maximum likely rate of investment under the various credit alternatives which would be feasible for long run profitability.

Important Areas for Future Research

There are at least four areas for future research which the model suggests as profitable.

1. Forage Grasses. The model results have suggested that the yields obtained from land in forage crops are very important for the overall model because of their effects on herd size and density. The overall inadequacy of the available forage grasses, especially perennials, is well known by the plant scientists in the Northeast (11). Continued research in productivity and viability in droughty conditions for grasses is urged by the author.
2. Credit System. Research should be conducted in the adequacy and consequences of the current credit system and the terms of credit with respect to cattle production.
3. Input markets for beef production. The innovational process as described in the model will require a great deal of inputs. If the input markets are unable to handle such a demand, serious adverse effects on the process can be foreseen. The net result of an inadequate market is a slowing of the innovational process in the aggregate by greatly increasing the price of necessary inputs. This suggestion does not come as a result of the model itself but because of what the model indirectly implies.
4. Alternative methods of increasing the herd size. As TDN becomes available, larger herds can be supported on the same amount of land. The question then becomes: Is it more profitable, both in the short term and the long term,

to allow the herd to increase naturally or to increase herd size by purchasing feeder cattle? If natural increase is selected, then output (and thus revenues) will be reduced in the short term as females are withheld from sale for use as breeding animals. Natural increase could have unfortunate long term consequences if, for example, the discount rate remained high due to high risk; then the present value of an increased herd size in the distant future might not be sufficiently large to outweigh the reduced revenues in the short run. Alternatively, if feeder cattle are bought to increase the size of the herd, then there is no short term reduction in revenue. There is, however, an added cash cost which will be reflected in the profit and loss statement and thus, eventually, in the present value of the increased herd. A third alternative would be to buy breeding stock. An added cash cost in the short run would not be repeated in the long run. The analysis is similar to that for a natural increase in herd size. To determine which of these alternatives, or what combination of choices is appropriate will be very important to the profitability of the firm and, consequently, to the future of beef production in the Northeast.

APPENDIX I

GLOSSARY

A1 = Total live births/year (kilo animals/year)

A2 = Live births (kilo animals/year)

A1P = An exponential Average of A1

ALPH = A correction factor to keep the sales of males in line with that of females (K animals)

ANETF = The net change of females in the transitional herd (K animals/yr.)

ANETM = The net change of males in the transitional herd (K animals/yr.)

BETA = A correction factor to keep the sales of females in line with the available nutrition

BF = Female births per year (K animals/yr.)

BM = Male births per year (K animals/yr.)

BR = Live birth rate--proportion of all females calving per year

C1 = Decision variable, a scale factor influencing the rate of sales of traditional females

C2 = Decision variable, determining the rate that the sales of traditional males in equilibrium is to be changed

C3 = Decision variable, a scale factor influencing the sales policy of modern females

C4 = Decision variable, a scale factor influencing the sales policy of modern males

C5 = Decision variable, the number of standard doses of medicine per animal in the modern herd

C6 = A parameter that determines the extent in influence of grazing rate upon the range condition

C7 = A decision variable, the percentage of land taken from native pasture which goes to sorghum

C8 = A parameter, the rate of subsidy of credit

C9 = A decision variable, the percentage of forage production to be stored per year

C10 = Decision variable, the rate at which land is taken out of annual cotton production (%/yr.)

C11 = Decision variable, the percentage of remaining land in perennial cotton to be removed in the coming year

C12 = Decision variable, the percentage of land remaining in palma to be removed in the next year

C13 = Decision variable, determining the rate at which the storage deficit is to be made up

C14 = Decision variable, the rate at which land is transferred from native pasture (%/yr.)

C15 = Decision variable, the percentage of land taken from native pasture which goes to forage (%/yr.)

C16 = Decision variable, the percentage of land taken from native pasture which goes to improved native pasture (%/yr.)

C17 = Decision variable, the percentage of land taken from native pasture which goes to artificial pasture (%/yr.)

C20 = A parameter determining the initial value of land per hectare (NCR$/ha.)

C21 = Rate of repayment of debt

C24 = Parameter: the minimum rate at which traditional females must be sold (%/yr.)

C25 = Parameter: the minimum rate at which transitional females must be sold.

C26 = Parameter: the minimum rate at which modern females must be sold.

CAP = The desired amount of storage needed for silage (K# TDN/yr.)

CBS = Input costs for building storage facilities (NCR$/#TDN)

CC = Cost of supplemental feed (NCR$/#TDN)

CF = Number of cuttings of forages per year

CFCM = Input costs for routine herd management (NCR$/animal)

CFCT = Input costs for routine herd management (modern herd)

CHP = Cost of harvesting Palma (NCR$/#TDN)

CIAP = Cost of inputs to artificial pasture (NCR$/ha)

CIC = Cost of inputs to perennial cotton

CIF = Cost of inputs to forages

CIHC = Cost of inputs to annual cotton

CIINP = Cost of inputs to improved native pasture

CIIP = Cost of inputs to irrigated forages

CINP = Number of cuttings of improved native pasture per year (a dummy parameter)

CIP = Costs of inputs to palma

CIS = Cost of inputs to sorghum

CM = Cost of medicine/standard dose

CMDAP = Cost of inputs to initially establish artificial pasture

CMDF = Cost of inputs to initially establish forages

CMDINP = Cost of inputs to initially establish improved native pasture

CMIP = Cost of inputs to initially establish irrigated forages

CMS = Cost of inputs to initially establish sorghum

CPH = Pounds of supplement per head (bulk material)

CPHT = Decision variable, amount of supplement per animal (# supplement/animal)

CS = Cuttings of sorghum per year

CTDN = See DTDN

CUIP = Number of cuttings of irrigated forages per year

C41 = Decision variable, a scale factor influencing sales policy of transitional females

C42 = Decision variable, a scale factor influencing sales policy of transitional males

C44 = A parameter to differentiate the death rate of females from that of males

C50 = An initialization parameter to balance the traditional herd with the native pasture

C60 = Decision variable, the number of standard doses of medicine per animal in the traditional herd

C62 = Decision variable which scales the value of ALPH1 by a constant percentage

C64 = Decision variable which scales the value of ALPH2 by a constant percentage

C66 = Decision variable which scales the value of ALPH3 by a constant percentage

C68 = Decision variable, the total number of modern land to be obtained by the innovational process

C69 = Decision variable to determine what percentage of the traditional females must be left to switch to a modern sales policy

C70 = Decision variable, the rate at which females are brought under modern management

C71 = Decision variable, the rate at which males are brought under modern management

D1, D2
D3, D4,
and D5, = (Years) Time delays in determining birth rates, death rates, etc.

DEL1,...
, DEL12 = (Years) Time delays in determining the gestation lag in the innovational process

DIST = The rate of depreciation of capital

DT = The basic unit of time in the model 1/10 of one year

DTDNA = A control parameter, the desired rate of nutrition/animal

ECB = Extension labor units per pound of storage facilities

EDAP = Extension labor units per ha. of artificial pasture established (man-days/Ha.)

EDF = Extension labor units per ha. of forages established

EDINP = Extension labor units per ha. of improved native pasture established (man-days/ha.)

EH = Extension labor units per animal transferred to the modern sector.

EIP = Extension labor units per ha. of irrigated forages established

ES = Extension labor units per ha. of sorghum established

GRE = Equilibrium grazing rate (animals/ha.)

GTDNA = Total TDN available per animal per year lb./animal-yr.)

EMP = Rate of employment (K man-days/yr.)

EMPM = Rate of employment on land innovations (K m-d/yr.)

