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# A RECURSIVE PROGRAMMING MODEL OF REGIONAL AGRICULTURAL DEVELOPMENT IN SOUTHERN BRAZIL (1960-1970): AN APPLICATION OF FARM SIZE DECOMPOSITION

DISSERTATION

Presented : Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

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* * * * *

The Ohio State University
1972

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A RECURSIVE PROGRAMMING MODEL OF REGIONAL AGRICULTURAL DEVELOPMENT IN SOUTHERN BRAZIL (1960-1970): AN APPLICATION OF FARM SIZE DECOMPOSITION

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The Ohio State University, 1972

Professors Francis E. Walker and Inderjit Singh, Co-Advisers

The general objective of this study was twofold: (1) to develop an operational model of regional agricultural development that incorporates the complex dynamic decision making process of farm-firms within their given economic environment under selected policy instruments, and (2) to test the general hypothesis that given similar economic opportunities and faced with a similar policy environment, differences in farm size, as reflected in differences in relative on-farm resource endowments, lead to dissimilar dynamic paths of development.

The methodology used was similar to the recursive programming models of regional agricultural development by Day, Heidhues and Singh that focused on multi-dimensional features of agricultural transformation. The model considered technological change, decision strategies, dynamic behavioral feedback accounting for risk and uncertainty, and firm-household interdependence in on-farm activity set. As an important methodological extension from the previous regional models,

this study introduced explicitly farm size differences (small, medium, and large farms) for regional aggregation through the application of the decomposition principle of linear programming. Putting the farm size subaggregates, with different resource availabilities and factor proportions, in an angular matrix form, the model accounted for intra-farm competition for regional resources under common exogenous economic and policy conditions.

The setting for this study was the wheat region in the state of Rio Grande do Sul, Southern Brazil. The region is fairly homogeneous with regard to agro-climatic environment but has a wide farm size distribution. During the last decade under a highly favorable wheat pricing policy and a subsidized credit program (negative real interest rate), the region has experienced a continued transformation from predominantly extensive range livestock farming to intensive cropping agriculture with wheat, soybeans, and corn in a double cropping system along with intensive livestock production on improved pasture systems. This transition has brought about substantial agricultural growth accompanied by rapid mechanization and vast changes in the cropping patterns and increased use of commercialized inputs.

The recursive programming model used simulated the regional economic history for the decade of the sixties. This simulation generated patterns of resource use including technological change, factor productivities, factor proportions and income distribution by farm size. The model results were validated with the partial historical data available. As a result, the following general conclusions were

drawn: (1) from the methodological point of view, the intra-farm differences in various activity decisions in the model support the contention that the decomposition principle has important economic implications in capturing different dynamic paths of development and intra-farm competition for regional resources that would have been totally subsumed otherwise; (2) differences in farm size and hence varying on-farm resource endowments is one of the most important factors in explaining differences in cropping pattern, on-farm labor employment, capital utilization, adoption of technologies, factor productivities, and income distribution; and (3) in general, whereas the output pricing policy provided the incentive for the regional transition, the subsidized credit program provided the means for it. However, these policy instruments appear to have intensified differences between small and large farms by favoring large farms.

# DEDICATION

To My Mother and Father

With Love and Thanks

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# CHAPTER I

# THE COMPLEXITY OF AGRICULTURAL DEVELOPMENT

## I.1) Introduction

It is widely recognized that agriculture in less developed countries (LDC's) presents a complex set of development problems. The problems of agricultural development in a given LDC revolve around many variables such as endowment of natural resources, density of population, levels of technology, organization and economic structure of production, social, cultural, and political systems, and stages of economic development in both the agricultural and non-agricultural sectors. Agricultural development problems may become more complex if the specific LDC studied consists of several diverse agro-climatic regions. This study attempts to deal with only a subset of those variables which crucially affect agricultural development in a major region of a developing country.

The major problem in regional agricultural development identified for this study is resource allocation through time for individual farm-firms within an environment affected by a multitude of physical and economic variables. This environment can further be influenced by a set of policy instruments. This suggests that regional agricultural development can be explained at least partly, by an "interaction

system" composed of these three forces; (1) individual farm-firms, (2) physical and economic environment, and (3) policy instruments. The interaction system in this context is viewed as a decision-making process which allocates resources on individual farm-firms and includes (1) various simultaneous relationships among the three system components, (2) detailed economic structure of production and natural resource endowments, and (3) decision making strategies.[1]

From one agricultural region to another, the interaction systems among these three forces may not be uniform, but diversified. Even within a topographically homogeneous region, farms of different size may vary in their patterns of production and investment. They may not have the same responses toward changes in their economic environment. For example, the decision making process of a subsistence farm with a few hectares may be significantly different from that of a large farm with several thousand hectares in employing new technologies and adopting new cropping practices. Large farms in general have relatively greater access to various economic opportunities and may show

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[1]In order to capture this complexity of interactions, Day and Singh (1971), define what they call "strategic details of development" which include (a) microeconomic aspects of technology, (b) decision strategies such as lexicographic ordering of utility functions, and (c) market environment. More recently Johnson, et al. (1971) employed a computer system simulation approach to describe agricultural sector analysis. The complexity of agricultural development in their study was explained in terms of several thousand difference equation systems which represent a group of interactions among a number of sub-model components, such as regional classification, and the agricultural sector vis-a-vis a non-agricultural sector in order to generate the time paths of the likely consequences of alternative resource allocations under different development programs.

differential responses toward changes in input and output prices. Therefore, farm size is a crucial resource base in regional analysis, and hence determines the factor proportions with other inputs upon which production, consumption, investment, and financial decisions depend.[2]

The purpose of this study is to construct an operational regional model of agricultural development which will explicitly incorporate (1) the complex dynamic (multi-period) microeconomic decision-making process on farm-firms within their given environments under selected policy instruments, and (2) an aggregation of farm sizes in arriving at regional behavioral and resource aggregates. The resulting methodology is a regional recursive programming model with decomposition by farm size. The model is used to simulate and analyze the actual history of agricultural development in a specified region.

The general framework of analysis used is similar to the models of regional agricultural development pioneered by Day (1963a), further extended by Heidhues (1966), and recently applied to agriculture in the LDC's by Singh (1971a). These prototype dynamic regional models focused on multi-dimensional transformation features, both with regard to agricultural production and technological change assuming economic rationality, and incorporating firm-household interdependence.

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[2]In this study "farm size" refers to land area on which agricultural production takes place. It is equivalent to, in a very narrow sense, the "size of the firm's plant" or its "scale of plant" which sets the upper limit of firm's production capacity per unit of time.

As an important methodological departure from previous regional models, this study relaxes the usual assumption of homogeneous farm size over which farms in a given region are aggregated; that is, it explicitly treats the farm size issue by considering different farm size aggregates with different resource availabilities and factor proportions, all facing a similar exogenously given economic environment and competing for the same scarce regional resources. The introduction of farm size differences for this methodological extension is made through the application of the decomposition principle of linear programming.

By considering the complexity of agricultural development and the related farm size differences in an operational framework, this study is able to increase our understanding of the spectrum of possible development trajectories experienced in a region. A detailed analytic understanding of the resource allocation process by farm size allows us to develop a tool for the efficient planning of agricultural development.

## I.2) The Objectives

The objective of this study is to develop a dynamic microeconomic model of agricultural development, using the principle of decomposition, that predicts regional production, investment, and capital formation. This model incorporates at a regional level;

1. the details of firm-household interdependence and the intra-farm competition of production, consumption and investment decisions.

2. differences in farm size, the resulting differential factor proportions, and intra-farm regional competition,
3. technological change over time including aspects of capital use and capital formation in farm power sources,
4. regional physical and financial resource endowments, and
5. policy variables in the form of pricing and resource controls under which farmers in the region operate.

Specifically investigated in this context will be (1) growth and decay of various farm production activities, (2) intra-farm factor productivities, (3) intra-farm resource use, and (4) intra-farm income distribution over time.

## I.3) Farm Size Issues and Hypotheses

The general focus of the model is the decision making process at the farm-firm level with the already tested notion of interdependent production, consumption, and investment decisions.[3] These interdependent decisions are made within the constraints of the changing economic environment facing farm operators. To the extent that farmers face a similar exogenous economic environment in a relatively homogeneous zone with respect to climate and topography, their

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[3]The interdependence of farm-firm and farm-household decisions was first investigated by Heady, Back and Peterson (1953), their implications in the content of the LDC's has been discussed by Nakajima (1957, 1965) and Mellor (1964, 1966), and this interdependence has been explicitly accounted for in a regional model of agriculture in the LDC's by Singh (1971a). Also see Day and Singh (1971).

decisions are aggregatable, and these aggregates represent regional behavior and production response.[4] However, unless farm units are also fairly homogenous with respect to their endogenous economic environment, especially the availability of on-farm resources, aggregation can and does lead to serious errors in regional analysis. It is, therefore, desirable to consider an analytical framework that minimizes the possibility of such errors by explicitly treating different farm sizes with inherent differential factor endowments.[5]

The importance of farm size and its relation to such problems as economies of scale, risk and uncertainty, and market response has long been emphasized by many economists (Steindl (1945), Hicks (1948), Heady (1952), Bachman and Christensen (1967)). Heady suggests that differences in farm size are among the most important factors explaining differences in the decision making process of farm-firms, especially in response to various economic opportunities involving risk and uncertainty.[6] Bachman and Christensen argue that questions about optimum sizes of farms need to be analyzed in connection with agricultural development problems and economic conditions of particular

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[4]For conditions of representative firm aggregation for a regional analysis employing a single linear programming technique, see Day (1963b, 1969), and Day and Singh (1971).

[5]Of course, a certain amount of aggregation is unavoidable unless we treat each farm unit separately. Where differences in farm size are relatively small (as in the case of the Indian Punjab, cf Singh (1971a), aggregation is somewhat excusable, but where differences in farm size are very large, aggregation errors become serious.

[6]Heady (1952).

countries and farming areas. They need to be examined on the grounds of economic incentives, the adoption of improved technology and capital formation.[7] During agricultural development the economics of farm size becomes important when factor proportions vary as output is increased, because the variable factor proportions are crucial in determining technological choices.

Treating farm size as fixed, one can imagine sequential pictures of average cost curves for individual farms of different sizes connected by an envelope curve showing a long run average cost curve. It follows that the farm whose average cost curve is tangent to the lowest point of the long run average cost curve is most efficient. That is, it has the least-cost combination of resources per unit of production among all farms. Hence the efficiency problem relating to farm size is "one of deciding in what quantities and in what proportions scarce resources need to be combined on farm units to achieve low-cost expansion of farm production."[8]

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[7]Bachman and Christensen (1967).

[8]Bachman and Christensen, ibid., p. 237.

In contrast to the various farm size economics discussed above, Raup views the farm size problem on a socio-political ground. He argues that industrial nations have constructed major policies around an implicit or explicit model of what was believed to be a desirable structure of farm sizes. For example, the creation of large collective and state farms in the Soviet Union after 1928 both altered and defined the nature of the Soviet interpretation of Socialism. The "Kibbutz" system in Israel also has similar socio-political implications. With respect to the future trend of farm size in U.S. agriculture, Raup concluded that (a) optimum farm size is a cultural variable, (b) given the levels of efficiency that can be achieved on moderate sized farms in U.S. agriculture, the question of farm size expansion

The explicit treatment of farm size differences in a regional model of agricultural development might shed some light on returns to scale if both the quantities and the qualities of the productive factors remain unchanged. Schultz points out, however, that the returns to scale question in developing agriculture is irrelevant since developing agriculture "always entails the introduction of one or more new agricultural factors, and therefore it gives rise to a process in which the critical question is not one of scale but of factor proportionality."[9]

In this regard, one of the important resource combinations (factor proportions) in developing agriculture involves the adoption of new technologies in relation to the relative endowments of two primary resources, land and labor, In their "induced development model" Hayami and Ruttan hypothesized that the state of relative endowments and accumulation of two primary resources, land and labor, is a critical element in determining a viable pattern of technical change in agriculture. Depending on the relative scarcity of land and labor, technical change embodied in new and more productive inputs may be induced primarily either to save labor or to save land.[10]

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is largely irrelevant on agro-technical grounds, but (c) it is highly relevant on social, political, and, in the broadest sense, cultural grounds. A consideration of farm size issues following Raup's approach, however, is beyond the scope of this study.

For a more thorough discussion on the socio-political aspects of farm size issues, see Raup (1972).

[9]Schultz (1964).

[10]Hayami and Ruttan (1971), p. 4.

As a result of the importance of farm size issues in agricultural development, this study attempts to propose at least conceptually the following farm size hypotheses:

1. Larger farms operating on a larger scale, and with higher farm incomes, generate a larger volume of savings and hence rely more on internal financing for their consumption, production and investment decisions. In addition, a larger asset base allows them greater access to external sources of credit. This ability to generate substantial financial capital allows a greater access to markets for both outputs and inputs, a greater degree of commercialization and consequently a quicker response to changes in the market environment. In contrast, small subsistence farms, with smaller surpluses, are less commercialized, have less access to markets and therefore, respond more slowly to changes in the market environment.[11]

2. Differences in farm size naturally imply dissimilar factor proportions. Land is relatively scarce on small farms, while family labor is relatively scarce on large farms, and given economic rationality one would expect, diverse production (output) and resource (input) mix for different farms as a result of attempts to economize on different

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[11]This does not imply that smaller farmers are economically "irrational," only that their ability to respond is limited due to their smaller access to liquidity.

relatively scarce factors. In general one would expect relatively labor intensive and land saving production patterns on small farms and labor saving and land using production methods on large farms. Similarly, small farms will be more likely to utilize scarce financial capital carefully, while larger farms will tend to be relatively "inefficient" in the use of their liquidity.

3. Farms of different sizes may choose equipment of unequal sizes due to the technical economies of scale inherent in the equipment, or if one considers equipment of the same size one can expect the rates of investments in this equipment to differ among different farm size groups in a region.

4. Farms of various size exhibit a differential rate of adoption and adjustment to both new mechanical and biochemical technologies due to different access to markets and disparities in managerial abilities and entrepreneurship that may result.

5. Differences in the degree of subsistence and commercialization lead to variations in the degree of risk aversion and, hence, to a differential response to a changing economic environment.

These and other factors make it essential that, given the large dissimilarity in farm size observed in a region, one treats, explicitly, different farm size groups in order to capture the large structural and behavioral differences among farms in the region. A regional

model that accounts for differences in farm size would be able to predict important variations with regard to technical change, cropping patterns, employment, resource use and farm specialization in the region.

## I.4) Justification

While the agricultural sector in many LDC's remains at the heart of development strategies, only recently, with advent of the "green revolution," is increased attention being given to the complex nature of agricultural development. One example in this context would be the empirical investigation of multi-dimensional features of farm activities. Of great importance are the two dimensional aspects of the firm-household decisions. The importance of this concept has already been recognized in a developing agriculture.[12] The firm-household interdependence suggests that decisions on consumption, production, and investment should be considered simultaneously to fully understand the farm decision making process.

Furthermore, three important interdependences also exist on the production side of farm-firm decisions. They are (1) the interdependence of multi-products using common inputs, (2) the interdependence of multi-inputs used for common output, and finally, (3) the

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[12]For example, Singh explicitly considered the following three components as related to firm-household interdependence in traditional agriculture: (1) the interdependence of consumption and production, (2) the interdependence of consumption and investment, and (3) the interdependence of marketable surplus, investment, and consumption. For the detailed discussions of these interdependencies, see Singh (1971a).

interdependence of farm decision making units competing for regionally limited resources. These inherent interdependencies in agriculture play a crucial role in determining the time paths of "development variables".

In a developing agriculture, multiple technologies frequently exist. Differential levels of biochemical inputs, often different qualities as well, are used. Both traditional (animal) and modern (mechanical) farm power sources are also used. The role of technological change, as one of the most important factors in accelerating agricultural development, has long been emphasized by many economists. Recently it has been treated endogenously in the agricultural development models.[13]

In the past, most empirical studies have focused on undimensional aspects of agricultural development. Some examples are studies of production functions, on-farm consumption behavior, fertilizer response in a single equation analysis, and the role of a specific policy instrument such as subsidized credit programs or minimum producer pricing policies. Partial analysis does not take into account the complex interdependencies agricultural development. A methodology which combines multiple interdependencies of farm decision and the

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[13]In his article on technological change in a regional agricultural development, Day explicitly treated multi-levels of fertilizer applications and differential degrees of mechanization as endogenous variables in a recursive programming model. See Day (1967b). Singh followed the same methodology in his Punjab model with a comprehensive study on the fertilizer response functions. See Singh (1971a). Hayami and Ruttan focused on specific technologies as an important endogenous component in their induced development model. See Hayami and Ruttan (1971).

"interaction system" among the decision making units, the economic environment, and selected policy variables is helpful in understanding the complex multi-dimensional nature of agricultural development. Activity analysis is well suited to handling these complexities. The relevance of a mathematical programming approach to the complexities including multiple technological choices has been emphasized by many economists.[14]

In this study, emphasis is given to a decomposition technique (principle) useful in deriving regional subaggregates of resources and capturing the distributional effects of resource allocation. The decomposition technique is normally used as a computational device for a large system in a mathematical programming problem. In addition it has great value for showing how decentralized decision making is conducted. The decomposition principle is used in this study to capture farm size subaggregates and their related differential factor proportions in an agricultural region where farm size distribution is very wide. Moreover, the decomposition scheme provides two additional important properties in model structuring. First, the interdependence of different farm size groups competing for regional coupling

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[14]Economists who used a mathematical programming approach to explain economic theories and behaviors include Leontief (1951), Koopmans (1951), Von Neumann and Morgenstern (1953), Samuelson (1958), Kuhn and Tucker (1953), and Heady (1958). To deal with agricultural development, Day laid out theoretical prototypes by applying a recursive programming methodology to industrial and agricultural performance (see Day (1963a, 1965, 1967a, 1967b, 1970)). Recursive programmers who have made an extended application to agricultural development include Heidhues (1965, 1966), Schaller (1965), Singh (1971b), and Mudahar (1971).

resources can be properly constructed in the system. This will serve as an allocation device for guiding regional resources to different farm size groups.[15] Second, the farm size decomposition gives a method for analyzing distributional effects of "development through time". Few studies in the past have dealt with the distributional aspects of development such as growth and decay of a cropping activity by farm size and the disparity of income distribution by farm size.

Agricultural development is subject to dynamic processes. Multi-period optimum decision models have been developed to study these dynamic processes. Recursive programming is a multi-period sequential optimization technique, allowing for behavioral bounds and a feedback mechanism. Its theory and applications to dynamics of various industries have been fully explored by Day and others.[16]

In sum, it is argued that a multi-dimensional resource allocation process with crucial differences in factor proportions, that characterize differences in region, can be suitably handled in a recursive programming framework using the decomposition principle to arrive at valid regional aggregates for analysing, understanding, and planning the process of regional agricultural development.

The next chapter describes the agricultural transformation that has occurred in the recent decade in Southern Brazil including an

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[15]For mathematical properties and economic interpretation of the decomposition principle, see Lasdon (1970).

[16]For discussions of recursive decision system theory, see Day (1963a), and Day and Kennedy (1970).

agricultural region selected for this study. In Chapters III-V an operational model which captures the complexities emphasized above, specifically on-farm decision making mechanism, the recursive feedbacks, and the farm size decomposition is developed. In the sixth chapter model results are discussed and the predictive performance of the model is evaluated. The last chapter contains conclusions with some policy implications for agricultural development and some suggestions for further research.

## CHAPTER II

## REGIONAL AGRICULTURAL TRANSFORMATION IN SOUTHERN BRAZIL

### II.1) The Setting for the Study

Since the general purpose of this study is to simulate a quantitative economic history of agricultural development at the regional level the selection of an area to fit for this study is important. A region experiencing substantial economic progress, involving a wide range of farm size distribution and operating under a set of influential policy instruments is desirable. For this purpose, the subregion (Planalto Medio and Missoes regions) in the state of Rio Grande do Sul, Southern Brazil, is eminently suited.

This region is fairly homogeneous with regard to climate and agricultural practices. It covers some 5.7 million hectares and accounts for over 50 percent of the total wheat production in Brazil (Tables 4 and 5). Between 1960-1970, this region played a crucial role in the very rapid growth in agriculture. This growth has been accompanied by rapid mechanization, vast changes in the cropping patterns and the increased use of commercial inputs such as seed, fertilizers and credit. This dramatic agricultural transformation appears to be closely associated with two major policies; (1) the minimum producer-pricing policy for agricultural crops, and (2) the subsidized credit programs.