ER = Extraction ratio for males, the percentage of males which may be removed from the herd without decreasing the size of the herd.

ERF = Same as ER except for females

EXTM = Total rate of extension work required for the model (K m-d/yr.)

HAP = Hectares of land in artificial pasture (Kha)

HC = Ha. of land in perennial cotton

HF = Ha. of land in forages

HHC = Ha. of land in annual cotton

HINP = Ha. of land in improved native pasture

HIP = Ha. of land in irrigated forages

HNP = Ha. of land in native pasture

MONTH = Number of iterations per simulation cycle

NYEAR = Number of cycles per simulation

PA = Average value of animals in the herd (NCR$/animal)

PBH = Farm price of beef per head

PC = Farm price of cotton (NCR$/kg.)

PFCA = Percentage of the total females lactating

PHC = Farm price of annual cotton

PRC = Price of milk (cheese) NCR$/kg.)

PF = Number of females in the herd (K animals)

PM = Number of males in the herd (K animals)

PTD = Level of current debt (K NCR$)

PTC = Total accumulated costs (K NCR$)

PTR = Total accumulated revenue (K NCR$)

QCH = Total quantity of milk produced (K kg./yr.)

RAP = Rate artificial pasture is replanted (%)

RC = Rate annual cotton is replanted

RF = Rate forages are replanted

RFC = Rate of inflation of cattle prices (%)

RFFP = Rate of inflation of farm product prices

RFG = General rate of inflation

RFI = Rate of inflation of input prices

RFL = Rate of inflation of wages

RFLND = Rate of inflation of land prices

RHC = Rate annual cotton is replanted

RINT = Rate of commercial interest

RINP = Rate of replant of improved native pasture

RIP = Rate of replant of irrigated forages

RS = Rate of replant of sorghum

RCON = Range condition

RFAM = Rate animals are removed from the transitional herd (females) (K animals/yr.)

RMAM = Rate males are removed from the transitional herd (K animals/yr.)

RRP = Rate of repayment of long term credit (%)

SF = Sales of females (K animals/yr.)

SM = Sales of males (K animals/yr.)

SC = Sharecroppers' share of the perennial cotton (%)

SCS = Vaqueiros' share of the cattle sector (%)

SHC = Sharecroppers' share of the annual cotton (%)

SR = Sex Ratio (PM/PF)

SRD = Sex ratio "desired"

STOR = Total storage capacity (K#TDN/yr.)

TMU = Total medicine used (K doses/yr.)

TR = Tax revenue (K NCR$)

TH = Total herd (PF+PM)

TCFFC = Technical coefficient changing milk into cheese

TDNK = TDN value from supplemental feed (%)

TDNAK = TDN value per animal of supplemental feed (#/animal)

VALCAP = Value of the capital accumulated through the innovational process (K NCR$/yr.)

VALC = Value of the total stock of capital (K NCR$)

VALLND = Value of the land (market value) (K NCR$)

WCB = Labor requirements to build storage facilities for silage (man-days/#TDN)

WCC = Labor requirements for tending the cattle (m-d/animal)

WCS = Total labor available in the herd management sector (K m-d/yr.)