## II.2) Recent Agricultural Development in Brazil

Brazil is an immense country of substantial regional diversity. It is greater in area than the continental United States, spanning almost half the South American continent. The preliminary results of census data collected in 1970 estimated the population of the country at 94.5 million, with 44 percent of it classified as rural.[1] The estimated gross national product in 1968 was U.S. $23,218 million. In per capita terms this was equivalent to U.S. $260.[2] The population, which grew at roughly 3.0 percent per year during 1950-1970, is distributed very unevenly over the country with a major concentration in the southern three states (Table 1).

Although the Brazilian economy grew very rapidly after World War II, its growth began to slow down in the late 1950's and came to a virtual standstill in 1963. An accelerated rate of inflation in 1963 and 1964 (Table 2) and a political crisis involving a revolution in March 1964 were responsible for this. The new government has adopted a technocratic administration and has initiated a set of economic policies designed to speed up economic progress with a major emphasis on controlling inflation. As a result, the rate of inflation has been

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[1]See the preliminary 1970 census of the Brazil "Sinopse Preliminar do Censo Demografico - VIII Recenseamento Geral-1970," Fundacao IBGE - Instituto Brasileiro de Estatistica, Department de Censos, Brasil.

[2]Schuh (1970), p. 3.

TABLE 1: REGIONAL DISTRIBUTION OF POPULATION IN BRAZIL (1970)

| Region | Population | Density (persons/Km$^2$) |
|---|---|---|
| North | 3,602,171 | 1.03 |
| Northeast | 28,150,068 | 18.59 |
| Southeast | 39,872,625 | 43.90 |
| South | 16,510,485 | 29.68 |
| Central West | 5,079,952 | 2.75 |
| TOTAL | 93,215,301 | 11.18 |

Source: Anuario Estatistico do Brasil - 1971, Fundacao IBGE - Instituto Brasileiro de Estatistica, pp. 46 and 54.

Note: It is important to recognize that the "South" region is made up of the three states namely Parana, Santa Catarina, and Rio Grande do Sul; while the "Southeast" region includes Sao Paulo that is the most densely populated state in Brazil.

TABLE 2: GROSS NATIONAL PRODUCTS, PER CAPITA GROSS PRODUCT AND INFLATION IN BRAZIL (1961-1970)

| | Gross National Product | | | Per Capita Gross Product | | | Inflation | |
|---|---|---|---|---|---|---|---|---|
| Year | 1949 Constant Prices (in millions) | Real Indices 1949=100 | Real Annual Growth (%) | 1949 Constant Prices | Real Indices 1949=100 | Real Annual Growth (%) | Wholesale Price Indices 1949=100 | Rate of Inflation |
| 1961 | 521.6 | 226.9 | 10.3 | 7.2 | 160.0 | 6.7 | 776.9 | 33.3 |
| 1962 | 549.0 | 238.8 | 5.3 | 7.4 | 163.3 | 2.1 | 1,202.4 | 54.8 |
| 1963 | 557.5 | 242.5 | 1.5 | 7.3 | 160.8 | -1.5 | 2,139.7 | 78.0 |
| 1964 | 573.8 | 249.6 | 2.9 | 7.3 | 160.4 | -0.2 | 4,018.0 | 87.8 |
| 1965 | 589.5 | 256.4 | 2.7 | 7.2 | 159.8 | -0.4 | 6,245.6 | 55.4 |
| 1966 | 619.6 | 269.5 | 5.1 | 7.4 | 162.7 | 1.8 | 8,670.8 | 38.8 |
| 1967 | 649.2 | 282.4 | 4.8 | 7.5 | 165.2 | 1.5 | 11,011.4 | 27.1 |
| 1968 | 709.7 | 308.7 | 9.3 | 7.9 | 174.9 | 5.8 | 14,073.5 | 27.8 |
| 1969 | 773.6 | 336.5 | 9.0 | 8.4 | 184.7 | 5.6 | 17,207.5 | 22.3 |
| 1970 | 847.2 | 368.5 | 9.5 | 8.9 | 195.8 | 6.0 | 20,611.9 | 19.8 |

Source: Anuario Estatistico Do Brasil - 1971. Fundacao IBGE - Instituto Brasileiro de Estatistica, p. 512.

consistently brought down since 1965 and a strong economic performance was revived in the late 1960's—more than 9 percent per annum between 1968 and 1970 (Table 2).[3]

During the past few decades, agriculture has been a major sector of the Brazilian economy. It has provided the major share of employment opportunities, produced a substantial portion of the gross national product and been the significant source of export earnings. For example, agriculture in Brazil generated about 26.9 percent of the Brazilian domestic product, employed 58.5 percent of the economically active population, and accounted for 98.4 percent of the total national exports in 1960.[4]

It is generally agreed that agriculture played a major role in creating the substantial industrial base found in Brazil in the early 1950's.[5] Schuh argues that the contribution of agriculture to the growth of the total economy in Brazil is crucial through the roles of: (a) expanding the non-farm labor force, (b) providing capital formation for industrialization, (c) providing an adequate diet for the total population, (d) providing a market for the non-farm sector, and (e) providing a source of export earnings.[6]

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[3]Schuh (1970), p. 4.

[4]Shotwell (1969), pp. 64-114.

[5]Furtado (1963), p. 285.

[6]Schuh (1970), pp. 69-101.

However, the relative contribution of agriculture in the Brazilian economy has been declining over the decades. The real income of the agricultural sector rose by 153.7 percent during 1950-1960 while the industrial and service sectors grew by 238.9 and 163.4 percent respectively. The share of the agricultural sector in gross national product was 1.3 times higher than that of the industrial sector in 1950. But the share due to the industrial sector was 1.18 times higher than the agricultural sector in 1960.[7] As a source of employment for an economically active population its share declined from 71.0 percent in 1940 to 58.5 percent in 1960. Industry and service sectors have grown more rapidly than agriculture. The relative rates of growth in this regard during 1950-1960 were 4.7 percent in agriculture and 8.9 percent in industry. A reinforced trend is evident in the rate of per capita sectoral growth over the same period. Between 1950 and 1960, agricultural growth per capita averaged 1.7 percent a year while per capita industrial growth showed a rate of 5.9 percent a year. Even this low rate of agricultural growth per capita was made largely through the expansion of area planted and was not through increases in yields or other factor productivities.[8] This low agricultural productivity compared to other sectors has been recognized as one of major problems of the Brazilian economy with a rapidly increasing population. The low agricultural productivity partly led to

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[7]Schuh (1970), p. 71.

[8]Schuh (1970), p. 94, also see Table 5.

the "food crisis" of 1962-1963, which brought about high prices on food, large food imports, and stagnant agricultural exports.[9] Many Brazilians became convinced that disincentive product and input prices, plus limited supply of some major inputs, were partly responsible for the poor performance of the agricultural sector. As a result, starting in the early 1960's, Brazilian agricultural policies showed a sharp change from the traditional attitude of placing minor priority on the agricultural sector.[10]

These policy changes have taken some distinctive forms. The most important of these policies were a minimum-producer-price policy and subsidized credit programs.

## II.3) Selected Policy Programs

### Minimum-Producer-Pricing-Policy

One of the most important policy changes during the 1960's was activation of a minimum-producer-price program especially in rice, corn, beans, and wheat in order to reduce Brazil's reliance on foreign supplies. This price program not only provided some forward pricing advantages to the farmers, but it also gave farmers substantially higher price incentives at least in the case of wheat.[11] The wheat

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[9]Adams (1971b), and Knight (1971), pp. 112-134.

[10]Adams (1971b), p. 49.

[11]Ibid., p. 49.

price program was institutionalized in 1962-63 and established the Bank of Brazil as official purchaser at the pre-announced price level substantially above the international price level.[12] As a result, the increase in wheat production has been especially impressive. Domestic wheat production increased from 303,396 metric tons in 1962 to 1,600,000 metric tons in 1970. Yet Brazil was able to meet only 50 percent of national consumption level of wheat in 1970.[13] During the period of 1962-70 the area planted to wheat increased 2.5 times--743,458 to 1,895,249 hectares. It is also noteworthy that soybean production has followed the same increasing trend at a lesser rate. In 1970, Brazil produced 1,508,540 tons of soybeans on 1,318,809 hectares compared to 345,175 tons on 313,640 hectares. The increase in soybean production was partly due to the minimum-producer-price program and partly due to its complementarity to wheat production.[14] Data on physical output and cultivated area for both wheat and soybeans suggest that the increased production of both crops was possible primarily through the increased use of land rather than improving yield per hectare.[15]

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[12] Engler (1971). For example, in 1970 the Bank of Brazil fixed the domestic price of wheat at U.S. $100 per metric ton, while the price for imported wheat is U.S. $58 per metric ton. Also see Knight (1971), pp. 92-93.

[13] Anuario Estatistico do Trigo, 1962/63 and 1969/70.

[14] Anuario Estatistico do Brasil, 1962 and 1970. Also see Engler (1971), p. 9.

[15] Knight (1971), pp. 114-115.

The major producing area of wheat in Brazil is Rio Grande do Sul, the southern most state, which accounts for more than 80 percent of domestic wheat production. Rio Grande do Sul is also responsible for a substantial portion of soybean production. In Rio Grande do Sul, the two adjacent sub-regions called Planalto Medio and Missoes have been very important in this performance.

Subsidized Credit Program

Probably the most influential policy emphasis, during the 1960's was the huge increase in the amount of institutional credit made available to agriculture. During 1960-1968 the dollar value of this credit, expressed in year-end balances, increased from $606 million to $1,417 million. Adams pointed out that, since interest rates on agricultural credit ranged from 9 to 18 percent per year and inflation 25 to 85 percent a year during the 1960's, real interest rates were substantially negative. He also argued that an income transfer of $100 to $200 million per year moved from the public sector to the borrowers of agricultural credit in Brazil via these negative interest rates during the 1960's.[16]

The massive availability of the subsidized credit has facilitated increased use of modern inputs such as fertilizer, machinery, and certified seeds in Brazil. However, only very limited use was

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[16]Adams (1971b), p. 49.

made of these inputs on traditional small farms.[17] It has been widely appreciated that the credit program has substantially contributed to the agricultural growth during the 1960's.[18]

## II.4) Description of the "Wheat Region" in Rio Grande do Sul and its Agricultural Transition

In the past five years Rio Grande do Sul has experienced one of the highest rates of growth, roughly 8 percent per annum, in total agricultural output in the world. The two adjacent regions in Rio Grande do Sul—Planalto Medio (a plateau region) and Missoes (a lowland region)—provide an excellent case of this growth primarily due to the two favorable agricultural policies discussed above. In addition, these two sub-regions are fairly homogeneous with regard to soil, topography, vegetation, climate, and settlement pattern.[19] These sub-regions are selected for this study and will be referred to as the "wheat region" of Rio Grande do Sul in the remaining chapters in view of their major share in domestic wheat production (see Table 3).[20]

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[17] Rao (1970).

[18] For detailed discussions on policy implications of institutional agricultural credit for agricultural development in Brazil, see Adams (1971b); Smith (1967), pp. 213-265; Erven (1967); and Rao (1971).

[19] For a detailed description of the wheat region and Rio Grande do Sul as a whole, see Rask (1969).

[20] For example, in 1960 the wheat region accounts for 61 percent of wheat production in Rio Grande do Sul which is in turn 39 percent of total domestic wheat production (see Table 4).

TABLE 3: CULTIVATED AREA AND PRODUCTION OF SELECTED AGRICULTURAL CROPS AND BEEF IN THE WHEAT REGION, RIO GRANDE DO SUL (R.G.D.S.) AND BRAZIL (1961-1971)

| | Wheat | | | | | | Soybean | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wheat Region[a] | | R.G.D.S.[b] | | Brazil[b] | | Wheat Region[a] | | R.G.D.S.[b] | | Brazil[b] | |
| Year | Area* | Qty. | Area | Qty. | Area | Qty. | Area | Qty. | Area | Qty. | Area | Qty. |
| 1961 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | 120.3 | 121.1 | 227.2 | 252.6 | 240.9 | 271.5 |
| 1962 | 94.4 | 129.0 | 226.6 | 274.2 | 258.2 | 303.4 | 132.5 | 84.9 | 294.9 | 320.8 | 313.6 | 345.2 |
| 1963 | 161.9 | 63.9 | 278.9 | 103.4 | 302.1 | 115.7 | N.A. | N.A. | 318.3 | 294.8 | 339.8 | 322.9 |
| 1964 | 155.4 | 128.8 | 271.9 | 225.7 | 300.5 | 250.5 | N.A. | N.A. | 334.4 | 275.9 | 359.6 | 304.9 |
| 1965 | 188.9 | 136.8 | 325.4 | 236.9 | 354.7 | 256.7 | 138.9 | 147.9 | 386.5 | 463.2 | 432.8 | 523.2 |
| 1966 | 199.6 | 178.8 | 343.5 | 296.0 | 385.0 | 333.5 | N.A. | N.A. | 416.3 | 483.3 | 490.7 | 595.0 |
| 1967 | 292.9 | 195.8 | 487.7 | 339.6 | 562.0 | 405.7 | N.A. | N.A. | 490.9 | 550.8 | 612.1 | 715.6 |
| 1968 | 399.2 | 363.9 | 689.1 | 618.7 | 845.7 | 765.1 | N.A. | N.A. | 557.0 | 432.6 | 721.9 | 654.5 |
| 1969 | 602.2 | 664.1 | 1044.7 | 1090.1 | 1299.5 | 1303.4 | N.A. | N.A. | 649.1 | 744.5 | 906.1 | 1056.6 |
| 1970 | N.A. | N.A. | 1500.0 | 1500.0 | 1810.0 | 1784.0 | N.A. | N.A. | 871.2 | 976.8 | 1318.8 | 1508.5 |

TABLE 3 (cont'd.)

| Year | Corn | | | | | | Beef | | |
|---|---|---|---|---|---|---|---|---|---|
| | Wheat Region[a] | | R.G.D.S.[b] | | Brazil[b] | | Wheat Region[a] | R.G.D.S.[a] | Brazil[a] |
| | Area | Qty. | Area | Qty. | Area | Qty. | Qty. | Qty. | Qty. |
| 1961 | 287.3 | 358.1 | 1281.6 | 1765.0 | 6885.7 | 9036.2 | 2191.0 | 9692.0 | N.A. |
| 1962 | 295.9 | 369.1 | 1361.5 | 1870.6 | 7347.9 | 9587.3 | 2216.0 | 9707.0 | N.A. |
| 1963 | N.A. | N.A. | 1403.9 | 1947.8 | 7957.9 | 10478.3 | N.A. | 10344.0 | 79855.0 |
| 1964 | N.A. | N.A. | 1420.3 | 1773.8 | 8105.9 | 9408.0 | N.A. | 10664.0 | 84167.0 |
| 1965 | 332.0 | 427.5 | 1577.6 | 2243.9 | 8771.3 | 12111.9 | N.A. | 11126.0 | 90629.0 |
| 1966 | N.A. | N.A. | 1632.1 | 2280.9 | 8703.2 | 11371.5 | N.A. | 11607.0 | 89969.0 |
| 1967 | N.A. | N.A. | 1626.9 | 2331.0 | 9274.3 | 12824.5 | N.A. | 11801.0 | 89896.0 |
| 1968 | N.A. | N.A. | 1670.2 | 1971.4 | 9584.4 | 12813.6 | N.A. | 11974.0 | 92276.0 |
| 1969 | N.A. | N.A. | 1730.1 | 2233.7 | 9653.8 | 12693.4 | N.A. | 12052.0 | 95150.0 |
| 1970 | N.A. | N.A. | 1737.1 | 2386.6 | 9858.1 | 14216.0 | N.A. | 12563.09 | 97864.0 |

Source: [a]Anuario Agro-Pecuario, 1963. Anuario Agro-Pecuario, 1967.
Anuario Estatistico do Trigo, SAFRA 69/70, CCLEF, Ministerio da Agricultura.
[b]Anuario Estatistico do Brazil, 1961-1971.

Note: Measurement Units: The area for crops is in 1000 hectares. The quantity for crops is in 1000 tons. The quantity for beef is in 1000 heads.

N.A. denotes that the data are not available.

The wheat region comprises about one-fourth of the total land area in Rio Grande do Sul and belongs to the open plain of the plateau (Figure 1). In the early 1900's the region was settled in large estates for the production of beef. Rask observes that the present agricultural production in the wheat region is still predominantly range livestock carried on under reasonably large farm situations; but recently it has undergone a partial transition to highly mechanized wheat and soybean production.[21] Because of this transition, systems of farming vary from traditional to the most modern of mechanized units. Rask also points out that, because of the high cost of mechanization and reluctance on the part of traditional cattlemen to shift to more intensive land use, different tenure systems have evolved.[22] For example, professional or business people in the urban area generated initial impetus for change by purchasing machinery and renting land from cattlemen for wheat production. The introduction of mechanization in wheat farming has also led to the other possibility of using these machines for the establishment of improved pasture systems for cattle grazing.[23]

During the last decade, the two principal policy measures namely the price subsidy for wheat and the subsidized credit program tied with the purchase of commercial inputs have been to a great extent

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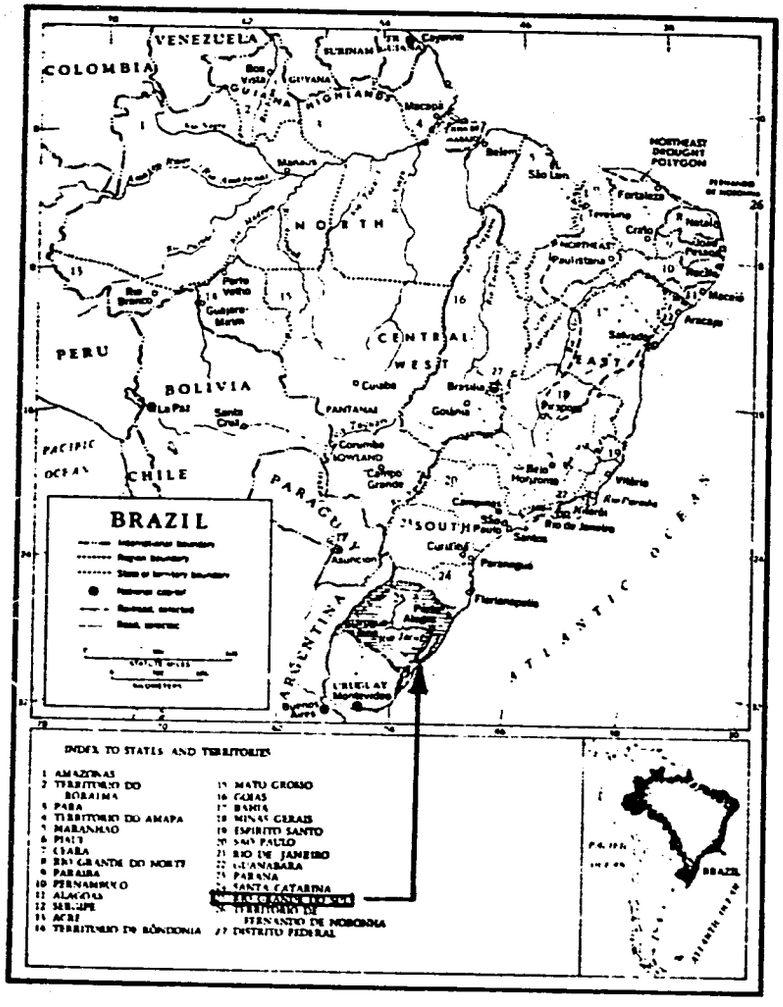
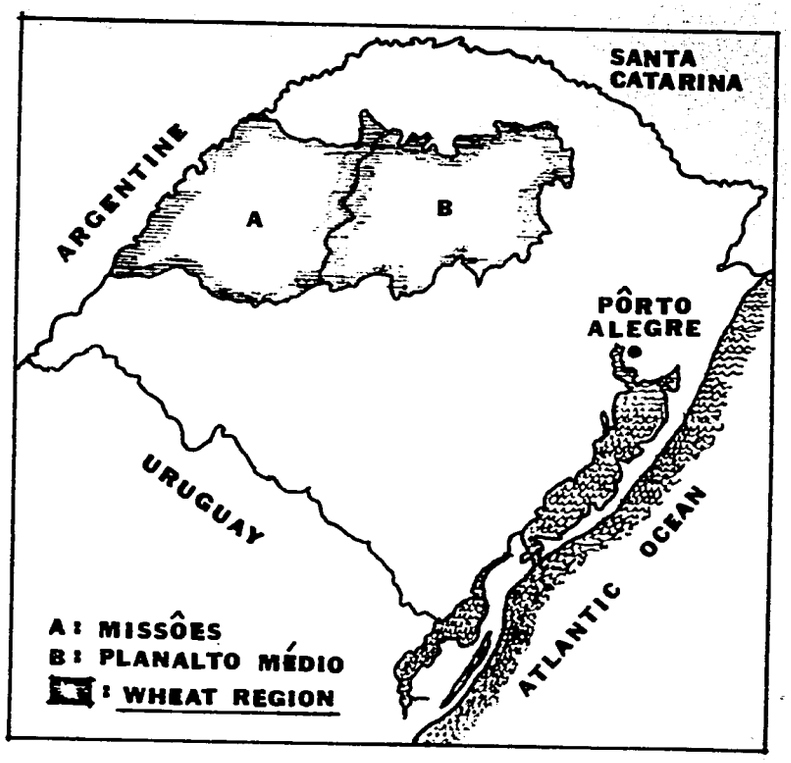
[21] Rask (1972), p. 9.

[22] *Ibid.*, p. 9.

[23] *Ibid.*, p. 9.




RIO GRANDE DO SUL



Figure 1. THE MAP OF THE WHEAT REGION, RIO GRANDE DO SUL, & BRAZIL

favorable to wheat production in Rio Grande do Sul including the wheat region. As a result, hectarages of wheat and of soybeans-following-wheat in crop rotation have undergone substantial increases in recent years while the outputs of other crops such as corn have grown at a low rate (see Table 3).[24] The mere transition from range livestock farming to cropping agriculture entailed a continued reduction of natural pasture land. However, the mechanized wheat farming that has been steadily increasing in the region makes an alternative cattle production system available. That is, the mechanized wheat farms can easily be converted to a highly productive improved pasture system for cattle production.

The dramatic increase in agricultural output in the wheat region last decade can be summarized in the following two dimensional transformations: (a) a shift from the traditional range livestock production on extensive natural pastures to intensive cropping of wheat and soybeans and intensive livestock on improved pasture systems, and (b) a consequent increase in mechanized crop farming.

While the wheat region is agro-topographically homogeneous, the regional farm size distribution ranges from a few hectares to several thousand (Table 4). This wide range of farm size distribution is also characterized by a highly skewed distribution in the number of farms.

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[24]The competitive nature of wheat is further enhanced by its complementary relationship to soybean production. Soybeans can be produced in the off season of wheat without fertilizer application, thus, allow fuller use of the labor and machinery inputs needed for wheat production.

See Engler (1971), p. 9.

TABLE 4: FARM SIZE DISTRIBUTION IN THE PLANALTO MEDIO AND MISSOES REGION (WHEAT REGION) OF SOUTHERN BRAZIL IN 1967

| Class by Hectares | Number of Farms | Total Farm Area | Percent of Farm Area | Area Exploited |
|---|---|---|---|---|
| 0 - 10 | 27,479 | 146,995 | 2.56 | 135,771 |
| 10 - 25 | 37,575 | 661,771 | 11.53 | 617,384 |
| 25 - 50 | 15,807 | 572,528 | 9.98 | 541,605 |
| 50 - 100 | 7,485 | 528,153 | 9.20 | 506,092 |
| 100 - 1,000 | 7,558 | 2,154,996 | 37.51 | 2,112,646 |
| 1,000 - 10,000 | 729 | 2,581,101 | 27.66 | 1,557,784 |
| 10,000 - 100,000 | 4 | 89,641 | 1.56 | 49,280 |
| Above 100,000 | — | — | | — |
| Total | 96,641 | 5,735,145 | 100 | 5,520,565 |
| Percent of the State of Rio Grande do Sul | (18.55%) | (23.52%) | | (23.82%) |

Source: Estrutura Fundiaria do Rio Grande do Sul — Instituto Brasileiro de Reforma Agraria Delegira Regional do Rio Grande do Sul. Also see Rask (1971), pp. 24-30.

Note : The area is in hectare.

In 1967, for example, a total of 80,861 farms were operated on less than 50 hectares, while 15,776 farms on more than 50 hectares (Table 4).

In his study of small farm agriculture in the small farm regions adjacent to the wheat region, Rask found that low productivity of crops and livestock, low income and lack of technical assistance forms a vicious circle of poverty.[25] A substantial portion of farms with a few hectares in the wheat region may well belong to the category of small farm agriculture. On the other hand, the highly mechanized large farms are oriented to commercial farming. This suggests that a bi-modal farm size continuum exists with substantial differences in agricultural structure.

There is another important aspect in the regional transformation involving number of farms. The number of farms in Rio Grande do Sul has increased notably in recent years. During the decade 1950-1960, farm numbers increased by 33 percent with the number of farms of less than 10 hectares doubling. The farm numbers in the wheat region, 71,829 in 1960, increased to 96,641 in 1967, indicating 34 percent growth in 7 years.[26] This unique bi-modal nature of regional farm size distribution is crucial in understanding regional agricultural development.

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[25] Rask (1964).

[26] See Censo Agricola de 1960: Rio Grande do Sul, IBGE - Servico Nacional de Recenseamento, Brasil. Also see Estrutura Fundiaria de Rio Grande do Sul - Instituto Brasileiro de Reforma Agraria Delegaria Regional do Rio Grande do Sul.

## CHAPTER III

## THE RECURSIVE PROGRAMMING MODEL OF THE REGIONAL FARM SECTOR

### III.1) Introduction

The mathematical model constructed for this study is a recursive programming model that Day pioneered as a general class of dynamic systems. Extending Henderson's model of agricultural land utilization, Day synthesized both linear programming and difference equations to derive a dynamic system in order to study agricultural production responses.[1] This dynamic system, properly called a "Recursive Decision System" by Day is a sequential optimization method involving behavioral

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[1]For comprehensive treatments of recursive programming theory, see Day (1963a). Day defined a dynamic system as a set of mathematical relations in which time enters either explicitly or implicitly. He gave a trend equation as an example of the explicit role of time and a linear homogeneous differential or difference equation with constant coefficients of the implicit role of time (ibid., p. 35).

It is noteworthy that the definition of recursive programming as a general class of dynamic systems is similar to the one of "Simulation Model of an Economic System," used by Johnson, et al. except that recursive programming contains an optimizing criteria explicitly. (See Johnson, et al., (1971), p. 30.)

Henderson's contribution in this context is "an ingeneous innovation which enabled linear programming to be applied as a predictive model of actual economic behavior." His land allocation model among a dozen major field crops rests on two basic principles: first, expected net revenues per acre of the crops, second, the "flexibility constraint" hypothesis that acreage plantings for each crop are assumed to be bounded by maximum and minimum limits which indicate "his desire for diversity and reluctance to depart from an established pattern" (see Henderson (1959)).

feedbacks which take account of uncertainty, myopia, limited information and the like. Therefore, a recursive decision system deals more with the temporal elements of decision making and less with what decisions ought to be made in terms of some optimum or normative decision rules.

As a unique property of the system, the recursive programming model deals with a multiple phase dynamic system whose behavior is determined by distinct "phases" but whose phases are governed by a single optimizing principle. Under a single rule, a new phase occurs when the time elapsed since the initiation of the current phase is sufficient to cause the optimizing rule to be broken.[2]

Several empirical studies employing the recursive decision system framework suggest that recursive programming models are capable of treating at least the following features of farm behavior.[3]

1. describe farm production and how it changes over time;
2. relate production decisions to household characteristics;
3. incorporate time in the two fold sense of a backward linkage of present possibilities to past events and a forward linkage of present decisions to anticipated future actions and events;

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[2]Day (1963a), pp. 35-56. In contrast to Day's multiple phase dynamic systems governed by a single optimizing rule, Hick's trade cycle study and Leontief's dynamic input-output model provide multiple phase dynamic models governed by a set of rules specifying the conditions under which the process is switched from one phase to the next.

[3]Day (1963a), p. 7. Also see Day and Heidhues (1967).

4. illustrate essential features of agricultural development such as changing technology and irreversible changes in resource allocation;

5. explain the changing pattern of capital use and capital formation on the structure of regional production.

Illustrative of these features are the Mississippi Delta model by Day (1963a), the regional model of crop production by Schaller (1965), the North German farm growth model by Heidhues (1966), and the Punjab model by Singh (1971a).[4] These models contain two basic components: (a) on-farm decision structure, and (b) feedback mechanism. A heuristic flow diagram of the on-farm recursive decision system components is presented in Figure 2. Given time period, t-1, one can realize that the on-farm decision making process is made up of the three basic forces described in Chapter I; that is, (1) the decision making unit--the farm-firm having multiple farm activities (decision variables along with some optimizing criterion), (2) the agricultural environment which includes market forces such as supply and demand or equilibrium prices, on-farm resource endowments, and non-farm linkages including urban out-migration and supply functions of non-farm inputs to agriculture, and (3) a set of predetermined variables which include exogeneous variables, such as policy instruments. The items (2 and 3) are contained in the three boxes outside the "on-farm decision box". All

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[4]Recursive Programming Models applied to industrial performance include Abe's Steel Industries Model (1969), Tabb's U.S. Coal Industry Model (1967), and Tsao's U.S. Iron and Steel Industry Model (1966).

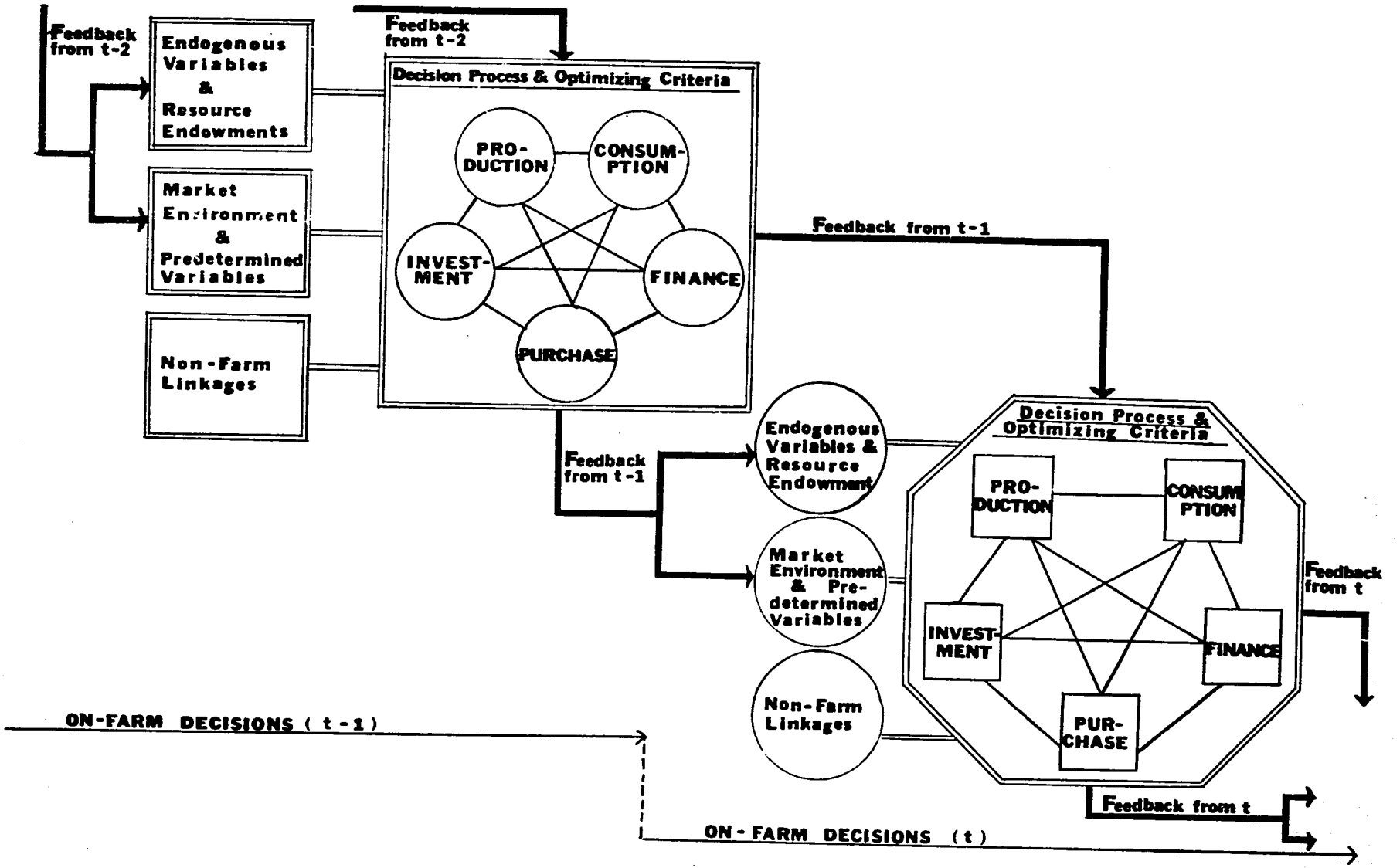


FIGURE 2: A HEURISTIC ON-FARM RECURSIVE DECISION SYSTEM

the components are connected by lines, describing the "interaction system" discussed in Chapter I. This then completes the fundamental model components at given time period t-1.

Of essence in recursive programming models is the existence of the recursive feedback mechanism which functionally relates on-farm decisions between two points of time, say t and t-1. The recursive feedbacks (the arrows linking the two on-farm decision boxes and endogenous variables) are an extended version of the generalized cob-web model and the Nerlovean distributed lag model, allow adjustments of expectations due to risk and uncertainty and due to learning and the process of diffusion in a changing environment, and account for changing decision rules.

The remaining sections of this chapter describe (1) regional farm activities, (2) optimizing criteria, and (3) the constraint structure that is the basic element in the "on-farm decision box" at given time period t. In Chapter IV, the recursive feedbacks are discussed; and in Chapter V, the decomposition principle by farm size is presented as an important methodological extension of the previous recursive programming studies.

## III.2) Regional Farm Activities

Since the model considers identical farm activities for the three different farm size groups which exhaust the total number of farms in the region, farm activities are described for one farm size group only. The farm activities for this study are categorized into five basic sets

that are interdependent. They are production by different technologies, consumption, investment, purchasing, and financial activities.

Production Activities by Technology

Production activities are processes that transform inputs into final outputs, and also into intermediate outputs that in turn are used to produce final outputs. Field crop production activities have associated with them: (1) the cost of all inputs that are not explicitly considered in purchasing activities; (2) an output (final or intermediate) per unit level of the activity; (3) an input-output coefficient that defines various input requirements per unit level of the activity. A sequence of land preparation and harvesting tasks, and hence the use of distinctive farm power sources (mechanical technologies such as draft animal vs. tractor and combine operation) and differential levels of nutrients application by cropping activity (bio-chemical technologies), are used to distinguish technologies.

The existence of multiple technologies are associated with production activities and allow the incorporation of the concept of "technological change" during agricultural development. This has been a focal theme for understanding agricultural development. It is generally agreed that a technology is always embodied in particular factors and an integral part of the productive agents employed.[5] Therefore,

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[5]A classical example of embodied technology would be hybrid seed corn which requires exactly identical corn production process as open-pollinated seed. Yet in analyzing the production of corn, both are crucially identifiable and measurable factors. (See Griliches (1958).)

Following the identical logic, Jorgensen and Griliches found that the percentage rate of output growth explained by the rate of

when all the factors are completely specified, the technology is also specified. Thus, Schultz points out that the notion of a "technological change" is in essence a consequence of either adding, or dropping, or changing at least one factor of production.[6] But it is frequently accepted that both theoretical analysis and empirical investigations proceed with an analytical device of placing some things into a compound such as "technology" to be held constant. However, Schultz further argues that "when such a compound variable as technology becomes an important variable over time, as is the case in modern economic growth, the particular factors that are in it must be examined and their economic behavior analyzed if growth is to be satisfactorily explained."[7]

Indeed, the existence of multiple technologies, and hence multiple paths of technological change in agriculture available to a society, is a major premise in the "Induced Development Model" of Hayami and Ruttan. They emphasize an optimum path of technological change as follows:[8]

> The constraints imposed on agricultural development by an inelastic supply of land may be offset by advances in biological technology. The constraints imposed by an inelastic supply of labor may be offset by advances in

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growth in inputs in U.S. manufacturing industries to be 96.7 percent if the value share aggregation method that accounts for changes in qualities of factors is employed. (See Jorgensen and Griliches (1967), pp. 249-283).

[6]Schultz (1964), p. 134.

[7]Ibid., p. 133.

[8]Hayami and Ruttan (1971), p. 54.

> mechanical technology. The ability of a country to achieve rapid growth in agricultural productivity and output seems to hinge on its ability to make an efficient choice among the alternative paths. Failure to choose a path which effectively loosens the constraints imposed by resource endowments can depress the whole process of agricultural and economic development. The construction of an induced development model involves--an explanation of the mechanism by which a society chooses an optimum path of technological change in agriculture.

Hayami and Ruttan's emphasis on the mechanism of an optimum choice of multiple technologies as an endogenous variable in a development model has been empirically investigated by Day (1967) and Singh (1971a). As pointed out in Chapter II, the agricultural growth in Southern Brazil in the last decade involved primarily extensive use of land; therefore, treat explicitly two classifications of technology, namely traditional technology (draft animal use for land preparation, for planting field crops, and manual harvesting) and modern technology (tractor and combine use for land preparation and harvesting) with a constant level of fertilizer application for each technology.[9]

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[9]As for the explicit treatment of classifications of "mechanical technology," Singh, et al. define several standard tasks for the land preparation process, each of which can be performed in several distinct ways by the use of a given implement-power combination. For the detailed discussion, see Singh, et al. (1968).

The level of nutrients application considered in this study is equivalent to Engler's "Medium Productivity Level" of various cropping activities. Engler also considers a "High Productivity Level" for a single representative of highly mechanized crop farms in the "wheat region". But it is suggested that on a regional level, the medium productivity level is much more acceptable (Engler (1971)). Of course, multiple nutrients levels can be easily incorporated in the model with information from nutrient response functions by crops and soils in the region.

Consumption Activities

Consumption activities involves the farm-household's consumption of farm outputs. There are normally two types of consumption activities: (1) the consumption of foodgrains and food items by the farm family and sometimes hired labor when the wage is given in kind, and (2) the consumption of animal fodder crops for the maintenance of draft animals.

The amounts of farm outputs reserved for domestic consumption and hence the marketable farm surplus depend upon such factors as the size of the household and the prices of farm outputs. The fodder requirements depend upon the number of work animals and the degree of mechanization. The firm-household interdependence is accounted for by considering consumption requirements as a constraint on the sale of farm outputs and on the production of alternative crops. Singh argues that this is where the nature of "subsistence production" is defined in traditional agriculture.[10]

Both consumption activities can be treated explicitly as activity columns, i.e., decision variables, or as feedback components. The latter method was used in this study by reserving a certain proportion of farm outputs from time t for domestic use in t + 1.

Investment Activities

Investment activities are associated with the replacement and additions to the capacities of quasi-fixed inputs such as draft animals,

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[10]Singh (1971a), p. 31.

tractors and combines. Investment purchases compete for cash both with consumption and production purchases. All investment activities augment available capacities for use on the farm, while their physical depreciation reduces available capacities. Investment activities are considered in a simple "capacity exhaustion hypothesis," with a net cost calculated on a payback principle and cash outlay for purchases.[11]

## Purchasing Activities

Purchasing activities involve cash outlays to purchase variable inputs such as nutrients, wage labor, transportation, insecticides, oil and lubrications for machine operation, salt and bone meals, and medicines and vaccines for beef enteprises. Of course, these items can be treated explicitly as activity columns. However, they also can be treated implicitly (their cost incorporated in with production activities) so that production activities take account of final outputs as well as a subset of these variable inputs.

## Financial Activities

Financial activities are associated with cash flows in a given production period and, as such, can be considered a monetary link that binds the other economic activities involving the use of cash inputs.