WF = Labor requirements for planting forages

WHAP = Labor requirements for harvesting artificial pasture

WHC = Labor requirements for harvesting perennial cotton

WHF = Labor requirements for harvesting forages

WHHC = Labor requirements for harvesting annual cotton

APPENDIX II

PRINTOUT OF THE COMPLETE MODEL

```
'JOB,542864,BRZMOD,2.59,LEHKER,JOHN
'FOR,L,X,
      PROGRAM BRAZMOD
      DIMENSION VAL1(9),VAL2(9),VAL3(9),VAL4(9),VAL5(9),CROIP(9),
     1 CROINP(9),CROAP(9),CROS(9),                          CROAT1(9),
     2CROAT2(9), CROF(9)
   99 FORMAT(1H1,50X*BRAZIL MODEL*///6X*STATE VARIABLES A-E*,35X*POLICY
     1VARIABLES F,G,H*,12X*CRITERION VARIABLES I,J,K*///9X*A*,11X*B*,11X
     2*C*,11X*D*,11X*E*,11X*F*,11X*G*,11X*H*,11X*I*,11X*J*,11X
     3   ,*K*)
  100 FORMAT(1X,*TIME*///115X*VALC*/7X,*ERT*,9X,*ERM*,9X,*RCON*,8X,*HC*,
     110X,*HINP*,8X,*RLLC*,
     2 8X,*SFT*,9X,*PTC*,9X,*RETCAP*,6X,*PROFIT*,6X,*CCM*/7X,*PFT*,9X,*P
     3FM*,9X,*FRD*,9X,*HHC*,
     4  9X,*HAP*,9X,*RLLHC*,7X,*SMT*,9X,*PTR*,9X,*WB*,10X,*VALCAP*,6X,*
     5WE*/7X,*PMT*,
     6     9X,*PMM*,9X,*PFD*,9X,*HNP*,9X,*HIP*,9X,*RLLP*,8X,*SFD*,9X,*SFM
     7*,9X,*WB3*,9X,*TPRFT*,7X,*EXTM*/7X,*SRT*,9X,*SRM*,9X,*PMD*,9X,*HP*
     8,10X,*HF*,10X,*RLLNP*,7X,*SMD*,9X,*SMM*,9X,*EMP*,9X,*PTCM*,8X,*TR*
     9/7X,*TDNAT*,7X,*TDNAM*,7X,*SRD*,21X,         *HS*,22X,         *TQ
     1C*,9X, *QMS*,9X,*EMPM*,8X,*PRD*,9X,*GP*/127X,*SRCC*)
  101 FORMAT(1H0,F4.1,  E10.3,10(2XE10.3)/
     1                          5X,10(E10.3,2X),E10.3/5X,10(E10.3,2X)
     2,E10.3/5X,                10(E10.3,2X),E10.3/5X,3(E10.3,2X), 12X,E10
     3.3,14X,4(E10.3,2X),E10.3/
     4              113X,E10.3,2X,E10.3)
      PRINT 99
      PRINT 100
      DO 3 M=1,21
      C1 =1.
      C2=1.
      C3 =1.
      C4=1.
      C5=.6
      C6 = .003
      C8=.02
```

```
C9=.25
C13=2.
C15 = .33
C16 =.33
C17 =.34
C18=1.
C19=.2
C20=50.
C21=.2
C22=1.3
C23=1.3
C24=.04
C25=.035
C26=.03
C41=1.
C42=1.
C43=2.
C44=1.
C50=1.
C51=1.
C52=1.5
C60=.2
C62=3.
C64=3.
C66=3.
C68=1.
C69=1.
C70=0.
C71=0.
C72=1.1
CAP   = 1.
CBS=.001875
CC=.041
CF = 3.
CFCM=.1
```

```
      CHP=0.
      CIAP=35.
      CIC=.5
      CIF=35.
      CIINP=1.
      CIIP = 35.
      CIHC=.75
      CINP = 1.
      CIP=0.
      CIS=23.
      CM = 1.6
      CMDAP=30.
      CMDF=35.
      CMDINP=1.
      CMINP=1.
      CMIP=220.
      CMS=35.
      CPH =100.
      CPHT=25.
      CPPP =2.
      CS= 2.
      CUIP=6.
      D1=1.
      D2=3.
      D3=1.
      D4=1.
      D5=3.
      DEL1= 2.
      DEL3 = 2.
      DEL4=1.
      DEL5 = 2.
      DEL6=.3
      DEL12=.6666667
      DO 11I=1,9
   11 CPOINP(I)=0.
      DO12I=1,9
```

```
12 CROAP(I)= 0.
   DO 13 I=1,9
13 CROS(I)=0.
   DO18I=1,9
18 CROAT1(I)=0.
   DO19I=1,9
19 CROIP(I)=0.
   DO21I=1,9
21 CROF(I)=0.
   DO22I=1,9
22 CROAT2(I)=0.
   DIST = .1
   DT=.1
   DTDNAM=2700.
   DTDNAT=2000.
   FCB=0.001
   FDAP=8.
   FDF=8.
   FDINP=8.
   FH=.01
   FIP=1600.
   FS=8.
   GPE=12.1
   HAP  =0.
   HC=1.4
   HF=0.
   HHC=.07
   HINP =0.
   HIP =0.
   HNP=70.360
   HS  =0.
   K1  =  2
   K3  =  2
   K4  =  2
   K5  =  2
   K6=2
```

```
K11 = 4
K12 =4
MONTH = 10
NYEAR=20
PAM =  150.
PAT = .9 * PAM
PBH=160.
PC=.5
PFCAM=.57
PFCAD=.57
PFCAT=.57
PHC=.4
PRCM=.3
PRCD=.3
PRCT=.3
RAP=.2
RC=.2
RF=.2
RFC  =.2
RFFP =.2
RFG  =.2
RFI  =.2
RFL  =.2
RFLND=.2
RHC =1.
RINP=.2
RINT = .18
RIP=.2
RP=.2
RS=1.
SC=.5
SCS=.2
SHC=.5
SRDD=.45
SRDM=.45
SRDT=.56
```

```
STOR=0.
TAX=.18
TCFFCT=.1
TCFFCD = TCFFCT
TCFFCM=TCFFCT
TDNK = .65
VAL1(1)=.06
VAL1(2)=.19
VAL1(3)=.27
VAL1(4)=.33
VAL2(1)=.08
VAL2(2)=.29
VAL2(3)=.44
VAL2(4)=.54
VAL3(1)=.55
VAL3(2)=.22
VAL3(3)=.13
VAL3(4)=.11
VAL3(5)=.1
VAL3(6)=.09
VAL3(7)=.08
VAL4(1)=.5
VAL4(2)=.17
VAL4(3)=.1
VAL4(4)=.08
VAL4(5)=.07
VAL4(6)=.06
VAL4(7)=.05
VAL5(1)=1.
VAL5(2)=1.
WCB=.0002
WCCM=.01
WCCT=.005
WCS=7.
WDC=.00004
WED=.025
```

```
      WF=36.7
      WG=0.
      WHAP=0.
      WHC=2.
      WHF=3.
      WHHC=2.
      WHINP=0.
      WHIP=4.
      WHP=1.
      WHS=12.5
      WIDAP=58.
      WIDF=58.
      WIDINP=49.
      WIIP =100.
      WIS=63.
      WPAP=8.
      WPC=58.
      WPF=10.
      WPHC=10.
      WPINP=4.
      WPIP=10.
      WPP=8.
      WPS=13.
      WR=3.
      YAP=18250.
      YC  = 200.
      YF=16600.
      YHC=400.
      YINP=2200.
      YIP=53500.
      YMD=150.
      YMM=160.
      YMT=150.
      YP=66.
      YS=13500.
C INITIAL CONDITIONS
```

```
TPRFT=0.
DPD=0.
C7=0.
C10=0.
C11=0.
C12=0.
C14=0.
C15=0.
C16=0.
C17=0.
ERD=0.
ERFD=0.
ERFM=0.
ERFT=.035
ERT=.07
ERM=0.
PFD=.0000000001
PFM=.0000000001
PMD=.0000000001
PMM=.0000000001
PTD=0.
R1F=0.
R1M=0.
R2F=0.
R2M=0.
R3F=0.
R3M=0.
RCON=1.
RFAM=0.
RMAM=0.
RRP = C21
SFD=0.
SMD=0.
T= 0.
 TMU = 0.
TR=0.
```

```
      TDNAKT=CPHT*TDNK
      TDNAK = CPH * TDNK
      TTDNAT=DTDNAM-TDNAK+ TDNAKT
      DTDNT=DTDNAT-TDNAKT
      DTDN=DTDNAM-TDNAK
      TTF=DTDNT/GRF
      YTC=HC/(HNP+HC)*TTF
      YNP=TTF-YTC
      THT=HNP/GRE*C50
      PFT=THT*(1./(1.+SRDT))
      PMT=THT-PFT
      CTDN=DTDN
      VALCAP =0.
      A2T=.3*PFT
      A2D=.3*PFD
      A2M=.41*PFM
      A1PT=A2T
      A1PD=A2D
      A1PM=A2M
   41 DFT=.1 *PFT     *C44
      DFD=.1 *PFD   *C44
      DFM=.07 *PFM   *C44
      DMT = .1 * PMT
      DMD=.1*PMD
      DMM=.07*PMM
      DPD=0.
      IDT4 = 1.0 + 2.0 * FLOAT(K4) * DT/DEL4
      IDT6=1.0+2.0*FLOAT(K6)*DT/DEL6
      SPT = PMT/PFT
      VALLND=C20 *(    HNP+HC+HHC)
      YMD=YMT
      TDT=0.
      PMMM=PRCM
  900 DO 1 N = 1, NYEAR
  901 DO 2 J=1,MONTH
```

```
      TDNAKT=CPHT*TDNK
      TDNAK = CPH * TDNK
      TTDNAT=DTDNAM-TDNAK+ TDNAKT
      DTDNT=DTDNAT-TDNAKT
      DTDN=DTDNAM-TDNAK
      TTF=DTDNT/GRF
      YTC=HC/(HNP+HC)*TTF
      YNP=TTF-YTC
      THT=HNP/GRE*C50
      PFT=THT*(1./(1.+SRDT))
      PMT=THT-PFT
      CTDN=DTDN
      VALCAP =0.
      A2T=.3*PFT
      A2D=.3*PFD
      A2M=.41*PFM
      A1PT=A2T
      A1PD=A2D
      A1PM=A2M
   41 DFT=.1 *PFT     *C44
      DFD=.1 *PFD   *C44
      DFM=.07 *PFM   *C44
      DMT = .1 * PMT
      DMD=.1*PMD
      DMM=.07*PMM
      DPD=0.
      IDT4 = 1.0 + 2.0 * FLOAT(K4) * DT/DFL4
      IDT6=1.0+2.0*FLOAT(K6)*DT/DFL6
      SPT = PMT/PFT
      VALLND=C20 *(    HNP+HC+HHC)
      YMD=YMT
      TDT=0.
      PMMM=PRCM
  990 DO 1 N = 1, NYEAR
  991 DO 2 J=1,MONTH
```

```
      EMP=0.
  998 TDT=TDT+DT
      IF(TML-C68)992,993,993
  992 CONTINUE
      C10=.05
      C14=.005
      C15=.3
      C16=.3
      C17=.3
      C7 =.1
      GO TO 994
  993 CONTINUE
      C10=0.
      C11=0.
      C14=0.
  994 IF(GTDNA-1.05*DTDN)995,997,996
  995 IF(GTDNA- .95*DTDN)996,997,997
  996 CONTINUE
      C70=.6
      C71=.6
      GO TO 1000
  997 C70=0.
      C71=0.
 1000 CALL CROP (YC,HC,RC,WHC,WPC,CIC,PC,TAX,RFI,SC,PCTR,WB3C,TXRC,PCTC,
     1EMPC,QC,RFFP,    TDT)
 1010 CALL CROP (YHC,HHC,RHC,WHHC,WPHC,CIHC,PHC,TAX,RFI,SHC,PTRC,WB3H,TX
     1PH,PTHC,EMPHC,QHC,RFFP,    TDT)
 1012 PTC=PTHC+PCTC
 1013 PTR=PCTR+PTRC
 1014 WB3=WB3C+WB3H
 1100 TDNINP = YINP * HINP
 1110 TDNAP = YAP * HAP
 1120 TDNIP = YIP * HIP
 1130 TDNS = YS * HS
 1140 TDNF = YF * HF
 1170 TDNM = TDNINP + TDNAP + TDNS + TDNIP + TDNF
```

```
1190 THM = PFM + PMM
1200 THT = PFT + PMT
1201 THD =PFD +PMD
1202 TMU=THT*C60+C5*(THM+THD)
1204 PTC=PTC    +TMU*CM*EXP(RFI*TDT)
1220 TCU=CPHT*THT+CPH*(THM+THD)
1222 PTC = PTC + TCU*CC*EXP(RFI*TDT)
1223 EMP=TCU*WDC
1224 SRCC=TCU*C8*(CC*EXP(RFI*TDT))
1270 TDNNP = YNP * RCON * HNP
1280 TDNP = YP * HP
1160 TDNC = YTC * HC
1290 TDNT= TDNNP+TDNP+TDNC
1240 GRT=HNP/((THT+THD+THM)*(TDNT/(TDNT+TDNM)))
1250 RCON=RCON+DT*C6*(GRT-GRE)
1260 IF(RCON.LE..1) RCON = .1
     GTDNA=(TDNT+TDNM)/(THT+THD+THM)
     TDNAT=GTDNA+TDNAKT
     TDNAM=GTDNA+TDNAK
1292 RLLHC=C10*HHC*RHC
1293 RLLC=C11*HC*RC
1320 RLLP=C12*HP* RP
1340 RLLNP = C14 * HNP
1350 RLDF =  C15 * RLLNP
1360 RLDINP= C16 * RLLNP
1370 RLDAP= C17 * RLLNP
1371 RLDNS=C7*RLLNP
1390 CALL DELAY (RLLHC,RLAIP,CROIP, DELI,DT,K1)
1410 CALL DELAY (RLDF,RLAF,CROF,DEL3,DT,K3)
1420 CALL DELDT(RLDINP,RLAINP,CROINP,DEL4,IDT4,DT,K4)
1430 CALL DELAY (RLDAP,RLAAP,CROAP,DEL5,DT,K5)
1440 CALL DELDT(RLDNS,RLAS,CROS,DEL6,IDT6,DT,K6)
1442 HHC = HHC - DT * RLAIP
1460 HIP = HIP + DT * RLAIP
1562 HC = HC - DT * RLLC
1500 HP  = HP  - DT * RLLP
```

```
1190 THM = PFM + PMM
1200 THT = PFT + PMT
1201 THD =PFD +PMD
1202 TMU=THT*C60+C5*(THM+THD)
1204 PTC=PTC    +TMU*CM*EXP(RFI*TDT)
1220 TCU=CPHT*THT+CPH*(THM+THD)
1222 PTC = PTC + TCU*CC*EXP(RFI*TDT)
1223 EMP=TCU*WDC
1224 SRCC=TCU*C8*(CC*EXP(RFI*TDT))
1270 TDNNP = YNP * RCON * HNP
1280 TDNP = YP * HP
1160 TDNC = YTC * HC
1290 TDNT= TDNNP+TDNP+TDNC
1240 GRT=HNP/((THT+THD+THM)*(TDNT/(TDNT+TDNM)))
1250 RCON=RCON+DT*C6*(GRT-GRE)
1260 IF(RCON.LE..1) RCON = .1
     GTDNA=(TDNT+TDNM)/(THT+THD+THM)
     TDNAT=GTDNA+TDNAKT
     TDNAM=GTDNA+TDNAK
1202 RLLHC=C10*HHC*RHC
1203 RLLC=C11*HC*RC
1320 RLLP=C12*HP* RP
1340 RLLNP = C14 * HNP
1350 RLDF =  C15 * RLLNP
1360 RLDINP= C16 * RLLNP
1370 RLDAP= C17 * RLLNP
1371 RLDNS=C7*RLLNP
1390 CALL DELAY (RLLHC,RLAIP,CROIP, DEL1,DT,K1)
1410 CALL DELAY (RLDF,RLAF,CROF,DEL3,DT,K3)
1420 CALL DELDT(RLDINP,RLAINP,CROINP,DEL4,IDT4,DT,K4)
1430 CALL DELAY (RLDAP,RLAAP,CROAP,DEL5,DT,K5)
1440 CALL DELDT(RLDNS,RLAS,CROS,DEL6,IDT6,DT,K6)
1442 HHC = HHC - DT * RLAIP
1460 HIP = HIP + DT * RLAIP
1542 HC = HC - DT * RLLC
1500 HP  = HP  - DT * RLLP
```

```
1600 HNP = HNP - DT * RLLNP
1610 HF  = HF  + DT *          RLAF
1620 HINP= HINP+ DT *           RLAINP
1630 HAP = HAP + DT *           RLAAP
1640 HS=HS+DT*(RLAS+RLLP+RLLC)
     PRCD=PRCM
1652 CALL DEMOG(SFD,SMD,TDNAM,PFD,PMD,ERD,VAL1,680.,680.,3,VAL3,680.,34
    10.,6,D1,D2,D3,D4,D5,DMD,DFD,A2D,A1PD,RFTD,RMTD,DT,BRD,DRD,ERPD,A1D
    2,BRDELT,A3D,A4D,VAL5,PFCAD,YMAD,TCFFCD,QCHD,PRCD,YCD,BFD,BMD,0,DRF
    3D,RBD,ERPFD,ERFD,C44)
1660 RFTT=PFT*C70
1661 RMTT=PMT*C71
1668 ANETF=BFD-DFD-SFD
1669 ANETM=BMD-DMD-SMD
1670 R1F=R1F+DT/DEL12*(RFTT-R1F)
1671 R1M=R1M+DT/DEL12*(RMTT-R1M)
1672 R2F=R1F+ANETF
1673 R2M=R1M+ANETM
1674 R3F=R3F+DT/DEL12*(R2F-R3F)
1675 R3M=R3M+DT/DEL12*(R2M-R3M)
1676 RFAM=RFAM+DT/DEL12*(R3F-RFAM)
1677 RMAM=RMAM+DT/DEL12*(R3M-RMAM)
     IF (RMAM.LE..0000001)RMAM=0.
     IF (RFAM.LE..0000001)RFAM=0.
1678 RFTM=-RFAM
1679 RMTM=-RMAM
1680 PFD=PFD+DT*(RFTT-RFAM+ANETF)
1681 PMD=PMD+DT*(RMTT-RMAM+ANETM)
1682 SRT=PMT/PFT
1683 SRD=PMD/PFD
1684 SRM=PMM/PFM
1685 THD=    PFD+PMD
1686 RXH=EH*(RFTT+RMTT)
     CAPT=(TDNS+TDNIP+TDNF)*C9
     IF(STOR-CAPT)1687,1759,1759
1687 RPCAP=(CAPT-STOR)*C13*CBS*EXP(RFI*TDT)
```

```
      STOR=STOR+DT*(CAPT-STOR)*C13
      RXCAP=(CAPT-STOR)*C13*ECB
      RECAP=(CAPT-STOR)*C13*WCB
      GO TO 1760
 1759 RECAP=0.
      RXCAP=0.
      RPCAP=0.
 1760 CALL BOD (RLLHC,RFI,CMIP,EIP,      WIIP,REIP,RXIP,RPIP,    TDT)
      CALL BOD(RLDS,RFI,CMS,ES,WIS,RES,RXS,RPS,    TDT)
 1780 CALL BOD (RLDF,RFI,CMDF,EDF,      WIDF,REDF,RXDF,RPDF,    TDT)
 1790 CALL BOD (RLDINP,RFI,CMDINP,EDINP,WIDINP,REDINP,RXDINP,RPDINP,TDT)
 1800 CALL BOD (RLDAP,RFI,CMDAP,EDAP,       WIDAP,REDAP,RXDAP,RPDAP,TDT)
 1860  EMPM=REIP+REDF+REDINP+REDAP+RECAP +RES
 1880  PTCM=RPIP    +RPDF+RPDINP+RPDAP+RPCAP+RPS+ EMPM*WR*EXP(RFL*TDT)
 1891 RNT=RINT*PTD
 1892 RPD=RRP*PTC+RNT
 1893 IF(RPD.GE.DPD) GO TO 1895
 1894 PTCC=DPD
      GO TO 1897
 1895 PTCC=RPD
      DPD=RPD
 1897 PTD=PTD+DT*(PTCM+RNT-PTCC)
 1898 IF(PTD.LE.0.)PTD=0.
      CCM =             PTD*C8
      VALCAP=VALCAP+PTCM+DT*VALCAP*(RFG-DIST)
 1899 RXS=FS*RLDS
 1900  EXTM =RXIP+RXDF+RXDINP+RXDAP+RXCAP+RXH+RXS
 1950 WE =            WED* EXTM
 1960 PRCM=PMMM*EXP(RFFP*TDT)
 1964 PRCT=PRCM
      SFT1=C24*PFT
      SFD1=C25*PFD
      SFM1=C26*PFM
      ALPH1=(SRT-SRDT)*PFT*C62
      ALPH2=(SRD-SRDD)*PFD*C64
      ALPH3=(SRM-SRDM)*PFM*C66
```

```
      IF(ALPH1.LT.0.)ALPH1=0.
      IF(ALPH2.LT.0.)ALPH2=0.
      IF(ALPH3.LT.0.)ALPH3=0.
 1965 IF(C69*PFM-PFT)1966,1966,1967