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[11]The payback principle describes positive rather than normative aspects of the investment decision. Therefore the use of the payback principle can be considered a form of institutional or behavioral constraint on investments. There exist some questions on the use of the payback period to estimate depreciation costs (see Bierman and Smidt (1966)), but certain aspects of the payback principle are consistent with rational investment theory (see Smith (1967)). Also see Nelson (1970) and Singh (1971) for a similar method in arriving at investment costs in a programming model.

There are two types of financial activities: (1) saving activities associated with a bank deposit to represent the opportunity cost of capital as measured by an external rate of return which is a net subtraction from the cash flows when deposits are made, and (2) net borrowing activities associated with additions to the cash flow in the current period. The saving activity allows farmers to bank their liquid assets as an alternative to using capital in the farming process and the borrowing activity allows farmers to borrow working capital at appropriate rates of interest to augment their liquidity.

### III.3) Optimizing Criteria

The crucial component of the recursive decision system that distinguishes it from simulation models is the explicit formulation of an optimizing criteria. Adapting Debreu's notion of lexicographic utility functions, Day and Singh suggest that the preference (objective) function of the farmer is postulated in a lexicographic way with four major goals ranked in terms of absolute priority (lexicographic ordering).[12] The four goals include (1) satisfying subsistence consumption needs, (2) a utility function comparing cash consumption and future income, (3) a metric defining the distance of a given choice from a set of safe-enough choices, and (4) maximizing net cash returns.

Following the lexicographic ordering of utility functions, the model incorporates these sequential criterion: first, the subsistence

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[12] For the discussions on the lexicographic ordering of the four goals in the farm decision strategies, see Day and Singh (1971). For the discussion on the lexicographic utility function, see Deberu (1959), pp. 72-73.

consumption needs are specified in the retained domestic consumption of foodgrains through a feedback function in defining internal working cash availability for next period; second, a preference ordering among alternative cash consumption and future income streams is represented by the allocation of cash resources between consumption and saving; third, flexibility and adoption constraints (for which a discussion follows in the next chapter) define the safety metric representing a principle of cautious optimization very much like the safety-first principle or chance-constrained programming; fourth, this goal is met by maximizing net cash returns subject to the three previous goals. This decision rule differs substantially from that of maximizing short run net revenues. The specification of the first three goals makes the "feasibility region," i.e., a convex set formed by the linear inequality constraints, significantly smaller than the one otherwise obtained.

Based on these sequential optimizing criteria, the following objective function is maximized for each farm size group:

$$\begin{aligned}
\text{Max } \Pi\ (t) = & \sum_{j=1}^{8} \left[ Z_j(t)X_j(t) - C_j(t)X_j(t) \right] - \sum_{j=9}^{13} C_j(t)X_j(t) \\
& + \sum_{j=14}^{17} \left[ Z_j(t)X_j(t) - C_j(t)X_j(t) \right] - \sum_{j=18}^{20} C_j(t)X_j(t) \\
& - \sum_{j=21}^{23} C_j(t)X_j(t) - \sum_{j=24}^{26} C_j(t)X_j(t) - \sum_{j=27}^{27} C_j(t)X_j(t) \\
& + \sum_{j=28}^{28} C_j(t)X_j(t) \qquad (1)
\end{aligned}$$

Where: $Z_j(t)$; j=1...8 : the per hectare gross receipts of the jth crop which is produced under two distinctive technologies in year t (in Cr$ per hectare).

$C_j(t)$; j=1...8 : the summation of input prices of nutrients insecticides, transportation, and seeds needed to one hectare of the jth cropping activity in year t (in Cr$ per hectare).

$C_j(t)$, j=9...13 : total costs associated with fencing, nutrients, seeds, and transportation necessary for the jth pasturing activity in year t (in Cr$ per hectare).

$Z_j(t)$; j=14...17 : total value of one beef cow unit produced by the jth beef enterprise in year t (in Cr$ per cow unit).

$C_j(t)$; j=14...17 : total costs associated with bone meal, salt, medicines and vaccines, and bull replacement required to fatten one cow unit in the jth beef enterprise in year t (in Cr$ per cow unit).

$C_j(t)$; j=18...20 : investment costs on the jth farm power source that are calculated on the basis of payback principle in year t (in Cr$ per farm power source unit).

$C_j(t)$; j=21...23 : operation costs of the jth farm power in year t (in Cr$ per hour).

$C_j(t)$; j=24...26 : one hour hiring cost of the jth seasonal labor in year t (in Cr$ per hour).

$C_j(t)$; j=27 : the borrowing rate for short term institutional credit in year t, set at 15 percent per annum.

$C_j(t)$; j=28 : the interest rate on bank deposits in year t set at 6 percent per annum.

$X_j(t)$; j=1...28 : various farm activities as described in the appendix.

The specific variable (column variables) definitions are given in the Appendix A.

For the various cropping activities (j=1...8) and alternative beef enterprises (j=14...17), the differences $(Z_j(t) - C_j(t))$, are the objective function coefficients in year t. The formulation of the objective function above for one farm size group assumes zero cost for the use of family labor. As Singh points out, this does not mean a zero marginal value productivity because the feedback of the retained consumption explicitly accounts for the costs of its use and these costs are invariant with respect to the amount of family labor employed on the farm.[13]

## III.4) The Constraint Structure

The constraint structure involves six basic sets: (1) land restrictions by season and type, (2) family labor restrictions by season, (3) quasi-fixed factor capacity constraints which include total

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[13]Singh (1971a), p. 36.

available serviceable hours from last year's farm power stock less depreciation plus a power stock augmentation in the current year through investments, (4) financial constraints, (5) behavioral constraints, and (6) regional "coupling" constraints that provide common binding constraints for the three different farm size groups and which allow one to use the decomposition principle to aggregate for the region.

The RHS (right hand side) vector variables and their descriptions for a given farm size group are given in Appendix A. The objective function (1) is maximized subject to the following six subsets of constraints for a given year t.

Land Constraints

$$\sum_{j=1}^{8} A_{ij}X_j(t) + \sum_{j=9}^{13} A_{ij}X_j(t) \leq B_i(t); \quad i=1,2 \tag{2}$$

where $A_{ij}$ is the land input coefficient of the ith type for a unit level of the jth activity in year t. This states that the land allocated for both cropping (the first term) and pasturing (the second term) activities cannot exceed the total regional land available for the given season in year t.

$$- \sum_{j=9}^{13} A_{ij}X_j(t) + \sum_{j=14}^{17} A_{ij}X_j(t)$$

$$+ \sum_{j=20}^{20} A_{ij}X_j(t) \leq B_i(t); \quad i=3,4,5 \tag{3}$$

This inequation expresses that the beef enterprises (the second term) and animal fodder reservation (the third term) are bounded by the upper limit of the ith type of pasture land (the first term) in year t. These are balance constraints which represent the case where the intermediate outputs (pasture lands) are used for other products (beef and draft animal service).

$$- \sum_{j=1}^{2} A_{ij}X_j(t) + \sum_{j=3}^{4} A_{ij}X_j(t) \leq 0; \qquad i=6,7 \tag{4}$$

This assures that the hectarage planted to soybeans following wheat must, by definition of crop rotation, be less than or equal to the wheat hectarage under one type of technological choice in year t.

<u>Labor Constraints</u>

$$\sum_{j=1}^{8} A_{ij}X_j(t) + \sum_{j=9}^{13} A_{ij}X_j(t) + \sum_{j=14}^{17} A_{ij}X_j(t)$$

$$- \sum_{j=24}^{26} A_{ij}X(t) \leq B_i(t); \qquad i=8,9,10 \tag{5}$$

and

$$\sum_{j=24}^{26} A_{ij}X_j(t) \leq B_i(t); \qquad i=90,91,92 \tag{6}$$

Inequation (5) specifies that the cropping activities (the first term), the pasturing activities (the second term), and the beef enterprises (the third term) use first the family labor hours available for

the season. If this is not sufficient, it can be augmented by labor hiring activities by season (the fourth term) in year t.

Inequations (6) constrain the labor hiring activities by season by the regional supply of wage labor in year t.

Quasi-fixed Capacities (Farm Powers) Constraints

$$\sum_{j=1}^{8} A_{ij}X_j(t) + \sum_{j=9}^{13} A_{ij}X_j(t) - \sum_{j=21}^{23} A_{ij}X_j(t) \leq 0; \quad i=11,12,13 \quad (7)$$

and

$$- \sum_{j=18}^{20} A_{ij}X_j(t) + \sum_{j=21}^{23} A_{ij}X_j(t) \leq B_i(t); \quad i=14,15,16 \quad (8)$$

and

$$\sum_{j=18}^{18} A_{ij}X_j \leq B_i(t), \quad i=88 \quad (9)$$

where the inequations in (7) state that the cropping activities (the first term) and pasturing activities (the second term) are restricted by the amount of the "purchased hours" of farm power (the third term) transferred from the total farm power availability to account for their operation cost. The inequations in (8) specify that the total farm power use (the second term) is restricted by the serviceable hours of existing farm power stock which in turn can be augmented by the investment activities (the first term) in year t.

Inequation (9) describes the investment activities on modern technology being constrained by the regional supply functions of modern farm machinery.[14]

Financial Constraints

$$\sum_{j=1}^{26} A_{ij}X_j(t) - \sum_{j=27}^{27} A_{ij}X_j(t)$$

$$+ \sum_{j=28}^{28} A_{ij}X_j(t) \leq B_i(t); \quad i=17 \tag{10}$$

and

$$\sum_{j=27}^{27} A_{ij}X_j(t) \leq B_i(t); \quad i=89 \tag{11}$$

and

$$\sum_{j=21}^{23} A_{ij}X_j(t) - \sum_{j=29}^{29} A_{ij}X_j(t) = 0; \quad i=18 \tag{12}$$

The financial constraints link all farm activities. In (10) the activities of production, investment, and purchasing (the first term) and the saving activity (the third term) compete for the internal cash available which in turn can be increased by the borrowing activity (the

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[14]Note that the equation (9) is associated with tractors only. Since the land preparation by tractors is normally followed by the combine operated harvesting, the specification of the upper limit on regional tractor supply only places the limit on the regional combine supply as a scalar multiple of the former.

second term). But the borrowing activity is constrained by regional credit availability as specified in (11). Equation (12) is a computational mechanism to sum the amount of cash used for various investment activities.

Behavioral Constraints

Behavioral constraints are crucial components in a recursive programming methodology; therefore, their detailed discussion is deferred to the next chapter. The behavioral constraints include two broad categories, namely (1) flexibility constraints, and (2) adoption constraints.

$$\sum_{j=1}^{2} X_j(t) \leq B_i(t) = (1 + \overline{\beta}) \sum_{j=1}^{2} X_j(t-1); \qquad i=19,21,23,25,27,29 \tag{13a}$$

$$- \sum_{j=1}^{2} X_j(t) \leq B_i(t) = (1 - \underline{\beta}) \sum_{j=1}^{2} X_j(t-1); \qquad i=20,22,24,26,28 \tag{13b}$$

$$\sum_{j=18}^{18} X_j(t) \leq B_i(t); \qquad i=88 \tag{14}$$

Both $\overline{\beta}$ and $\underline{\beta}$ are an upper bound and lower bound coefficient respectively.

The constraints in (13) limit the hectarage planted to wheat, for example, at t between an upper limit and a lower limit, both of which are functionally related to the wheat hectarage sown in the past years.

The same holds true for soybeans, corn, beef enterprise using natural pasture, and beef enterprise using both summer and winter improved pastures.

In (14) investment in tractors follows behavioral bounds that will be discussed in the next chapter.

Regional Coupling Constraints

The regional supply of some strategic resources for which each farm size group competes includes off farm machinery, institutional credit, and wage labor classified by season. Their entry as a subset of the components in the RHS vector and their linkages to the activities and constraints have been discussed in the inequations (5), (6), (7), (9), (10), and (11). These coupling constraints are crucially associated with the process of decomposition in the model.

Non-negative Constraints

Of course, all the farm activities follow the usual non-negativity assumptions:

$$X_j(t) \geq 0; \quad j=1...29 \tag{15}$$

Summary

The regional farm activities and the constraint structure discussed above can be summarized in Figure 3. The zeros imply that there exist no input-output relationships between the activities and their corresponding constraints.

| Constraints | Production Activities | | Purchasing Activities | Investment Activities | | Financial Activities | RHS |
|---|---|---|---|---|---|---|---|
| | Traditional Technology | Modern Technology | | Traditional Farm Power | Modern Farm Power | | |
| Land by Type and Season | $A_{ij}$ | $A_{ij}$ | $A_{ij}$ | 0 | 0 | 0 | $B_a$ |
| Labor by Season | $A_{ij}$ | $A_{ij}$ | $A_{ij}$ | 0 | 0 | 0 | $B_b$ |
| Quasi-fixed Capacities | $A_{ij}$ | $A_{ij}$ | $A_{ij}$ | $A_{ij}$ | $A_{ij}$ | 0 | $B_c$ |
| Liquidity Constraints | $A_{ij}$ | $A_{ij}$ | $A_{ij}$ | $A_{ij}$ | $A_{ij}$ | $A_{ij}$ | $B_d$ |
| Behavioral Constraints | $A_{ij}$ | $A_{ij}$ | 0 | 0 | $A_{ij}$ | 0 | $B_e$ |
| Regional Coupling Constraints | 0 | 0 | $A_{ij}$ | 0 | $A_{ij}$ | $A_{ij}$ | $B_f$ |

FIGURE 3. FARM ACTIVITIES, INPUT-OUTPUT COEFFICIENTS, AND THE CONSTRAINT STRUCTURE FOR A GIVEN FARM SIZE GROUP

## CHAPTER IV

## RECURSIVE FEEDBACK AND PREDETERMINED VARIABLES

### IV.1) Introduction

Economic decisions are encompassed by time. The firms' decisions on resource allocation normally involve dynamic characteristics. Current decisions are functionally related to the decisions made in the past as well as the future expectation of relevant economic variables such as output and input prices. That is, the firms' actual behavior is "backward looking" because it involves the interaction between present and past outcomes. But its production plans are also "forward looking" because decisions made in the present will affect the future and because anticipated future conditions will condition present behavior. Baumol's "period analysis" follows precisely this scheme:[1]

> We can investigate the determination of output of the firm by considering the plans which are made at the beginning of each period on the basis of the results of

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[1]Baumol presents a working definition of "economic dynamics" as the study of economic phenomena in relation to preceding and succeeding events. Based on this definition, Baumol emphasized the operational importance of "period analysis" which enables a construction of a step-by-step analysis of economic changes through time rather than continuous through time, i e., a rate of flow at a point of time. However, an empirical analysis of economic variables viewed "infinitesimally" continuous through time is often impossible. As will be discussed later in this chapter, the recursive feedback belongs within the framework of Baumol's period analysis. Therefore, a clear distinction between such concepts as "ex ante," "ex post," "flow," "stock," and "initial conditions" of the system are very important in a recursive model. (For the discussions on period analysis, see Baumol (1959), pp. 127-138.)

> the last period and the expectations of the future they give rise to and by considering the putting into effect of the plans during the period. What is done during the period depends on the output plans made at the beginning, and these in turn depend on the results of previous periods.

In view of this, the feedback functions which link on-farm decisions between two points of time, say t-1 and t (see Figure 2), play a crucial role in recursive programming models. The most important elements in the feedback functions include "behavioral bounds" and resource augmenting equations resulting from well-established historical patterns of farm activities. As such, the behavioral feedback mechanism, while linking on-farm decisions at two different periods, specifies a limited subset upon which the current decisions are based. This then serves as a preoptimization condition in recursive programming models. Hence Day points out:[2]

> These constraints specify that in any one year only a limited change from the preceding year's production can be expected. This hypothesis is based on the conglomerate of forces which lead to caution by farmers in altering established production patterns. Primary among them are uncertainty of price and yield expectations and restriction on the aggregative supply of production inputs...

The feedbacks incorporating these "behavioral bounds," are called behavioral feedback and include (1) flexibility constraints and (2) adoption constraints. The former deal with the cropping portfolio decisions while the latter deal with adoption behavior pertaining to new technology and cropping practices.

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[2]See Day (1961), pp. 110-111.

Within the theory of feedback, some components of the RHS resource vectors are also generated in each period as a part of the dynamic behavior of the firm. A few examples of resource feedback are: cash on hand at the beginning of this year is associated with such factors as the value of the marketed farm surplus and debt repayment last year; the quasi-fixed farm capital stock available at the beginning of this year is associated with the quasi-fixed farm capital stock at the beginning of last year, new investment during last year, and depreciation. Of course, these subsets of RHS resources are functionally related through behavioral feedbacks, because working cash available at the beginning of this year due to the marketed crop surplus is an outcome of last year's cropping portfolio decisions. However, for the sake of clarity feedbacks of this nature are called "resource feedback."

The next section discusses behavioral feedback considered in this study; in section 3, resource feedback is presented; in section 4, predetermined variables in the model are discussed; the last section concludes with a derivation of flexibility and adoption coefficients and predetermined variables used in the model.

## IV.2) Behavioral Feedback

### Flexibility Constraints

For the purpose of illustrating the flexibility constraints, consider the following model of agricultural land utilization used by Henderson:[3]

$$\max_{X} \Pi(t) = Z_1X_1(t) + Z_2X_2(t) + \dots + Z_nX_n(t) \tag{16}$$

subject to

$$\begin{aligned} X_1(t) &\leq (1+\overline{\beta}_1)\, X_1^*(t-1) \\ X_2(t) &\leq (1+\overline{\beta}_2)\, X_2^*(t-1) \\ &\vdots \\ X_n(t) &\leq (1+\overline{\beta}_n)\, X_n^*(t-1) \end{aligned} \tag{17}$$

$$\begin{aligned} -X_1(t) &\leq -(1-\underline{\beta}_1)\, X_1^*(t-1) \\ -X_2(t) &\leq -(1-\underline{\beta}_2)\, X_1^*(t-1) \\ &\vdots \\ -X_n(t) &\leq -(1-\underline{\beta}_n)\, X_n^*(t-1) \end{aligned} \tag{18}$$

Where: $X_1,\dots,X_n$ : acreages of n different crops, respectively.

$Z_1,\dots,Z_n$ : net profits associated with $X_1,\dots X_n$.

$X_1^*,\dots X_n^*$ : actual acreages planted for n different crops.

$\overline{\beta}_i$ & $\underline{\beta}_i$ are called the upper and lower flexibility coefficient, respectively.

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[3] See Henderson (1959), p. 245.

This simple dynamic system asserts that the acreage of the ith crop at t cannot exceed the actual acreage for t-1 plus some positive proportion if it determined by the upper flexibility coefficient $\bar{\beta}_i$. This is where the third goal in the lexicographic ordering of utility functions, namely a metric defining the distance of a given choice from a set of safe-enough choices, is considered. This constrained feasibility region covers, in a simple and myopic way, "unpleasant contingencies other than those covered by the subsistence goal and is meant to represent a strategy to protect the farmer against uncertain but highly damaging feedback effects of extreme departures from previously experienced and successful behavioral patterns."[4] Thus, farmers like other decision makers are reluctant to make changes in their traditional cropping patterns in response to changes in their environment unless these changes persist over time.

Since the behavioral bounds are expressed in terms of $\bar{\beta}_i$ and $\underline{\beta}_i$ and also the predictive accuracy of the model hinges on them, the estimation technique employed to obtain the flexibility coefficients is very important. Recently, Miller succintly summarized the ten

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[4]See Day and Singh (1971), p. 8.
The constrained feasibility region based on historical cropping pattern leads us to regard on-farm recursive decision system as "dynamical and historical system" among his sixfold classification of dynamic systems by Samuelson. (For the classification of dynamic systems, see Samuelson (1947), pp. 315-317.)

alternative estimation procedures of the flexibility coefficients as follows:[5]

1. informed judgement whereby people who are familiar with the situation estimate the maximum changes that may be expected;
2. flexibility coefficients estimated as averages (means) of positive and negative percentage changes in the past;
3. flexibility coefficients described by method (2) plus (minus) the standard deviation of the respective increasing (decreasing) percentages;
4. flexibility coefficients defined as the maximum of historical percentage changes;
5. estimation of flexibility coefficients by the simple least square model,

$$X_t^1 = bX_{t-1}$$

6. estimation of flexibility coefficients by more general least square models, in general

$$X_t^1 = a + bX_{t-1} + C_1Z_1 + \ldots\ldots + C_pZ_p$$

where $Z_1 \ldots Z_p$ are explanatory variables other than the acreage variable, i.e., $X_{t-1}$;

7. least squares estimates of flexibility coefficients adjusted by standard errors. These standard errors may be either (a)

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[5]See Miller (1972), p. 69. Miller reviews those alternative estimation methods of flexibility constraints in order to compare their predictive performance.

the standard error of the regression coefficient b, or (b) standard error of the estimate of $X_t^1$;

8. use of a single least square equation to derive both bounds. In this case, a least square point estimate plus and minus some function of the standard error serves as upper and lower bounds. This procedure defines the allowable range around a forecast of year t rather than around the actual t-1 value;
9. analysis of the discrepancy between the optimum and the actual response;
10. basing the flexibility restraints on their shadow prices.