 1966 BETA=-C1*(TDNAT-DTDNAT)/DTDNAT
      GO TO 1990
 1967 BETA=-C1*(TDNAT-TTDNAT)/TTDNAT
 1990 SFT=(BFT-DFT)*EXP(BETA)
 1991 SMT=ERT*PMT*C2+ALPH1
 2000 SFD=(BFD-DFD)*EXP(-C41*(TDNAM-DTDNAM)/DTDNAM)
 2001 SMD=ERD*PMD*C42+ALPH2
 2010 SFM=(BFM-DFM)*EXP(-C3 *(TDNAM-DTDNAM)/DTDNAM)
 2011 SMM=ERM*PMM*C4+ALPH3
      IF(SFT.LT.SFT1)SFT=SFT1
      IF(SFD.LT.SFD1)SFD=SFD1
      IF(SFM.LT.SFM1)SFM=SFM1
      IF(SMT.LE.0.) SMT=0.
      IF(SMD.LE.0.) SMD=0.
      IF(SMM.LE.0.) SMM=0.
 2060 QMS=(SFT+SMT)*YMT+(SFD+SMD)*YMD+(SFM+SMM)*YMM
 2070 CALL DEMOG(SFM,SMM,TDNAM,PFM,PMM,ERM,VAL2,680.,680.,3,VAL4,680.,34
     10.,6,D1,D2,D3,D4,D5,DMM,DFM,A2M,A1PM,RFTM,RMTM,DT,BRM,DRM,ERPM,A1M
     2, BRDELM,A3M,A4M,VAL5,PFCAM,YMAM,TCFFCM,QCHM,PRCM,YCM,BFM,BMM,1,DR
     3FM,RBM,ERPFM,ERFM,C44)
 2080 CALL DEMOG(SFT,SMT,TDNAT,PFT,PMT,ERT,VAL1,680.,680.,3,VAL3,680.,34
     10.,6,D1,D2,D3,D4,D5,DMT,DFT,A2T,A1PT,RFTT,RMTT,DT,BRT,DRT,ERPT,A1T
     2, BRDELT,A3T,A4T,VAL5,PFCAT,YMAT,TCFFCT,QCHT,PRCT,YCT,BFT,BMT,1,DR
     3FT,RBT,ERPFT,ERFT,C44)
 2090 QCS =        QCHT +QCHD +QCHM
 2091 IF(PFT.LE..00000001)PFT=.0000000001
 2092 IF(PFD.LE..00000001)PFD=.0000000001
 2093 IF(PFM.LE..00000001)PFM=.0000000001
 2094 IF(PMT.LE..00000001)PMT=.0000000001
 2095 IF(PMD.LE..00000001)PMD=.0000000001
 2096 IF(PMM.LE..00000001)PMM=.0000000001
 2097 TML=HINP+HAP+HIP+HF+HS
```

```
2110 CALL PLAST (HP,CPRP,RP,WPP,CIP,RFI,WHP,CHP,PTC,EMP,TDT)
     CALL PLAST (HS,CS,RS,WPS,CIS,RFI,WHS,CHS,PTC,EMP,TDT)
     CALL PLAST (HIP,CUIP,RIP,WPIP,CIIP,RFI,WHIP,CHIP,PTC,EMP,TDT)
     CALL PLAST (HINP,CINP,RINP,WPINP,CIINP,RFI,WHINP,CHINP,PTC,EMP,TDT
    1)
     CALL PLAST (HAP,CAP,RAP,WPAP,CIAP,RFI,WHAP(CHAP,PTC,EMP,TDT)
     CALL PLAST (HF,CF,RF,WPF,CIF,RFI,WHF,CHF,PTC,EMP,TDT)
   2 PTRCH =        + YCT+YCD+YCM
2100 T = T + 1.
      PTC=PTC+PTCC
     EMP=EMP+THT*WCCT+(THM+THD)*WCCM
     PTC=PTC+THT*CFCT+(THM+THD)*CFCM
2120 GRC=(SFT+SMT+SFD+SMD+SFM+SMM)*PBH*EXP(RFFP*(TDT-.5))+PTRCH
2130 TRC = GRC * TAX
2131 TR=TXRC+TXRH+TRC
2140 PRC = (GRC -TRC) *(1.-SCS)
2150 WB2 = (GRC -TRC) - PRC
2160 EMP1= EMP + EMPM - WCS
2170 WB1=EMP1*WR*EXP(RFL*(TDT-.5))
2180 WB   = WB1 + WB2 + WB3
2190 PR = PTR +PRC
2201 GP = TR - CCM - EXTM-SRCC
2210 EMP=EMP+EMPM+EMPC+EMPHC
2231 PAT = PAT + RFC * PAT
2232 PAM = PAM + RFC * PAM
2233 PAD = PAT
2240 VALC=THT*PAT+THM*PAM+THD*PAD+VALCAP+VALLND*EXP(RFLND*TDT)
2241 PROFIT=PR-PTC
     RETCAP= PROFIT /VALC
2250 TPRFT = TPRFT + PROFIT/((1.+RINT+RFG)**T)
2980 TQC = QC + QHC
2990 PRINT101,T,ERT,ERM,RCON,HC,HINP,RLLC,SFT,PTC,RETCAP,VALC,CCM,PFT,P
    1FM,
    2ERD,HHC,HAP,RLLHC,SMT,PR,WB,PROFIT,WE,PMT,PMM,PFD,HNP,HIP,RLLP,
    3SFD,SFM,WB3,VALCAP,EXTM,SRT,SRM,PMD,HP,HF,RLLNP,SMD,SMM,EMP, TPRFT
    4,TR,TDNAT,TDNAM,SRD,    HS,      TQC,QMS,EMPM,PTCM,GP,PTD,SRCC
```

```
1 CONTINUE
3 CONTINUE
  END
  SUBROUTINE CROP (YIELD,HECT,RPR,WH,WP,CTOI,PRICE,TAX,RFLTI,SHAR,C,
 1WB3D,B,PTCD, EMPL,TOTC,      RFFP,    TDT)
1 TOTC = HECT * YIELD
2 A=TOTC*PRICE*EXP(RFFP*TDT)
3 B = A * TAX
42 C = (A - B) *          SHAR
5 WB3D=          (A-B)-C
6 D = HECT * RPR
7 PTCD=D*(CTOI*EXP(RFLTI*TDT))
8 EMPL=D*WP+HECT*WH
  RETURN
  END
  SUBROUTINE PLAST (HECT,CPR,RPR,WP,CTOIP,RFLTI,WH,CTOIH,PTC,EMPL,TD
 1T)
1 A = HECT*RPR*WP
2 B = HECT * RPR * CTOIP*EXP(RFLTI*TDT)
3 C = HECT * CPR
4 D = C * WH
5 E = C * CTOIH *EXP(RFLTI*TDT)
6 PTC = PTC + (E + B)
7 EMPL = EMPL + (A+D)
  RETURN
  END
  SUBROUTINE BOD (RHECT,RFLTI,CTOI, EXTC,WI,REMP,REXTC,RPTC,TDT)
11 RPTC = RHECT *  CTOI     *EXP(RFLTI*TDT)
2 REMP  = RHECT * WI
3 REXTC = RHECT * EXTC
  RETURN
  END
  FUNCTION TABLIE(VAL,SMALL, DIFF, K, DUMMY)
  DIMENSION VAL(1)
  DUM=AMIN1(AMAX1(DUMMY-SMALL,0.0),FLOAT(K)*DIFF)
  I=1+DUM/DIFF
```

```
      IF(I.EQ.K+1) I=K
      TABLIE=(VAL(I+1)-VAL(I))*(DUM-FLOAT(I-1)*DIFF)/DIFF+VAL(I)
      RETURN
      END
      SUBROUTINE DELAY(RINR, ROUTR, CROUTR, DEL, DT, K)
      DIMENSION CROUTR(1)
      DEL3=DEL/(FLOAT(K)*DT)
      RIN=RINR
      DO 7 I=1,K
      ABC=CROUTR(I)
      CROUTR(I)=ABC+(RIN-ABC)/DEL3
    7 RIN=ABC
      ROUTR=CROUTR(K)
      RETURN
      END
      SUBROUTINE  DELDT(RINR,ROUTR,CROUTR,DEL,IDT,DT,K)
      DIMENSION CROUTR(1)
      DEL1 =  DEL*FLOAT(IDT)/(FLOAT(K)*DT)
      ROUTR = 0.0
      DO 2 J = 1, IDT
      RIN = RINR/FLOAT(IDT)
      DO 1 I = 1, K
      ABC = CROUTR (I)
      CROUTR(I) = ABC+ (RIN-ABC)/DEL1
    1 RIN = ABC
    2 ROUTR = ROUTR + CROUTR(K)
      RETURN
      END
      SUBROUTINE DEMOG(SF,SM,TDNA,PF,PM,ER,VALB,SMALLB,DIFFB,KF,VALD,SMA
     1LLD,DIFFD,KD,D1,D2,D3,D4,D5,DM,DF,A2,A1P,RFT,RMT,DT,BR,DR,ERP,A1,B
     2RDEL,A3,A4,VAL5,PFCA,YMA,TCFFC,QCH,PRC,YC,BF,BM,KKK,DRF,RB,ERPF,ER
     3F,C44)
      DIMENSION VALB(9),VALD(9),VAL5(9)
    1 BR=TABLIE(VALB,SMALLB,DIFFB,KF,TDNA)
    2 DR=TABLIE(VALD,SMALLD,DIFFD,KD,TDNA)
    3 RB=PF*BR/(PF+PM)
```

```
31  ERP=RB-DR
32  ERPF=RB-C44*DR
 4  A1=BR*PF
 5  A1P=A1P+(DT/.3)*(A1-A1P)
 6  IF(A1-A1P) 7,7,9
 7  BRDEL=D1
 8  GOTO 10
 9  BRDEL=D2
10  A2=A2+(DT/BRDEL)*(A1-A2)
11  BF=.5*A2
12  BM=BF
121 DRF=C44*DR
13  A3=PF*DRF
14  DF=DF+(DT/D3)*(A3-DF)
15  A4=PM*DR
16  DM=DM+(DT/D4)*(A4-DM)
17  ER=ER+(DT/D5)*(ERP-ER)
171 ERF=ERF+(DT/D5)*(ERPF-ERF)
172 IF(KKK.EQ.0)GO TO 20
18  PF=PF+DT*(BF-DF-SF-RFT)
19  PM=PM+DT*(BM-DM-SM-RMT)
20  QM=PF*PFCA*YMA*TABLIE(VAL5,1360.,1360.,1,TDNA)
21  QCH=QM*TCFFC
22  YC=QCH*PRC
    RETURN
    END
'RUN,2.59,3000
```

```
31  ERP=RB-DR
32  ERPF=RB-C44*DR
 4  A1=BR*PF
 5  A1P=A1P+(DT/.3)*(A1-A1P)
 6  IF(A1-A1P) 7,7,9
 7  BRDEL=D1
 8  GOTO 10
 9  BRDEL=D2
10  A2=A2+(DT/BRDEL)*(A1-A2)
11  BF=.5*A2
12  BM=BF
121 DRF=C44*DR
13  A3=PF*DRF
14  DF=DF+(DT/D3)*(A3-DF)
15  A4=PM*DR
16  DM=DM+(DT/D4)*(A4-DM)
17  ER=ER+(DT/D5)*(ERP-ER)
171 ERF=ERF+(DT/D5)*(ERPF-ERF)
172 IF(KKK.EQ.0)GO TO 20
18  PF=PF+DT*(BF-DF-SF-RFT)
19  PM=PM+DT*(BM-DM-SM-RMT)
20  QM=PF*PFCA*YMA*TABLIE(VAL5,1360.,1360.,1,TDNA)
21  QCH=QM*TCFFC
22  YC=QCH*PRC
    RETURN
    END
'RUN,2.59,3000
```

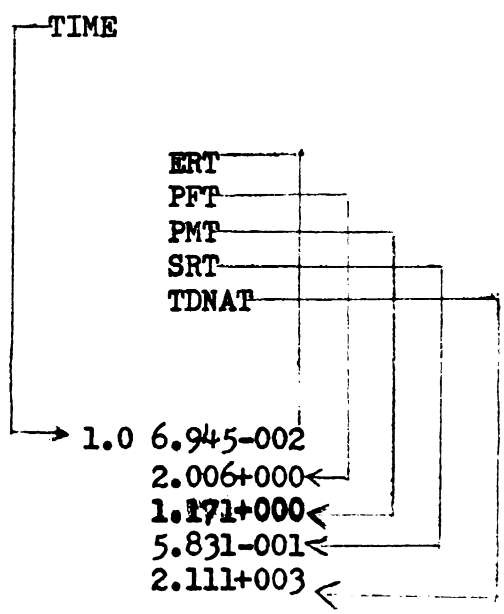
```
 31 ERP=RB-DR
 32 ERPF=RB-C44*DR
  4 A1=BR*PF
  5 A1P=A1P+(DT/.3)*(A1-A1P)
  6 IF(A1-A1P) 7,7,9
  7 BRDEL=D1
  8 GOTO 10
  9 BRDEL=D2
 10 A2=A2+(DT/BRDEL)*(A1-A2)
 11 BF=.5*A2
 12 BM=BF
121 DRF=C44*DR
 13 A3=PF*DRF
 14 DF=DF+(DT/D3)*(A3-DF)
 15 A4=PM*DR
 16 DM=DM+(DT/D4)*(A4-DM)
 17 ER=ER+(DT/D5)*(ERP-ER)
171 ERF=ERF+(DT/D5)*(ERPF-ERF)
172 IF(KKK.EQ.0)GO TO 20
 18 PF=PF+DT*(BF-DF-SF-RFT)
 19 PM=PM+DT*(BM-DM-SM-RMT)
 20 QM=PF*PFCA*YMA*TABLIE(VAL5,1360.,1360.,1,TDNA)
 21 QCH=QM*TCFFC
 22 YC=QCH*PRC
    RETURN
    END
'RUN,2.59,3000
```