Following method (4), the flexibility coefficients for wheat, soybeans, corn, and beef enterprises using natural pasture are derived for this study.[6] They are presented in Appendix B. The estimated flexibility coefficients are incorporated in the model in the context of the equations of (17) and (18).

Adoption Constraints

Adoption constraints place upper limits on the investments in new technologies (e.g. tractor) to reflect the fact that farmers are unwilling to completely switch over from "old" technology to "new" technology although investments in a new technology are profitable. Like flexibility constraints, the adoption constraints result from risk aversion attitudes and learning behavior on the part of farmers. An innovative production method which is highly profitable might be placed

[6]This is the method that Day and Singh have already used for their models. See Day (1963a), and Singh (1971a).

in the framework of adoption constraint considering the fact that a new innovation has to go through a time-consuming diffusion process. For example, one would expect the adoption of new improved pasture systems for beef production to follow such an adaptive path over time.

The adoption process involves two phases; (1) the adoption phase, and (2) the adjustment phase.[7] The path of investment in capital goods follows the familiar "S" shaped curve which follows the minimum rate of either the adoption or the adjustment phases. Investments in quasi-fixed inputs such as tractors and combines, grow slowly at first, but more rapidly later as diffusion and learning proceeds so that the adoption phase is approximated by an exponential equation:

$$K_j(t) = (1 + \rho)^n K_j(t-n); \qquad 0 < \rho < 1 \tag{19}$$

where $K_j(t)$ is the number of units of the jth investment good in use in t, $\rho$ is the rate of growth during the adoption phase, and n is the number of years elapsed.

In the second phase investments in capital goods are dominated by an adjustment process based on the hypothesis that capacity is adjusted towards the long run desired capacity of the capital good in question. Singh defines the long run desired capacity for investment in any capital goods in agriculture as "that capacity which will allow all of the

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[7]These two phases have been analyzed and empirically tested by Day (1963a), Tsao (1966), Tabb (1967) and Singh (1971a) in studies of investment behavior in various industries using recursive programming technique.

task under consideration to be performed by the new operation."[8] Based on this definition, the adjustment phase in the jth investment good is specified in the following equation:

$$I_j(t) = \alpha(\bar{K}_j(t) - K_j(t-1)); \qquad 0<\alpha<1 \tag{20}$$

where $\bar{K}_j(t)$ is the long run desired capacity of the jth investment good viewed at t; $K_j(t-1)$ is its capacity utilized at t-1, that is, equal to the capacity available at t-1 according to the capacity exhaustion hypothesis in investment theory; $\alpha$ is a constant; and $I_j(t)$ is the new investment in the jth good at t. Equation (20) asserts that as the capacity available at t-1 approaches the long run desired capacity the investment in capital goods tends to slow down. Substituting $I_j(t) = K_j(t) - K_j(t-1)$, i.e., definition of investment, into the adjustment phase equation, one obtains

$$K_j(t) = \alpha(\bar{K}_j(t) - K_j(t-1)) + K_j(t-1); \qquad 0<\alpha<1 \tag{21}$$

Equation (21) states that the current capacity of the jth investment good is constrained by some proportion of the difference between its long run desired capacity and its previous year's available capacity, plus the previous year's capacity itself. Therefore, once $K_j(t)$ is estimated (here there be a previous year so that t-1 is also adjusted accordingly), one can immediately solve for unknown $\alpha$ which is called

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[8]See Singh (1971a), p. 217.

the adjustment coefficient and is associated with that phase. Combining both the adoption and adjustment equation and following the hypothesis that the capacity of the jth investment good at t must be less than or equal to the minimum of the two phase equations, one can specify

$$K_j(t) \leq \min \begin{cases} (1+\rho)^n K_j(t-n) \\ \alpha(\overline{K}_j(t) - K_j(t-1)) + K_j(t-1) \end{cases} \tag{22}$$

Since net investment in the jth good is defined as the difference in total capacity of the jth good over two periods, one can write

$$I_j(t) = K_j(t) - K_j(t-1) \tag{23}$$

On substitution of (23) into (22), equation (22) can be written in terms of investment activity of the jth good as follows:

$$I_j(t) \leq \min \begin{cases} \rho K_j(t-1) \\ \alpha(\overline{K}(t) - K_j(t-1)) \end{cases} \tag{24}$$

Equation (24) specifies the "S" shaped time path of an investment activity as illustrated in Figure 4.

The adoption constraints on new agricultural practices such as a highly productive beef enterprise using a combination of summer and winter improved pasture systems in case of the wheat region in this study can be treated in the same way as the time path of investment activity.

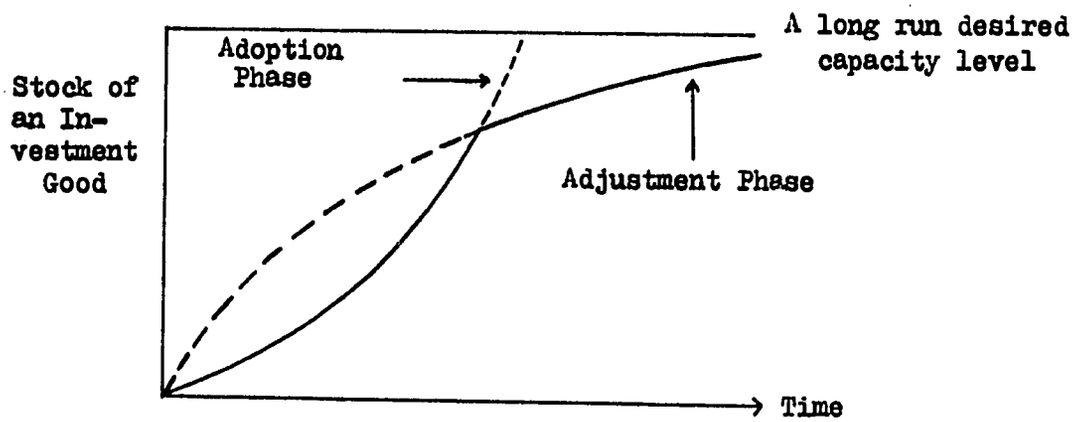


FIGURE 4. THE TIME PATH OF AN INVESTMENT ACTIVITY

## IV.3) Resource Feedback

This subset of the recursive feedback is also an outcome of the behavioral feedback discussed above. However, this set is separated in order to show explicitly the computational procedures involved. Feedback associated with quasi-fixed and variable resources belong to this category.

### Quasi-fixed Resources

Quasi-fixed resources on the farm-firm in the model include land and capacities of draft animals, tractors and combines. It is assumed that the total hectares of cultivable land in the wheat region is fixed through time. But the capacities of draft animals, tractors and combines are formulated with recursive feedback as follows:

1. Draft Animal Hours:

Draft animal hours available at t (DANH(t)) is last year's available capacity less depreciation on a straight line basis, plus

draft animal hours augmented by investment in animal units at t-1 (IVDA*(t-1)) and hence one can write

$$DANH(t) = (1 - \lambda)\ DANH(t-1) + \delta IVDA^*(t-1) \tag{25}$$

where $\lambda$ : an annual linear depreciation coefficient; $0<\lambda<1$

$\delta$ : a conversion coefficient of animal unit to serviceable hours

$\cdot^*$ : primal solution (exante planning value) of the model.

2. Tractor Hours:

Similarly, tractor capacity hours available at t (TRH(t)) is:

$$TRH(t) = (1 - \eta)\ TRH(t-1) + \theta IVTR^*(t-1); \quad 0<\eta<1 \tag{26}$$

where $\eta$ is an annual linear depreciation coefficient for tractor use and $\theta$ is a conversion coefficient of a tractor unit to serviceable hours.

Combine capacity hours at t (CBH(t)) follows the same equation but its solution is always assumed to be a scalar multiple of TRH(t), since it is assumed that for each tractor purchased a certain number of combines are also purchased, so their ratio remains constant.

## Variable Resources

Variable resources for a farm-firm include total labor hours, fodder requirements for working draft animals, wage labor hours, working cash available at the beginning of the year, and limitation of credit availability.

3. Total Labor Hours:

Total labor hours available during the jth season at t ($TLH_j(t)$) are equal to family labor hours for the jth season ($FL_j$) in the previous period plus increments through the regional growth in the farm population (at an annual rate, $\phi$ ) plus wage labor hours added by labor hiring activity ($HL_j$) in the current period.

$$TLH_j(t) = (1 + \phi)\ FL_j(t-1) + HL_j(t) \tag{27}$$

4. Wage Labor Hours:

Wage labor hours available during the jth season of the current period ($HLA_j(t)$) increase from last year's level by the rate of farm population growth ($\phi$) and by a proportion ($\delta$) of last year's labor hiring activity for the jth season ($HL_j^*(t-1)$); thus

$$HLA_j(t) = (1 + \phi)\ HLA_j(t-1) + \delta HL_j^*(t-1) \tag{28}$$

5. Fodder Requirements for Draft Animals:

Working draft animals on the farm must be fed to maintain them as a power source. For simplicity it is assumed that animals are grazed on improved pasture systems. The hectarage of improved summer pasture reserved for animal fodder ($SP(t)$) equals the hectarage reserved last year minus hectarage accounting for animal displacement by depreciation plus hectarage for newly purchased draft animals ($IVDA^*(t)$); thus

$$SP(t) = (1 - \gamma)\ SP(t-1) + \sigma\ IVDA^*(t) \tag{29}$$

where $\gamma$ is a depreciation coefficient and $\sigma$ is a conversion factor of animal units to fodder pasture. The feedback of the winter improved

pasture reserved for animal fodder follows the same functional form as in (28).

6. Working Cash Availability:

At the beginning of the year the amount of cash available (WCA(t)) to a farm-firm is the value of last year's total farm output minus last year's internal retained consumption and living expenditures, minus repayment of last year's debt with accrued interest, and plus any bank deposits (SAV) made last year with accrued interest.

$$WCA(t) = (1 - \psi) \sum_i P_i \, S_i(t) - (1 + r_b) \, BORR^* \, (t-1) + (1 + r_s) \, SAV^* \, (t-1) \qquad (30)$$

Where: $\psi$ : a coefficient accounting for internal consumption of food grains and living expenditure. $\psi$ 's differ according to farm size

$P_i$: market price per kilogram of the ith crop

$S_i$: total kilograms of the ith crop harvested

$r_b$: interest rate on working capital borrowed (15 percent)

$r_s$: interest rate available on bank deposits (6 percent)

The $\psi$ in equation (30) is the operational counterpart that accounts for the retained domestic consumption that was the first goal of the lexicographic utility functions discussed in Chapter III. In addition this capital can be augmented by current borrowing (BORR*).

7. Regional Credit Availability:

Short term credit availability at t (CRED(t)) has an upper limit defined by a proportion ($\theta$) of total regional farm gross revenue last year; thus:

$$CRED(t) = \theta \sum_i P_i S_i (t-1) \tag{31}$$

Where $\theta$ is the credit availability parameter which is one of the most important policy variables in the region, and both $P_i$ and $S_i$ are defined in equation (30). Since CRED(t) is a regional coupling constraint, the three different farm size groups compete for its use. During the second half of the last decade, the Brazilian banking agency has loaned agricultural credit up to 60 percent of the expected farm gross revenue at t provided that the loans are used to purchase modern commercial inputs, and paid back with the principal plus carrying charges at t + 1.[10] In order to conform with this institutional regulation, the model takes 60 percent of the realized farm gross revenue at t-1 as a proxy ($\theta$ = 0.6).

## IV.4) Predetermined Variables

Both the behavioral feedback and the resource feedback discussed above have dealt with the RHS vector of the model Another set of feedbacks is associated with the other two components of the model, namely the objective function and the input-output matrix. Covering the

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[10] Engler (1971), p. 69.

fourth goal of the lexicographic ordering of utility functions, the objective function coefficients take account of the market prices of outputs and inputs in order to derive a short run net profit function expressed in equation (1) of Chapter III. Sequential changes through time in the working capital row in the input-output matrix are also treated in a feedback mechanism.

In this study most of output and input prices are controlled variables as discussed in Chapter II. Hence time series of input-output prices are treated in the model as exogeneous to the system without attempting in a distributed lag form to develop an endogenous forecasting feedback as suggested by Day.[11] Since most of output prices in the wheat region for this study have been announced prior to crop planting seasons with an assured official purchaser at that price, farmers receive price information with perfect knowledge. The domestic historical prices of inputs and outputs during 1960-1970 used in the model are presented in Appendix B. Appendix B also includes derivations of flexibility and adoption coefficients used in the model.

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[11] For example, an output price can be treated in a linear inverse demand function formulated in an adaptive distributed lag form under perfectly competitive market assumption. (See Day and Tinney (1967).)

In order to examine the impacts of price distortion due to this unique pricing policy, another set of output prices, international market prices instead of domestic historical prices, can be easily incorporated in the model as a set of exogenous data.

## CHAPTER V

## THE DECOMPOSITION PRINCIPLE BY FARM SIZE

### V.1) Introduction

In Chapters III and IV, the microeconomic dynamics of a farm firm have been fully discussed for a single farm with a recursive decision system framework. A natural question to be raised next is how to aggregate on-farm decisions, i.e., aggregate micro-level decisions to a regional farm-sector level. The theory of aggregation required to go from the micro-level to a regional aggregate is too complex to be dealt with here in detail.

The purposes of this chapter are (1) to review briefly the conditions for regional homogeneity used by the three regional models; Day (1963a), Heidhues (1966), and Singh (1971a)[1] and propose an alternative aggregation technique which employs a decomposition principle in linear programming, (2) to discuss the implications of utilizing the decomposition principle in economic analysis, and finally (3) to

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[1]Regional homogeniety refers to uniform characteristics of economic structure and physical environment prevailing in the region. This condition is a common denominator in the Mississippi Delta model, the North German Farm Growth model, the Punjab model. One important factor defining economic characteristics is farm size, a concept which was defined in Chapter I. Farm size decomposition in this study refers to a stratification of regional farms by a land hectarage category, in order to group them separately.

present a descriptive model summary. Finally the model components in connection with a farm size decomposition, for the initial year 1960 (initial conditions) by farm size, are presented in Appendix C.

## V.2) Conditions of Regional Aggregation

### Previous Model Assumptions for Regional Homogeneity

In order to apply mathematical programming to industrial performance, Day has shown that production decisions for atomistic firms in an industry can be represented by a single linear programming model provided that one can observe (1) proportional variations of resources and behavioral bounds, (2) proportional variation of expected net return among all firms, and (3) common technological coefficients.[2] Under these conditions, a single linear programming model for the aggregate is equivalent to a direct aggregation of the solutions to a set of individual firm models. Day's "institutionally" proportional resource vectors and "pecuniously" proportional net returns of atomistic firms are aggregated to industry level with standard linear unit-sum weights to obtain optimum solutions for that industry.[3]

The aggregation approach to a regional agricultural sector using the unit-sum weighted average method covering the "atomistic farms" in

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[2]Day (1963b), p. 797 and also Day (1969).

[3]This is the case of so-called proportional heterogeneity used in theorem 2 by Day. For discussions and proof of the existence of optimal solutions for an industry for this case, see Day (1963b), p. 802. The standard linear unit-sum weights ($\lambda_i$) here refer to

$$\lambda_i = 1 \text{ and } 1 > \lambda_i > 0 \text{ for all } i.$$

the region was the basis on which the "three regional models" referred to earlier were represented by a single linear programming problem. Thus, a region, where an individual farm's resource vectors are "institutionally" proportional and their short run net return functions are "pecuniously" proportional, is aggregatable and allows individual decision units to be subsumed.

An Alternative Aggregation Technique

If the atomistic firms in an industry, say agriculture, are characterized by substantial differences in resource composition, one might have a case where a large farm is endowed with a specific resource, e.g. a tractor, while a small farm is not, and that lead the aggregation weight of the "tractor resource" for the small farm to zero. If this is the case, the proportionality assumptions for regional aggregation breaks down. This is also true when the technical coefficients differ in accordance with a farm size classification. Therefore, stratification by farm size, if farm size varies substantially in the region studied, is desirable for regional aggregation. This is precisely the point where this study departs from the previous models. An emphasis on farm size as a principle factor in determining a viable pattern of technological change in a developing agriculture has already been discussed in Chapter I. Furthermore, it has been pointed out that farm size in the wheat region ranges from a small farm operating 10 hectares to highly mechanized commercial farms with several thousand hectares (Table 5). This entails substantial differences in cropping patterns, changing composition of resource mix, and technological change.

Under a single representative farm size aggregation for the region where farm size differs significantly, these crucial structural and behavioral differences are totally subsumed. However, an explicit treatment of farm size differences at least in a few categories enables one to scrutinize the important structural and behavioral differences.[4] In fact, Day has already pointed out that stratification may be useful by stating that suitable aggregates may be composed by a research worker for reducing the number of linear programming models needed to describe an atomistic industry.[5] For this study the "suitable aggregates" result in a methodology that utilizes the decomposition principle of linear programming to analyze three different farm size subaggregates.

## V.3) Farm Size Decomposition and Its Economic Implications

### The Decomposition Principle for a Large System

In order to discuss the structural form of the decomposition principle and its subsequent economic implications, consider the following heuristic problem in Figure 5.

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[4]In a sense this is a position between two extremes in treating farm size differences. One extreme position would be individual treatment of all farms in the region. The other extreme position would be a single representative farm model for the entire region.

[5]Day (1963b) and also Day (1969).

$$\text{Max } \pi = C_1X_1 + C_2X_2 + Z_1Y_1 + Z_2Y_2$$

Subject to

$$\begin{array}{lll}
A_{11}X_1 + A_{12}X_2 & & \leq B_1 \\
A_{21}X_1 + A_{22}X_2 & & \leq B_2 \\
 & A_{33}Y_1 & \leq B_3 \\
 & A_{44}Y_2 & \leq B_4 \\
 & A_{53}Y_1 + A_{54}Y_2 & \leq B_5 \\
A_{61}X_1 + A_{62}X_2 & + A_{63}Y_1 + A_{64}Y_2 & \leq B_6
\end{array}$$

and

$$X_1, \quad X_2, \quad Y_1, \quad Y_2 \geq 0$$

FIGURE 5. A HEURISTIC DECOMPOSITION PROBLEM

This problem has two independent blocks and one coupling constraint. This sort of matrix is called an angular structure, i.e., one or more independent blocks linked by coupling equations. Some angular structural forms are almost always found in truly large problems, since these commonly arise from a linking of independent units in either time or space. The Dantzig-Wolfe decomposition principle in 1960 was developed to provide specialized solution algorithms in order

to gain computational efficiency and reductions in core requirements for computer memory.[6]

This kind of linear programming structure consists of a set of almost separable sub-problems but linked together by several common resource constraints. An economic example would be a corporation with multiple branch plants which might have resources unique to each of the plants and also, common resources open for competition by all plants. A branch plant makes decision within its own unique resource constraints but its decisions are bounded by overall corporate constraints of which decentralized decision-making has to take account. Therefore, the decomposition principle developed as a computational device for a large system carries important economic implications.

In this study, the decomposition principle is used not as a computational device in solving a large system, but in order to capture

---

[6]For the discussions on the decomposition principle, see Dantzig and Wolfe (1961), Dantzig (1963), Baumol and Fabian (1964), Simmonard (1966), Haller and Lieberman (1967), and Lasdon (1970).

The Dantzig-Wolfe algorithm operates by forming an equivalent "master program," with only a few more rows than there are coupling equations in the original problem but with very many more columns. This program is solved by the so called "column generation" method. The resulting algorithm involves iteration between a set of independent subproblems whose objective functions contain variable parameters, and the master program. The subproblems receive a set of parameters (simplex multipliers) from the master program. They send their solutions to the master program, which combines these with previous solutions in an optimal way and computes new prices. These are again sent to the subproblems, and the iteration proceeds until an optimality test is passed. Thus, the master program coordinates the actions of subproblems by setting prices on resources used by these problems.

the economic implications of the farm size differences.[7] These implications revolve around (1) a decentralized decision making process and, hence, (2) equilibrium rationing of the regional resources.

Assumptions for the Farm Size Decomposition

The underlying theory of the decomposition principle is well suited to our regional analysis with farm size differences. One might consider each farm size group as a branch plant which has initially different resource endowments but which are linked together to compete for scarce regional resources. These regionally scarce resources to which all farms have access in the present model include wage labor, credit, and regional supplies of modern farm machineries. An individual farm-firm makes decision within the boundary of its own feasibility set (essentially a decentralized decision making process) revised within the limit of additional regional resources. Thus, for example, production decisions of a group of homogeneous farms are constrained by on-farm resources, but financial resources can be augmented by regional credit agencies. Regional resources of this nature are competed for by all farms in the region, and actual use by any farm size group will depend upon the group's capital productivity, the competitive demand for the resource by other farm size groups, and

---

[7]For discussions of how a large-scale system arises from real world problems and existing computer algorithms to solve such a large system, see Dantzig (1965).

In this study, the computer solutions of the problem is obtained by putting the angular matrix structure into a single matrix inversion process instead of solving the three block matrices separately first and later coordinating them.

institutional factors on the supply side. The decomposition principle allows one to take account of this.

In Figure 6, the farm size decomposition structure in the model is represented by non-empty input-output matrices along the diagonal, and by null matrices in the off-diagonal zones bordered at bottom by an array of non-empty matrices representing regional resource availability and competition along with a row at the top of sub-vectors containing the objective functions. Each sub-vector in the objective function corresponds to the specific technology matrix of Figure 3.

| | | | | |
|---|---|---|---|---|
| Regional objective function → | $Z^s(t)$ + | $Z^m(t)$ + | $Z^l(t)$ | |
| Input-output matrix for each farm type → | $A^s_{ij}(t)$ | 0 | 0 | $\leq B^s(t)$ |
| | 0 | $A^m_{ij}(t)$ | 0 | $\leq B^m(t)$ |
| | 0 | 0 | $A^l_{ij}(t)$ | $\leq B^l(t)$ |
| Regional coupling constraints → | $T^s_{kj}(t)$ | $T^m_{kj}(t)$ | $T^l_{kj}(t)$ | $\leq B^r(t)$ |

FIGURE 6. BRIEF MODEL STRUCTURE OF REGIONAL FARM SIZE DECOMPOSITION

The first row contains the objective functions for small, medium and large farm types at time period t. The regional objective function is the summation of the three sub-objective functions. The superscripts s, m, l, and r represent the small, medium, large farm types and regional binding constraints, respectively. The subscript j

denotes the activities, i the resource constraints unique to each farm type, and k the regional coupling resource constraints. The B vectors are resource limitations for each farm type and the limit of regional resources.

In structuring the model by farm size in the decomposition framework illustrated in Figure 6, the following assumptions are made:

1. All farms belonging to a specific size group have both "institutionally proportional" resource variations and "pecuniously proportional" net returns so that the farms of one size group are considered homogeneous and aggregatable.[8]
2. The regional objective functions are the summation of the three separable sub-objective functions attached to the three farm size groups, respectively.[9]
3. The farmers in each size group have the same degree of information and knowledge on prices of inputs and outputs, cropping system and technological choices. Therefore, all

[8]In this study, three different farm size groups are considered--small farms (0-50 hectares), medium farms (51-300 hectares), and large farms (300+hectares). This classification was suggested by Rask (1969).

This assumption implies that the farms in the same group have similar resource endowments and similar net returns. Further, the three farm size groups have identical kinds of resources although the initial factor endowments differ substantially for each group. This is why the number of rows for each farm size group is identical (see Appendix B). The same holds true for the number of activities, i.e., columns of the model.

[9]This implies that net returns in one farm size group does not depend on the profits in another group, and the regional net returns are weighted sums of individual net returns in the various farm size groups.

farmers, regardless of their farm size, operate with identical exogeneously given price data and with full knowledge of alternative technologies.

4. All farm size groups have identical input-output coefficients except where economies of scale accrue to machine operations on larger farms.[10]

5. All farm size groups compete for the use of regional coupling resources such as wage labor, regional credit, and modern farm powers (e.g., tractors and combines) via the regional coupling constraints.

## Economic Implications of the Farm Size Decomposition

The situation where the three different farm size groups are structured in an angular matrix form is similar to the three branch plants of a large corporation. One "farm plant" first makes initial decisions unaware of the existence of the other two "farm plants". Thus individual plant's optimal decision strategies are made within the feasibility region constrained by its own unique resource vector. This is the decentralized decision making process corresponding to solving a sub-program tied to a specific block matrix.[11] The iterative

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[10] Economies of scale are allowed in the land preparation and harvesting tasks specifically. As an example of such economies consider large farms which have fewer turning points for tractor disking than smaller farms.

[11] The "decentralized decision making" holds true only in the sense that the subprogram proposals are made first within a block matrix constraint. In case of a linear system, the subprogram proposals take an extreme point of a convex set. As Lasdon points out, the extreme point proposals by a subsystem (a block matrix in the angular structure) are further revised through the central agency by assigning optimal weights to subsystem proposals. Therefore, the final optimal activity levels by the central agency may well be interior to the

subprogram proposals (temporary optimal solutions) are tied together in a master program which is constrained by coupling equations. This iterative process continued for a finite number of cycles (Figure 7) until an optimality test is passed. As Dantzig points out, the overall operation of a large corporation (regional farm planning) is possible by the central staff (regional farm manager) without having full knowledge of the technology matrix of each sub-plant (farm size group).[12]

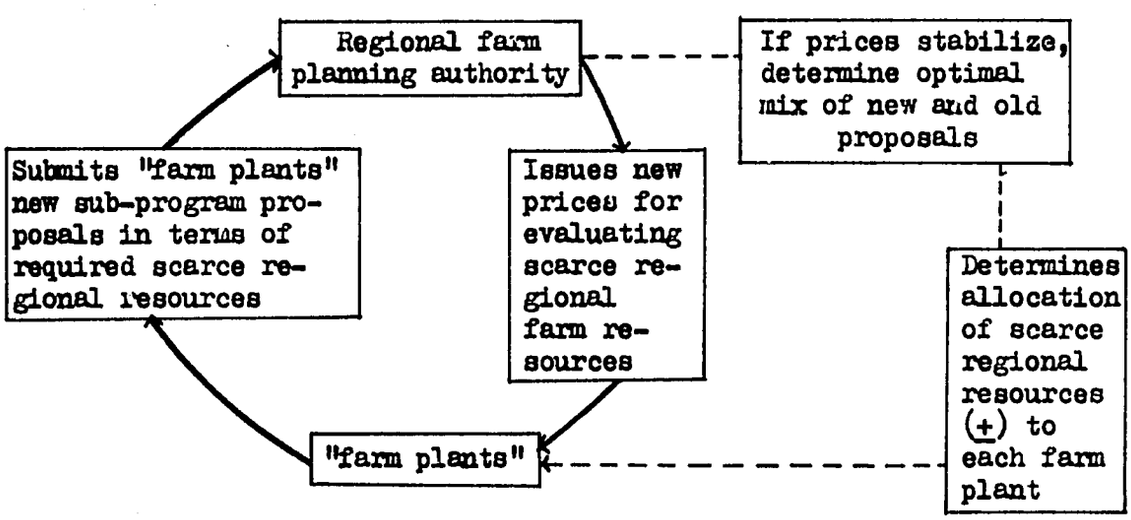


FIGURE 7. A FLOW DIAGRAM OF DECENTRALIZED FARM DECISION MAKING USING THE DECOMPOSITION PRINCIPLE[13]

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subsystem constraints. However, if the subsystem objective were non-linear, then non-extreme point solutions could be obtained directly so that a complete decentralization might be possible (see Lasdon (1970), pp. 160-163).

[12]For discussions on the economics involved in the use of the decomposition process of a large-scale operation system, see Dantzig (1963), pp. 448-470.

[13]The diagram is adapted from the illustration used by Dantzig. See Dantzig (1963), p. 465.

The subprogram proposals of individual farm size groups interact with regional resource equations to allocate the scarce regional resources for the intra-farm use. Since the interaction (an iterative coordination between the subprogram proposals and the master program) is made according to optimizing criterion and a "shadow pricing" scheme of resource evaluation, the decomposition principle indeed serves as a short-run equilibrium rationing mechanism necessary to solve the intra-farm competition for the coupling resource use. Therefore, the decomposition principle can be used to ration regional resources among the three farm size groups on a competitive basis.[14]

The economic implications of the decomposition principle discussed above suggest that the principle can be applied as an operational tool to a farm sector analysis in a variety of ways. The same sort of methodology employed in this study can be used in (1) intra-regional study of agricultural production and investment (e.g., two ecological zones of agricultural production), (2) intra-sector study,

[14]As usual, the shadow price of resource i is defined as $\frac{\partial \Pi^*}{\partial b_i}$ (referring to Figure 5, $\Pi^*$ is the optimal objective function value). If the first subsystem, i.e., the first block matrix in Figure 5, chooses an activity, say $X_1$, it contributes a direct net profit $C_1X_1$. It also uses an amount, $A_{61}X_1$, of the coupling resource $B_6$, thus denying the resource $B_6$ to the second subsystem, and possibly decreasing their profit. Therefore, the first subsystem must be made to take this indirect, but important, contribution to profit into account. The simplest way to do this is to announce a set of shadow prices for the coupling resource, and force the subsystems to pay for whatever quantities of the resource they use. By so doing, the subsystems are discouraged to use excessive quantities of $B_6$. The two subsystems reach an equilibrium allocation of $B_6$ when the shadow prices of $B_6$, evaluated separately for both systems, are equated. This is the way in which a short-run equilibrium rationing of the coupling resource $B_6$ works. (For details, see Lasdon (1970), Chapter 3.)

such as agricultural and non-agricultural sectors, and (3) intra-country study of agricultural specialization (e.g., agricultural specialization by E.E.C. member countries). The coupling equations in these cases may include transportation system, labor movement, macro-demand and supply functions for agricultural outputs, new agricultural inputs, institutional credits, etc.

## V.4) Model Summary

The model is constructed in two steps: (1) develop an on-farm recursive programming model for one farm size group, and (2) aggregate by farm size to a regional level using the decomposition principle of linear programming. The model in the first step considers (a) five farm activity sets incorporating production, consumption, investment, purchasing, and financial decisions with explicit classification of production activities, by traditional and modern technologies, (b) constraints for on-farm land, labor, quasi-fixed capacities, liquidity and behavioral bounds, and the regional coupling resources, (c) a recursive feedback which relates last year's optimal decisions to the parameters of the current problem in a cautious and myopic expectation scheme which takes account of risk and uncertainty in crop selection decisions and adoption of new technologies, to the exogenously given policy variables such as input-output prices and credit availability, and to the on-farm fixed resources as the initial conditions for the model. Those components of the on-farm recursive model are aggregated by the three farm size groups in the second step and set up in an angular matrix form utilizing the decomposition principle of linear programming. The

decomposition principle as used allows one to capture the structural differences of cropping patterns and technological change due to different resource endowments and distributional effects of agricultural growth by different farm size groups.

The model was "estimated" on the "Recursive Decision System Processor", a computer package program available at the Social Science Research Institute at the University of Wisconsin.[15] The entire time path of decision variables (primal and dual) specified in the model are generated for the years of 1960-1970 in a sequence of "rolling plans" by a single run of the computer processor.

The initial model matrix including estimations of the input-output coefficients by technology and the RHS vector for the beginning year 1960 are available in Appendix C.

[15]For the operational discussions of the processor, see Mueller (1971). This processor accommodates problems with matrices of a maximum size of 100 x 120. A much larger processor is under development at the same institution.

# CHAPTER VI

# MODEL RESULTS AND EVALUATION

## VI.1) Introduction

The purposes of this chapter are (1) to present the results and to explain the dynamic path of agricultural transformation that has characterized the wheat region between 1960 and 1970, and (2) to examine the "goodness of fit" of the model to historical data. The discussion emphasizes the differential paths of development for different farm sizes.

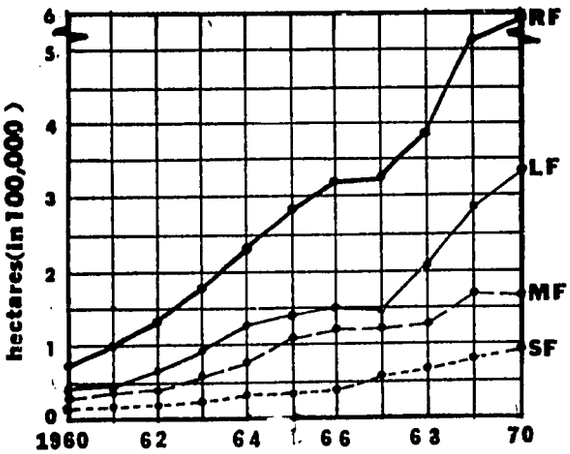
Regional model results for three farm size groups are presented in five sections: (1) regional resource use and technological change, (2) factor productivities, (3) factor proportions, (4) credit use, and (5) income distribution. The important variables associated with each section are displayed in graphs while the detailed results can be found in tables under identical headings in Appendix D. The chapter concludes with an evaluation of the model for predicting performance during the simulation period 1960-1970.

## VI.2) Regional Resource Use and Technological Change

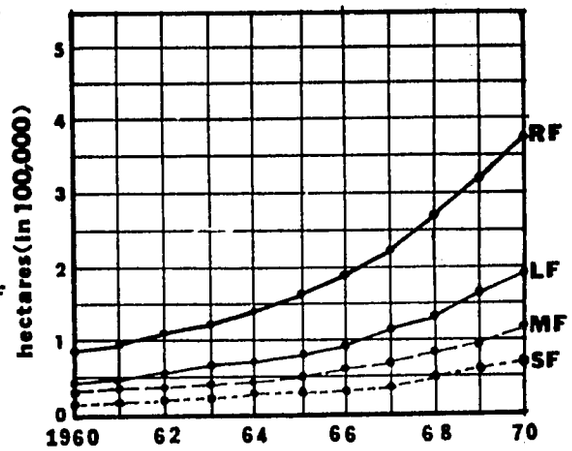
### Land Use and Cropping Patterns

Land use and cropping patterns for the region by farm size and technology are presented in Tables 11 to 19. Graphs 1 to 6 display

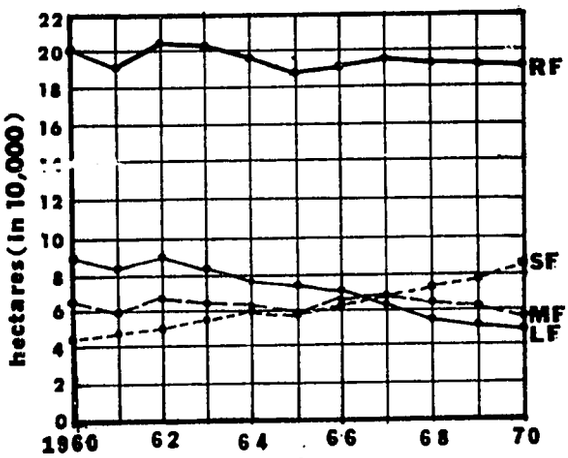
# REGIONAL RESOURCE USE BY FARM SIZE



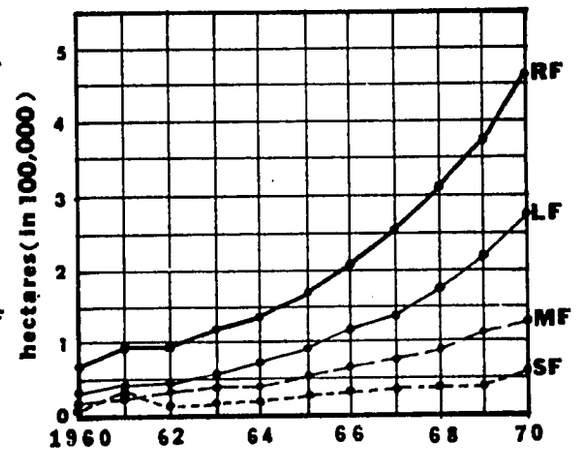

GRAPH 1: Wheat



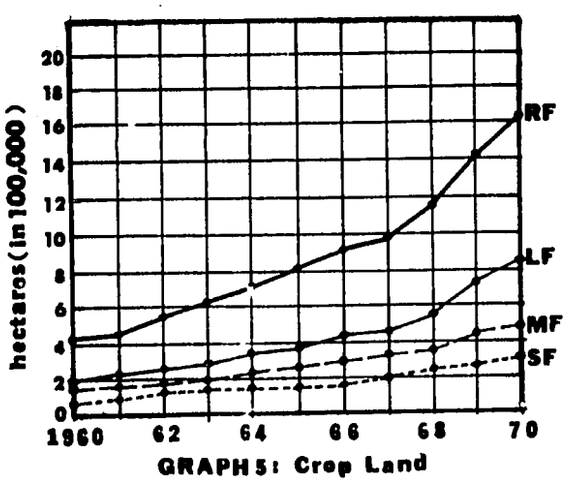

GRAPH 2: Soybean



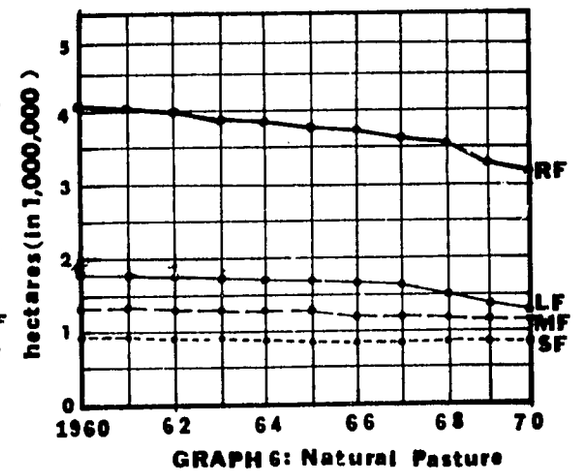

GRAPH 3: Corn




GRAPH 4: Improved Pasture




GRAPH 5: Crop Land




GRAPH 6: Natural Pasture

SF: Small Farms
MF: Medium Farms
Source: Model Results

LF: Large Farms
RF: Regional Total Farms

Wheat Region in the State of Rio Grande Do Sul, Southern Brazil(1960-1970)

the most important transition in the region, a shift from the extensive range livestock enterprise using natural pasture to intensive crop farming and livestock production on the improved pasture (summer and winter pastures) systems. The most significant change is the increased wheat hectarage. Even though that the model assumed constant crop yields per hectare during the sample period 1960-1970, wheat production on small, medium, and large farm size groups increased approximately 6.2, 6.4, and 9.6 fold, respectively. Along with increases in wheat production, soybeans (both following and independent of wheat) increased but at a slower rate than wheat. Taking advantage of the doubling cropping practice, soybeans following wheat grew about 4.7, 4.5, and 5.3 times on small, medium, and large farms respectively, whereas the increases in independent soybeans are far less significant (Table 11). Interestingly there was a 1.9 fold predicted increase of corn on small farms, but a 13 percent decline on medium, and a 43 percent decline on large farms (Table 11) so that total regional corn hectarage remained almost constant for the entire decade. This trend was strongly associated with the labor requirement for corn harvesting and the labor scarcity on larger farms.