APPENDIX III

FIFTEEN YEARS OF SIMULATION OF THE TRADITIONAL FIRM

Notes on the interpretation of this appendix:

1. All numbers are "E" values (see footnote following Table VII).
2. All values have the magnitude assigned in the glossary (e.g., if PFT is 3.0E0-3. this means the value of PFT is 3000 according to the glossary).
3. Diagram showing how to read the tables:
   a. Each time period is set apart from other time periods by being a separate group as shown below. The year of the simulation is the number at the extreme left of the page under the column heading TIME.
   b. The first lettered variable in each column corresponds to the first number in each time group in that column, the second to the second, etc.



TIME	A	B	C	D	E	F	G	H	I	J	K
										VALC	
	ERT	ERM	RCUN	HC	HINP	RLLC	SFT	PTC	RETCAP	PROFIT	CCM
	PFT	PFM	ERU	HHC	HAP	RLLHC	SMT	PTR	WR	VALCAP	WE
	PMT	PMM	PFD	HNP	HIP	RLLP	SFD	SFM	WR3	TRSFT	EXTM
	SPT	SRM	PMD	HP	HF	RLLAP	SMD	SMM	EMP	PTCM	TR
	TDNAT	TDNAM	SRD		HS		TCC	QMS	EMPM	PRU	GP
											SRCC
1.0	6.780-002	4.143-002	9.998-001	1.400+000	0.000+000	0.000+000	1.489-001	1.212+001	2.179-002	5.336+003	0.000+000
	3.720+000	1.000-010	8.990-003	7.000-002	0.000+000	0.000+000	3.050-001	1.284+002	6.579+001	1.162+002	0.000+000
	2.136+000	1.000-010	1.000-010	7.036+001	0.000+000	0.000+000	4.901-012	1.778-011	7.572+001	0.000+000	0.000+000
	5.743-001	1.000+000	1.000-010	0.000+000	0.000+000	0.000+000	1.285-010	1.688-010	1.992+001	8.423+001	4.769+001
	1.947+003	1.996+003	8.763-001		0.000+000		3.080+002	6.808+001	0.000+000	0.000+000	4.754+001
										0.000+000	1.467-001
2.0	6.632-002	7.118-002	9.996-001	1.400+000	0.000+000	0.000+000	1.477-001	1.463+001	2.168-002	6.488+003	0.000+000
	3.690+000	1.000-010	1.554-002	7.000-002	0.000+000	0.000+000	2.957-001	1.553+002	7.998+001	1.407+002	0.000+000
	2.118+000	1.000-010	1.000-010	7.036+001	0.000+000	0.000+000	4.568-012	1.795-011	9.248+001	0.000+000	0.000+000
	5.740-001	1.000+000	1.000-010	0.000+000	0.000+000	0.000+000	1.289-010	1.719-010	1.991+001	1.581+002	5.784+001
	1.962+003	2.011+003	8.756-001		0.000+000		3.080+002	6.651+001	0.000+000	0.000+000	5.765+001
										0.000+000	1.77[illegible]-001
3.0	6.583-002	9.313-002	9.998-001	1.400+000	0.000+000	0.000+000	1.462-001	1.763+001	2.167-002	7.866+003	0.000+000
	3.652+000	1.000-010	2.069-002	7.000-002	0.000+000	0.000+000	2.907-001	1.866+002	9.741+001	1.709+002	0.000+000
	2.096+000	1.000-010	1.000-010	7.036+001	0.000+000	0.000+000	4.486-012	1.814-011	1.130+002	0.000+000	0.000+000
	5.739-001	1.000+000	1.000-010	0.000+000	0.000+000	0.000+000	1.292-010	1.741-010	1.991+001	2.231+002	7.034+001
	1.982+003	2.031+003	8.752-001		0.000+000		3.080+002	6.554+001	0.000+000	0.000+000	7.012+001
										0.000+000	2.149-001
4.0	6.610-002	1.096-001	1.000+000	1.400+000	0.000+000	0.000+000	1.448-001	2.127+001	2.173-002	9.5[illegible]+003	0.000+000
	3.617+000	1.000-010	2.486-002	7.000-002	0.000+000	0.000+000	2.866-001	2.296+002	1.188+002	2.063+002	0.000+000
	2.076+000	1.000-010	1.000-010	7.036+001	0.000+000	0.000+000	4.496-012	1.835-011	1.380+002	0.000+000	0.000+000
	5.739-001	1.000+000	1.000-010	0.000+000	0.000+000	0.000+000	1.295-010	1.758-010	1.991+001	2.806+002	8.571+001
	2.003+003	2.051+003	8.749-001		0.000+000		3.080+002	6.501+001	0.000+000	0.000+000	8.545+001
										0.000+000	2.600-001
5.0	6.688-002	1.219-001	1.001+000	1.400+000	0.000+000	0.000+000	1.436-001	2.570+001	2.179-002	1.166+004	0.000+000
	3.587+000	1.000-010	2.825-002	7.000-002	0.000+000	0.000+000	2.876-001	2.798+002	1.449+002	2.541+002	0.000+000
	2.058+000	1.000-010	1.000-010	7.036+001	0.000+000	0.000+000	4.551-012	1.854-011	1.685+002	0.000+000	0.000+000
	5.739-001	1.000+000	1.000-010	0.000+000	0.000+000	0.000+000	1.298-010	1.771-010	1.991+001	3.314+002	1.045+002
	2.022+003	2.070+003	8.747-001		0.000+000		3.080+002	6.468+001	0.000+000	0.000+000	1.042+002
										0.000+000	3.148-001
6.0	6.797-002	1.311-001	1.003+000	1.400+000	0.000+000	0.000+000	1.426-001	3.111+001	2.187-002	1.419+004	0.000+000
	3.562+000	1.000-010	3.104-002	7.000-002	0.000+000	0.000+000	2.871-001	3.413+002	1.769+002	3.102+002	0.000+000
	2.044+000	1.000-010	1.000-010	7.036+001	0.000+000	0.000+000	4.630-012	1.872-011	2.058+002	0.000+000	0.000+000
	5.739-001	1.000+000	1.000-010	0.000+000	0.000+000	0.000+000	1.300-010	1.760-010	1.991+001	3.7[illegible]3+002	1.275+002
	2.038+003	2.087+003	8.746-001		0.000+000		3.080+002	6.445+001	0.000+000	0.000+000	1.272+002
										0.000+000	3.819-001
7.0	6.917-002	1.382-001	1.004+000	1.400+000	0.000+000	0.000+000	1.418-001	3.772+001	2.194-002	1.726+004	0.000+000