In the transition from livestock to intensive crop farming the increases in crop production are generally offset by a substantial decline in natural pasture which accounted for approximately 90 percent of total land use at the beginning of the sample period (Table 19). The decline in natural pasture on the three farm size groups is almost a mirror image of the increasing wheat hectarage. Small farms show a

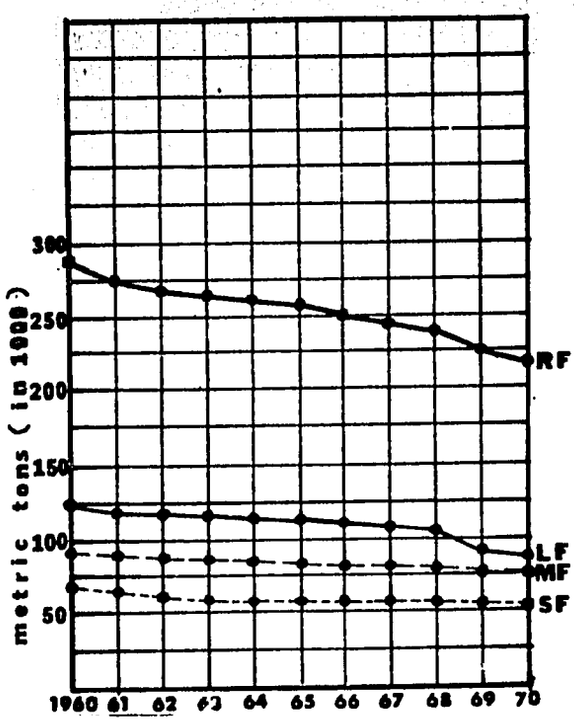
decline of 21 percent, medium and large farms of 22 percent and 34 percent, respectively, in area devoted to natural pasture. Finally, for improved pasture land (summer and winter pastures), that is regarded as a crop land due to its inherent similarity to cropping activities, the model predicts the same pattern of growth as for soybeans, but at a slightly faster rate. It should be stressed here that the trends of improved pasture by farm size are very similar to those of wheat. Due to this trend of increasing improved pasture, regional total beef production by both natural and improved pasture systems increased 1.2 times during 1960-1970 despite the substantial decline in area of natural pasture land (Graph 7). The total beef production grew about 1.01, 1.17, and 1.30 fold on small, medium, and large farms, respectively.

In spite of the model assumption that the land endowments are fixed over the decade, increasing total land use reflects an increasing trend in the double cropping of wheat and soybeans following wheat (Graph 8).

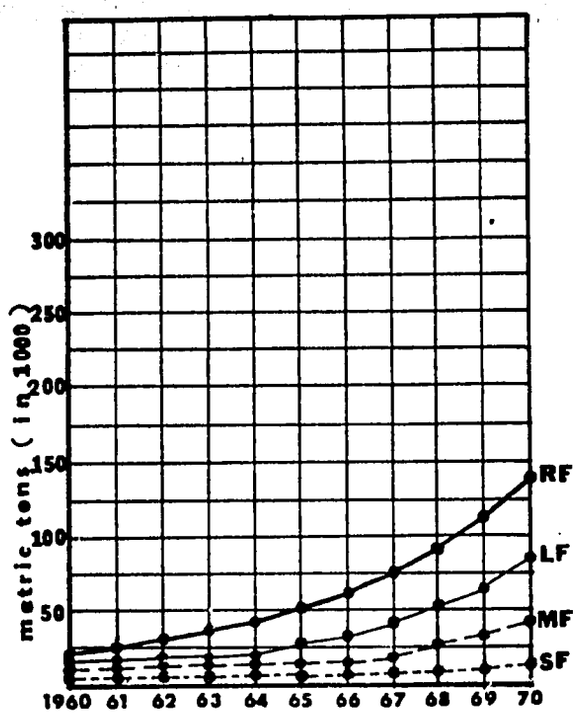
Farm Technologies

Although the three different farm sizes follow similar trends in their cropping patterns, their choice of technologies reveals a striking difference (Graphs 12-15). Small farms with relatively abundant labor employ only traditional draft animal technologies and at an increasing rate. On the other hand, large farms with relatively scarce labor utilize exclusively modern tractor-combine technologies. Between these two extremes, the medium sized farms show a mixed pattern, but

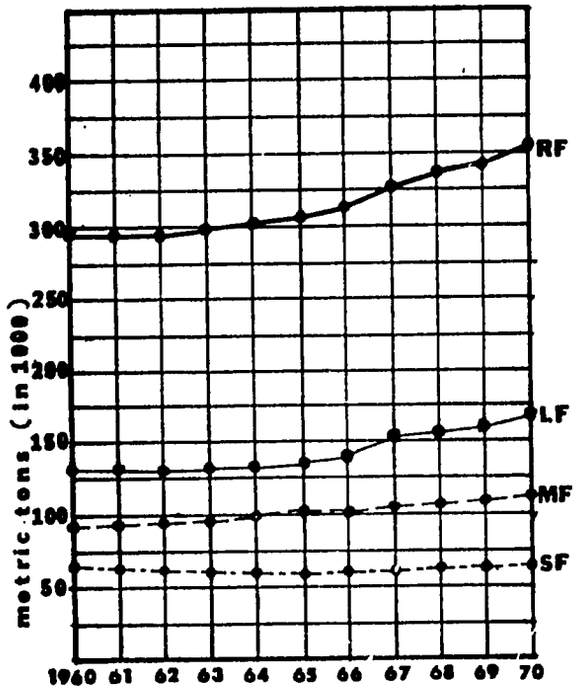
# BEEF PRODUCTION BY FARM SIZE




Using Natural Pasture




Using Improved Pasture



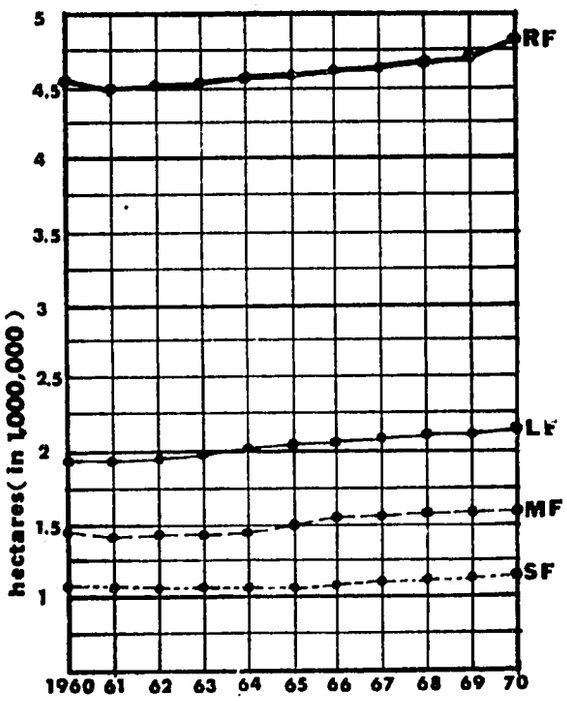

Total Beef Production

GRAPH 7 : Beef Productions

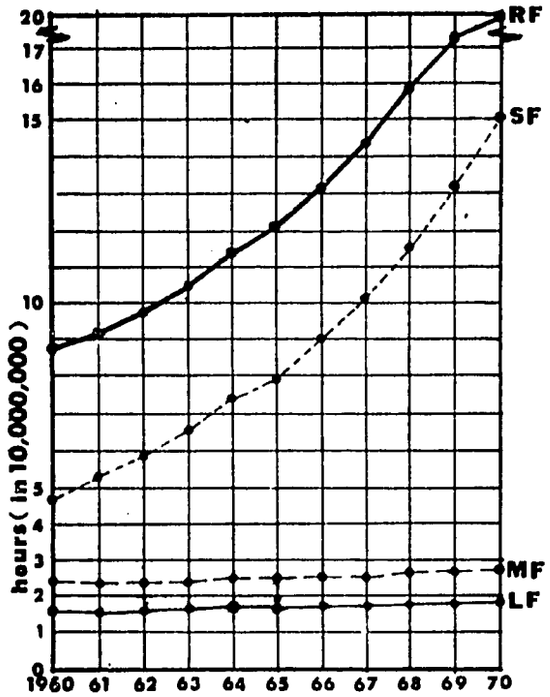
SF: Small Farms
MF: Medium Farms
Source: Model Results

LF: Large Farms
RF: Regional Total Farms

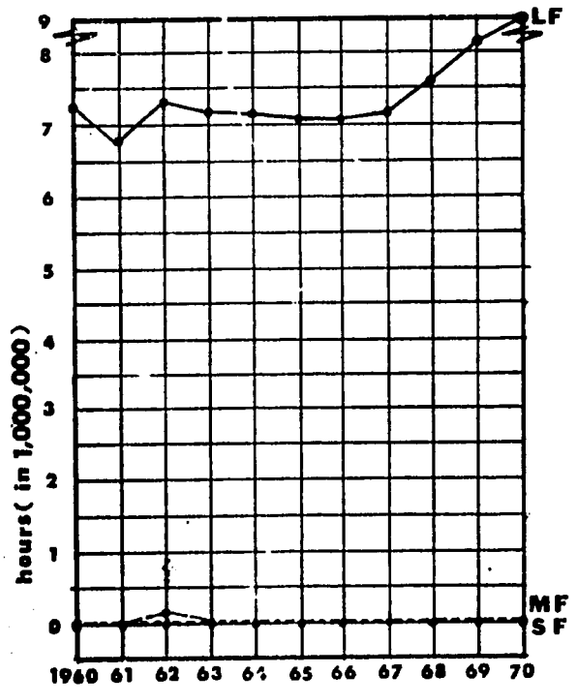
Wheat Region in the State of Rio Grande Do Sul, Southern Brazil (1960-1970)



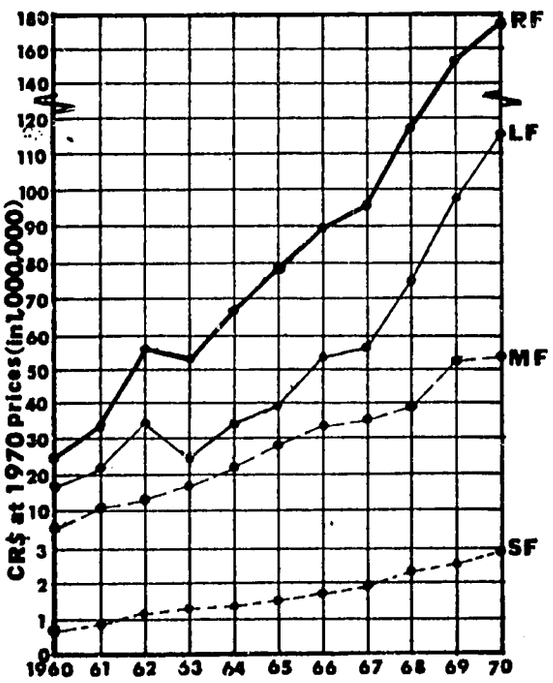

GRAPH 8: Total Land Use




GRAPH 9: Total Labor Use




GRAPH 10: Total Hired Labor

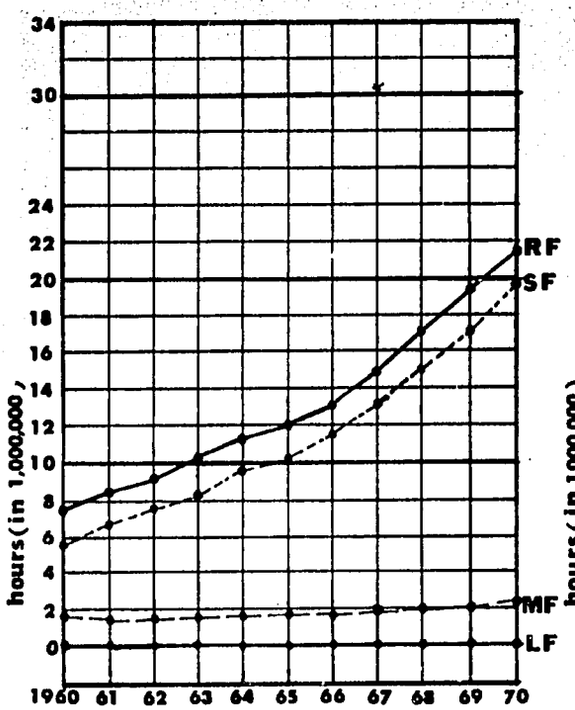



GRAPH 11: Capital Stock in Farm Power

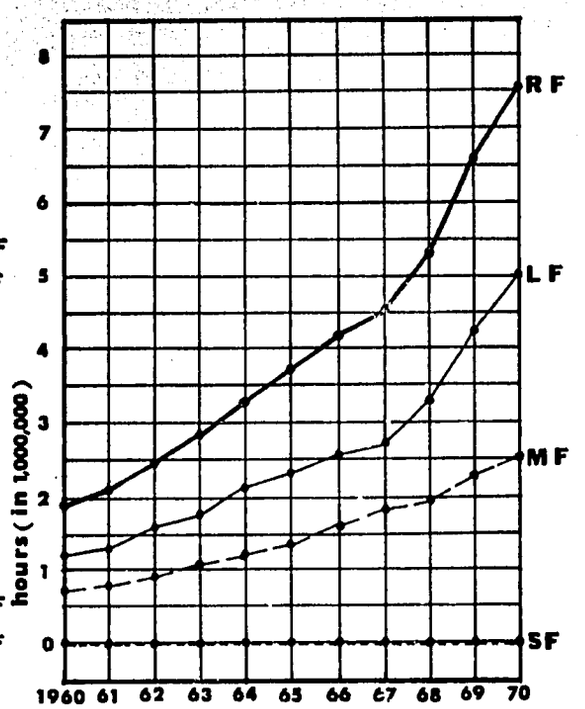
S F: Small Farms
MF: Medium Farms
Source: Model Results

L F: Large Farms
R F: Regional Total Farms

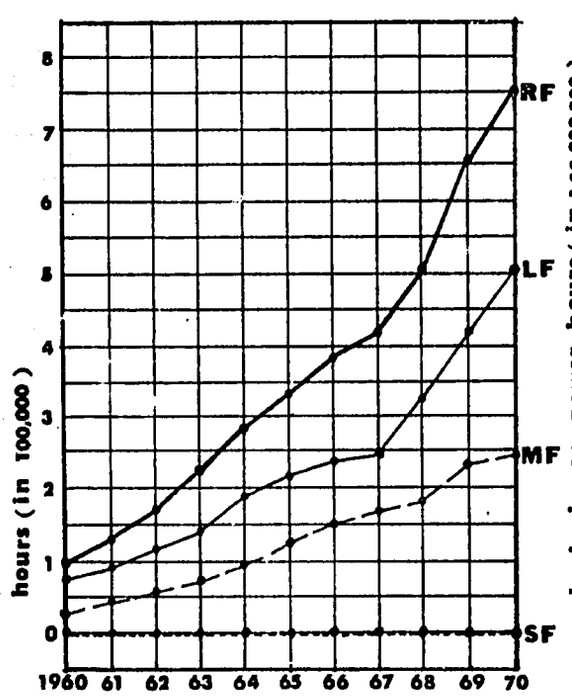
Wheat Region in the State of Rio Grande Do Sul, Southern Brazil(1960-1970)



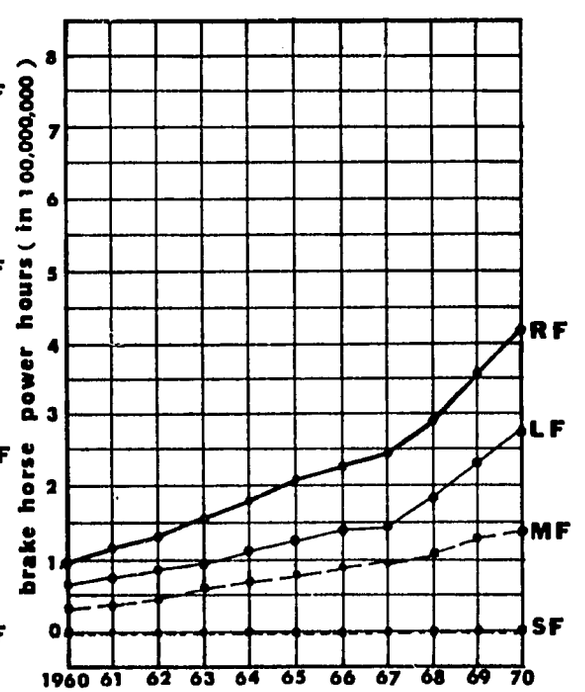

GRAPH 12: Total Draft Animal Use




GRAPH 13: Total Tractor Use




GRAPH 14: Total Combime Use




GRAPH 15: Total Mechanical Power Use

SF: Small Farms
MF: Medium Farms
Source: Model Results

LF: Large Farms
RF: Regional Total Farms

Wheat Region in the State of Rio Grande De Sul, Southern Brazil (1960-1970)

inclined towards the labor-saving modern technologies. The increase in the use of modern farm power is dramatic--a 3.5 and 4.2 fold increase in tractor use and a 10.3 and 7.1 fold increase of combine hours on medium and large farms, respectively. However, draft animal use increased 3.4 times on small and 1.1 times on medium sized farms. Graph 15 shows various trends of total mechanical power use by farm size.[1]

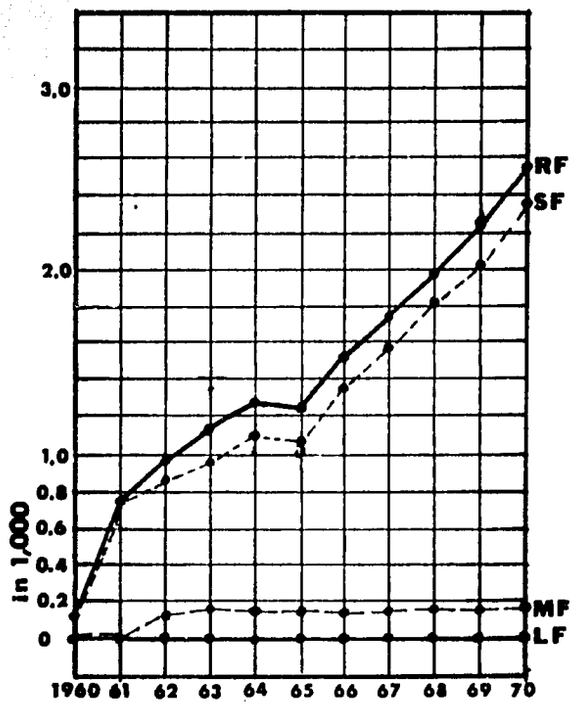
On-Farm Investments

The investment patterns are implicit in the choice of technologies. There is a marked upward trend in gross new investments for draft animals on small farms, with roughly a 20 fold increase over the decade, whereas only a slight increase (1.8 times) is evident on medium farms (Graph 16).[2] In contrast to draft animals, gross new investments in tractors grew by 320 percent on large farms and 200 percent on medium farms during the same period (Graph 17). Therefore, there is a symmetry in the gross investment patterns in traditional and modern mechanical technology and farm size.

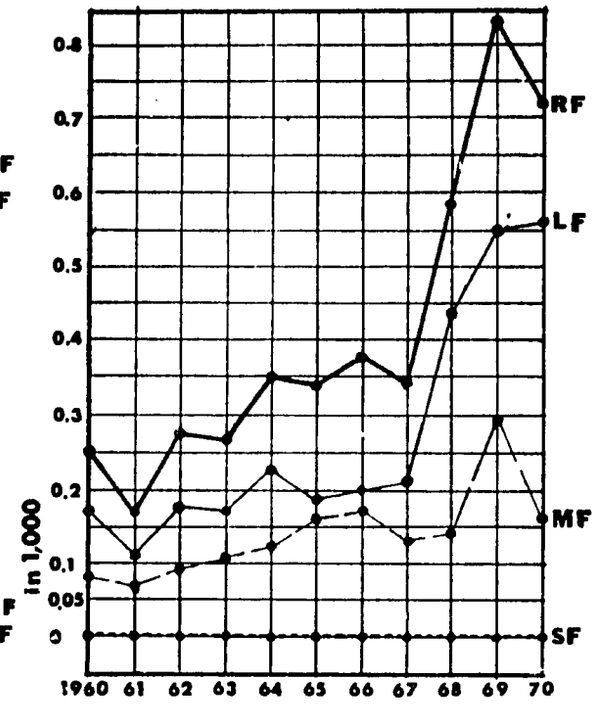
[1]It should be pointed out that small farms, although endowed with some tractor capacity, adopt exclusively traditional technology due to an abundance of family labor which is assumed to have a zero opportunity cost compared to the operating cost of modern farm power. The opposite holds true on large farms. Large farms are also endowed with some draft animal capacity but this was not used because it requires complementary labor resources. Since family labor is scarce its opportunity cost then equals the costs of wage labor, which large farms have to supplement their labor resources.