	3,542+000	1,000-010	3,365-002	7,000-002	0,000+000	0,000+000	2,867-001	4,104+002	2,160+002	3,787+002	0,000+000
	2,032+000	1,000-010	1,000-010	7,036+001	0,000+000	0,000+000	4,716-012	1,839-011	2,514+002	0,000+000	0,000+000
	5,738-001	1,000+000	1,000-010	0,000+000	0,000+000	0,000+000	1,301-010	1,768-010	1,991+001	4,160+002	1,556+002
	2,053+003	2,101+003	8,745-001		0,000+000		3,080+002	5,427+001	0,000+000	0,000+000	1,552+002
										0,000+000	4,637+001
8,0	7,035-002	1,436-001	1,006+000	1,400+000	0,000+000	0,000+000	1,411-001	4,561+001	2,200-002	2,101+004	0,000+000
	3,527+000	1,000-010	3,528-002	7,000-002	0,000+000	0,000+000	2,863-001	5,081+002	2,636+002	4,623+002	0,000+000
	2,023+000	1,000-010	1,000-010	7,036+001	0,000+000	0,000+000	4,807-012	1,903-011	3,070+002	0,000+000	0,000+000
	5,736-001	1,000+000	1,000-010	0,000+000	0,000+000	0,000+000	1,303-010	1,793-010	1,991+001	4,511+002	1,900+002
	2,065+003	2,114+003	8,744-001		0,000+000		3,080+002	6,411+001	0,000+000	0,000+000	1,894+002
										0,000+000	5,637+001
9,0	7,149-002	1,478-001	1,007+000	1,400+000	0,000+000	0,000+000	1,406-001	5,569+001	2,207-002	2,558+004	0,000+000
	3,515+000	1,000-010	3,691-002	7,000-002	0,000+000	0,000+000	2,860-001	6,202+002	3,219+002	5,645+002	0,000+000
	2,014+000	1,000-010	1,000-010	7,036+001	0,000+000	0,000+000	4,893-012	1,916-011	3,750+002	0,000+000	0,000+000
	5,735-001	1,000+000	1,000-010	0,000+000	0,000+000	0,000+000	1,304-010	1,797-010	1,991+001	4,822+002	2,319+002
	2,076+003	2,125+003	8,744-001		0,000+000		3,080+002	6,400+001	0,000+000	0,000+000	2,312+002
										0,000+000	6,861+001
10,0	7,255-002	1,512-001	1,009+000	1,400+000	0,000+000	0,000+000	1,403-001	6,778+001	2,213-002	3,115+004	0,000+000
	3,506+000	1,000-010	3,827-002	7,000-002	0,000+000	0,000+000	2,858-001	7,571+002	3,931+002	6,893+002	0,000+000
	2,010+000	1,000-010	1,000-010	7,036+001	0,000+000	0,000+000	4,973-012	1,927-011	4,581+002	0,000+000	0,000+000
	5,733-001	1,000+000	1,000-010	0,000+000	0,000+000	0,000+000	1,305-010	1,801-010	1,991+001	5,098+002	2,832+002
	2,086+003	2,135+003	8,743-001		0,000+000		3,080+002	6,392+001	0,000+000	0,000+000	2,823+002
										0,000+000	8,357+001
11,0	7,353-002	1,538-001	1,011+000	1,400+000	0,000+000	0,000+000	1,400-001	8,257+001	2,219-002	3,794+004	0,000+000
	3,500+000	1,000-010	3,943-002	7,000-002	0,000+000	0,000+000	2,858-001	9,244+002	4,800+002	8,418+002	0,000+000
	2,006+000	1,000-010	1,000-010	7,036+001	0,000+000	0,000+000	5,048-012	1,937-011	5,595+002	0,000+000	0,000+000
	5,732-001	1,000+000	1,000-010	0,000+000	0,000+000	0,000+000	1,306-010	1,804-010	1,991+001	5,341+002	3,458+002
	2,094+003	2,143+003	8,743-001		0,000+000		3,080+002	6,386+001	0,000+000	0,000+000	3,447+002
										0,000+000	1,019+000
12,0	7,442-002	1,558-001	1,013+000	1,400+000	0,000+000	0,000+000	1,398-001	1,006+002	2,225-002	4,621+004	0,000+000
	3,495+000	1,000-010	4,042-002	7,000-002	0,000+000	0,000+000	2,857-001	1,129+003	5,863+002	1,028+003	0,000+000
	2,003+000	1,000-010	1,000-010	7,036+001	0,000+000	0,000+000	5,115-012	1,945-011	6,833+002	0,000+000	0,000+000
	5,730-001	1,000+000	1,000-010	0,000+000	0,000+000	0,000+000	1,307-010	1,806-010	1,991+001	5,557+002	4,223+002
	2,101+003	2,150+003	8,743-001		0,000+000		3,080+002	6,383+001	0,000+000	0,000+000	4,210+002
										0,000+000	1,243+000
13,0	7,522-002	1,575-001	1,016+000	1,400+000	0,000+000	0,000+000	1,397-001	1,228+002	2,231-002	5,629+004	0,000+000
	3,492+000	1,000-010	4,127-002	7,000-002	0,000+000	0,000+000	2,859-001	1,379+003	7,160+002	1,256+003	0,000+000
	2,001+000	1,000-010	1,000-010	7,036+001	0,000+000	0,000+000	5,175-012	1,953-011	8,346+002	0,000+000	0,000+000
	5,729-001	1,000+000	1,000-010	0,000+000	0,000+000	0,000+000	1,308-010	1,807-010	1,991+001	5,747+002	5,157+002
	2,107+003	2,156+003	8,743-001		0,000+000		3,080+002	6,383+001	0,000+000	0,000+000	5,142+002
										0,000+000	1,516+000
14,0	7,593-002	1,589-001	1,018+000	1,400+000	0,000+000	0,000+000	1,396-001	1,495+002	2,237-002	6,858+004	0,000+000
	3,491+000	1,000-010	4,199-002	7,000-002	0,000+000	0,000+000	2,859-001	1,684+003	8,746+002	1,534+003	0,000+000
	2,000+000	1,000-010	1,000-010	7,036+001	0,000+000	0,000+000	5,229-012	1,959-011	1,019+003	0,000+000	0,000+000
	5,726-001	1,000+000	1,000-010	0,000+000	0,000+000	0,000+000	1,308-010	1,809-010	1,991+001	5,916+002	6,290+002
	2,113+003	2,162+003	8,743-001		0,000+000		3,080+002	6,384+001	0,000+000	0,000+000	6,281+002
										0,000+000	1,851+000
15,0	7,657-002	1,600-001	1,020+000	1,400+000	0,000+000	0,000+000	1,396-001	1,829+002	2,243-002	8,356+004	0,000+000
	3,491+000	1,000-010	4,261-002	7,000-002	0,000+000	0,000+000	2,861-001	2,057+003	1,068+003	1,874+003	0,000+000
	1,999+000	1,000-010	1,000-010	7,036+001	0,000+000	0,000+000	5,277-012	1,965-011	1,245+003	0,000+000	0,000+000
	5,727-001	1,000+000	1,000-010	0,000+000	0,000+000	0,000+000	1,309-010	1,810-010	1,991+001	6,066+002	7,695+002
	2,118+003	2,166+003	8,743-001		0,000+000		3,080+002	6,387+001	0,000+000	0,000+000	7,672+002
										0,000+000	2,261+000

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