[2]No investment in draft animals occurred on medium farms for 1960 and 1961 because of excessive initial capacity endowments of work animals estimated for medium farms.

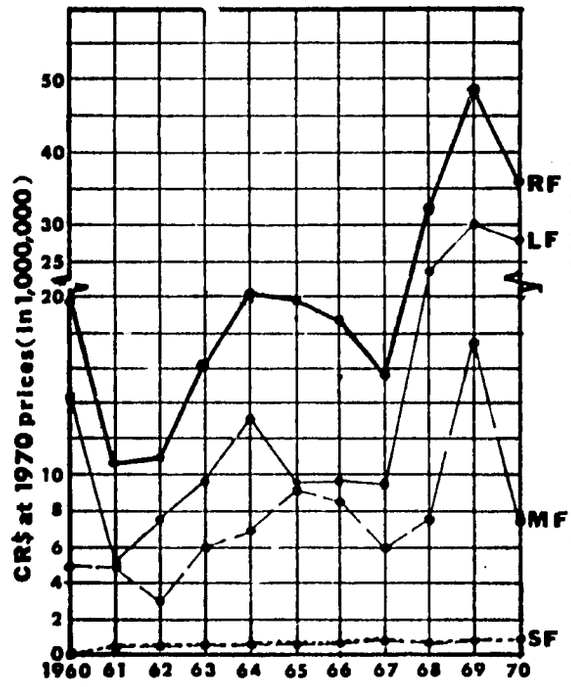
# REGIONAL INVESMENTS & TOTAL OUTLAYS BY FARM SIZE



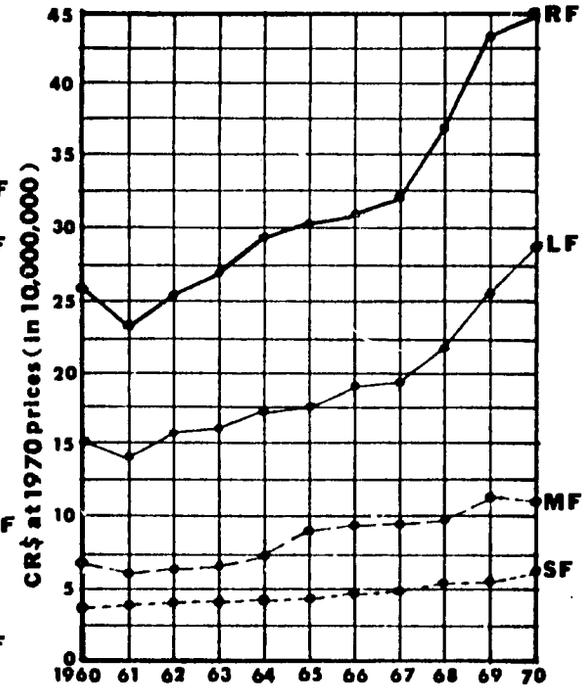

GRAPH 16: Gross New Investments in Draft Animals




GRAPH 17: Gross New Investments in Tractors




GRAPH 18: Total Outlays on Investments Goods




GRAPH 19: Total Outlays on All Inputs

SF: Small Farms
MF: Medium Farms
Source: Model Results

LF: Large Farms
RF: Regional Total Farms

Wheat Region in the State of Rio Grande Do Sul, Southern Brazil (1960-1970)

Farm Employment

The trends in farm employment by farm size (Graphs 9 and 10) are geared to the differences in the cropping patterns and technological changes discussed above. The total labor employment (family plus wage labor) on small, medium, and large farms increased by 314, 114, 123 percent, respectively. Small farms, resorting exclusively to traditional technologies, moved toward full employment of available family labor although only 68 percent of total family labor available was employed actively by 1970. On large farms, however, with family labor being fully employed almost a constant volume of wage labor was hired annually during 1960-1967 but increased very rapidly for the following three years (Table 22). In contrast to this, medium farms are situated on a "break-even" margin with full family labor employment since they have an internal adjustment mechanism not to hire wage labor by appropriately adjusting the technological choices between labor-saving modern farm power and labor-using (relative to the former) draft animals.[3]

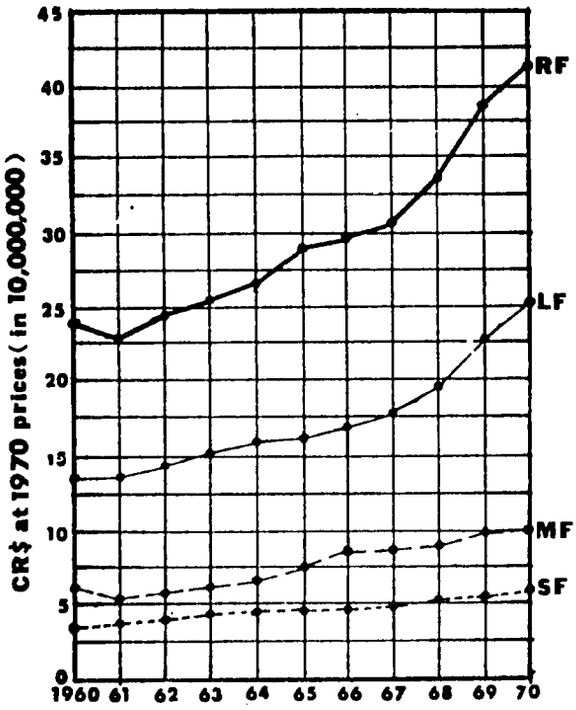
To summarize, the long run estimates show that total regional labor use increased more than 2 fold in the decade mainly due to

[3]The "break-even" margin of family labor employment implies available family labor on medium farms suffices for total labor requirements over all activities. This suggests that medium farms are under transition phase between the two technologies. If the family labor available on medium farms were sufficiently tight, they could have adopted exclusively the labor-saving modern technology. Some wage labor is hired on medium farms in 1960 (see Table 22), but this is due to errors in the initial condition of family labor endowments.

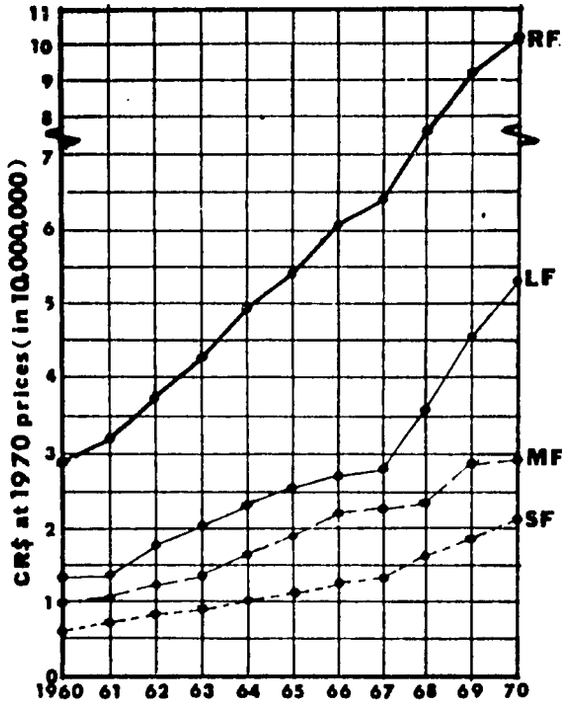
changes in the patterns of land use from range livestock to doubling crop farming and improved pasture systems. The increase in regional labor use was realized greatly by the growth in farm employment on small farms although the family labor available on small farms was substantially underutilized. Some change has also occurred in the seasonal demand for wage labor with labor scarcity especially on large farms, and most critically in November when wheat is harvested and land prepared for soybeans.

Capital Utilization

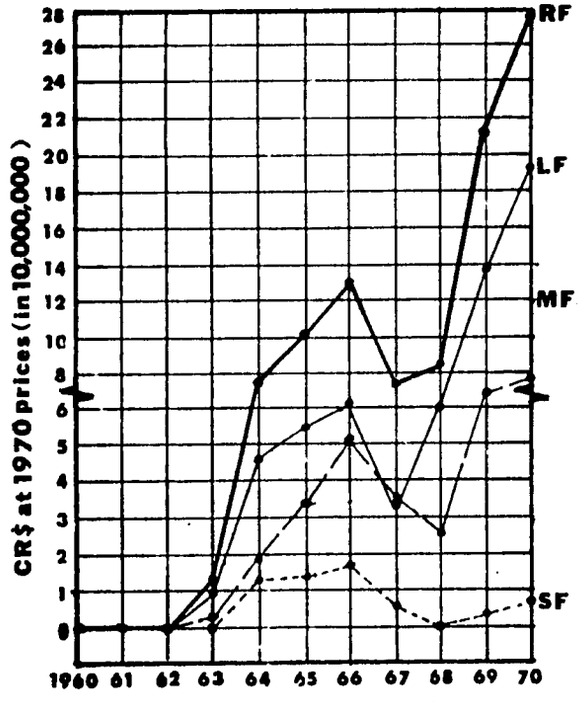
The continued transformation from natural pasture to crop land and the resulting technological change brought about a substantial growth in the use of both investment and working capital (Graphs 18-22). Using a weighted index of all inputs at constant 1970 prices, total cash outlays on small, medium, and large farms increased significantly by 178, 183, and 211 percent, respectively, during the decade of the sixties. The total cash outlays include (1) investment outlays on purchases of non-farm capital goods and (2) the working capital used for all variable production inputs. The ratio of investment capital to working capital was around 1 percent on small farms, roughly 7 percent on medium farms during the entire period, but grew from 4 percent to 10 percent on large farms between 1961 and 1970 (see Tables 35 and 36). This suggests that the rate of both capitalization and hence mechanization is positively correlated with farm size with large farms becoming capitalized at a faster rate. The different rates of mechanization and their inverse relationship to employment suggests




GRAPH 20: Total Outlays on Variable Inputs




GRAPH 21: Total Outlays on Nutrients




GRAPH 22: Total Demand for Debt

SF: Small Farms
MF: Medium Farms
Source: Model Results

LF: Large Farms
RF: Regional Total Farms

Wheat Region in the State of Rio Grande Do Sul, Southern Brazil (1960-1970)

that the extent of the long run substitution of capital for labor is positively correlated with farm size, not an unexpected result bearing in mind differences in resource endowments.

One of the most important on-farm outlays is on the use of fertilizer nutrients (Table 38). Although the model assumes a constant level of per hectare nutrient application independent of the mechanical technology employed, nutrients expenses have undergone a tremendous increase for all the farm size groups due to the changing composition of crop outputs from extensive livestock to intensive crop farming.

In connection with the technological change accompanying the regional transformation, capital formation in farm power exhibits an ever increasing trend through the decade for all farm size groups (Graph 11). These quasi-fixed capital stocks grew by 342, 489, and 643 percent on small, medium, and large farms respectively. Their growth is indeed significant when compared to the growths of other regional resources. As long as the current transition, namely range land to crop land proceeds, the dramatic growth of capital in farm power is expected to continue, and probably at accelerated rates.

Using the information on the value of crop and range land from sample data, an attempt is made to arrive at an estimate of total capital stock as the value of quasi-fixed farm power stock plus the value of land-in-use (Table 26). Although additional components such as the value of inventory and buildings are omitted, this definition of capital stock does provide partial and useful information on the process of capital formation by farm size since land and quasi-fixed capital provide the major source of this formation. Volume of capital

stock is seen to be an increasing function of farm size over the decade. However, intra-farm trends of capital formation are constantly changing through time, the rates of growth being substantially faster on larger farms. For example, the total capital stock of land and power sources grew by 116 percent on small farms, 128 percent on medium farms, and 143 percent on large farms between 1960 and 1970.

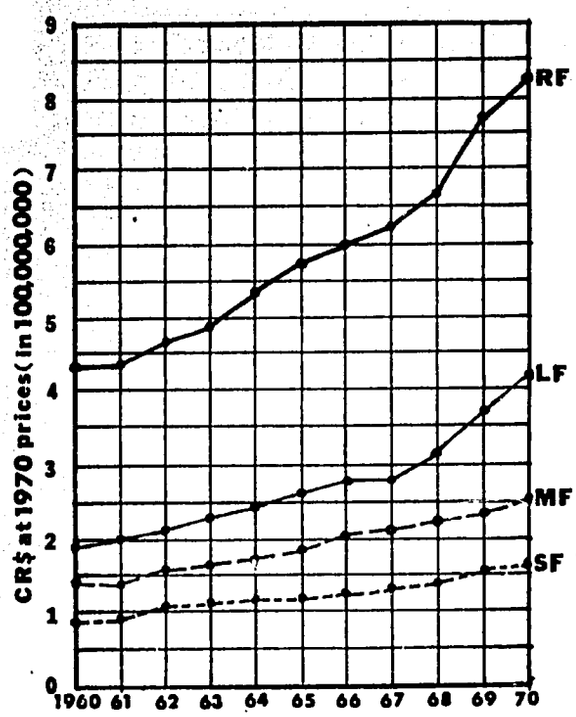
The substantial increase of total money capital including capital in farm power stocks has been financed partly from on-farm profits and partly from short-term borrowings of institutional credit. The increasing dependence on external funding, especially on larger farms, as the regional transformation proceeds is shown in Graph 22.[4] No external funding occurred for the region between 1960 and 1962 but the use of credit accelerated dramatically after that, especially in the late sixties, growing from 12.6 million Cr.$ in 1963 to 278 million Cr.$ in 1970. Some further aspects of credit use in relation to other factors are discussed in a later section on credit use by farm size.

### VI.3) Factor Productivities

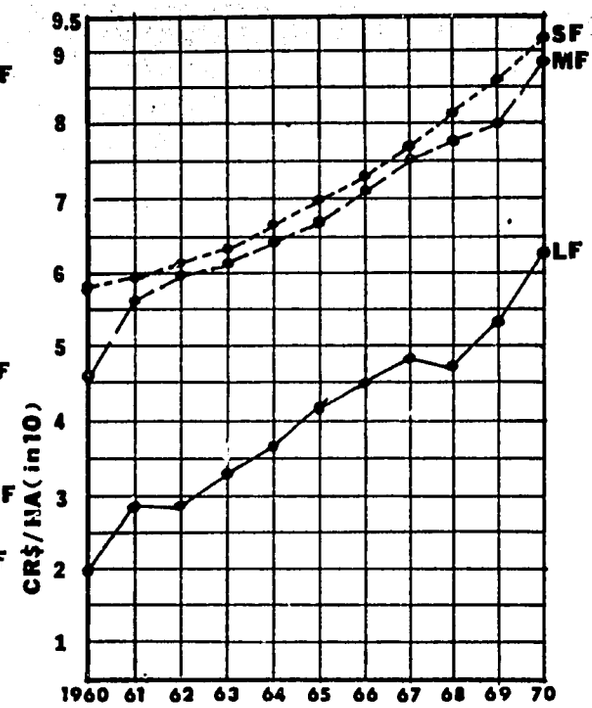
A constant conversion from range livestock to cropping agriculture has generated a substantial growth in the value of total output among all the farm size groups during 1960-1970 (Graph 23). Total output grew on small, medium, and large farms by 169, 177, and 216

[4]Total credit use is valued at constant 1970 prices. The price deflator used to eliminate inflationary trends is the Index of Wholesale Agricultural Prices in the state of Sao Paulo, Rio Grande do Sul. Source: Conjuntura Economica, 17, No. 9, 1970, p. 91.

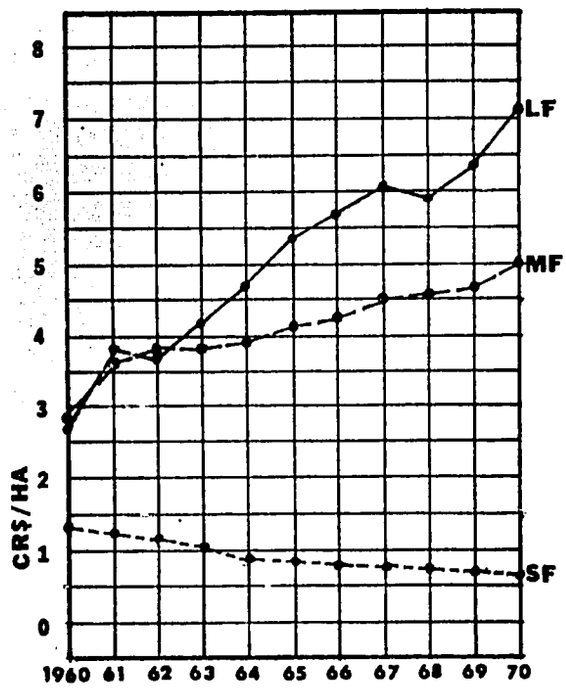
# OUTPUT AND FACTOR PRODUCTIVITIES BY FARM SIZE



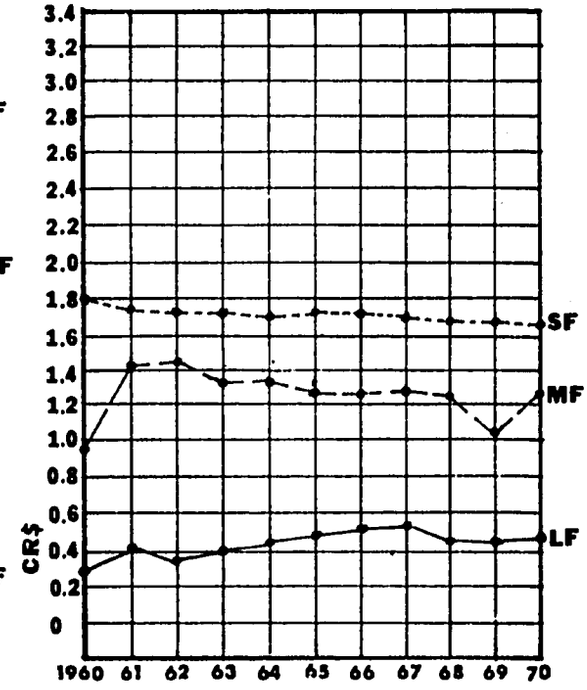

GRAPH 23: Total Output




GRAPH 24: Net Land Productivity per Hectare




GRAPH 25: Net Labor Productivity per Hour




GRAPH 26: Net Productivity of Annual Total Cash Outlays

SF: Small Farms
MF: Medium Farms
Source: Model Results

LF: Large Farms
RF: Regional Total Farms

Wheat Region in the State of Rio Grande Do Sul, Southern Brazil (1960-1970)

percent, respectively, over this period. The concept of factor productivities here is defined in an aggregate and average sense as the ratio of the value of total net output (total revenue minus total cost) to the amount of the principal outputs: land, labor, and capital at constant prices. Changes in average net productivity through time for land, labor, and capital are discussed below.

Land Productivity

Average net land productivity, measured as the ratio of total net revenue to total land use, including double cropped land, is a decreasing function of farm sizes (Graph 4). In 1960, the land productivity on small farms was 125 percent higher than on medium farms which in turn had a land productivity about 224 percent greater than on large farms. However, in 1970, the land productivity on small farms was only 103 percent higher than medium farms that in turn had a land productivity merely 142 percent higher than on large farms. Thus as the agricultural transition has proceeded, the net land productivity gap among different farm size groups has continually narrowed. Factors associated with this are the faster rate of transition to crop farming on larger farms and their increased use of commercial inputs over time.

One of the crucial features associated with the agricultural development in the wheat region is that an index of land productivity for all the farm size groups rose substantially over the last decade. Land productivity grew 158, 192, and 302 percent on small, medium, and large farms, respectively, between 1960 and 1970.

Labor Productivity

Unlike the trends in net land productivity, the index of average net labor productivity defined as the ratio of net revenues to total labor hours employed follow different paths through 1960-1970 (Graph 25). Most importantly, the labor productivity on small farms declined by 48 percent during the period, while labor productivities on medium and large farms increased by 176 and 262 percent respectively (Table 42). Thus labor productivity is an increasing function of farm size. The gap in intra-farm labor productivities continued to grow over time. Medium and large farms had almost identical levels of the labor productivity in 1960. This level was more than two times higher than the labor productivity on small farms. However, by 1970 labor productivity on medium farms was roughly 7.5 times higher than on small farms, labor productivity on large farms was more than 10 fold on small farms!

The differences in labor productivity are even greater if one measures returns to family labor available rather than per hour of labor employed, since labor use on large farms exceeds family labor available, while it is less than available family labor on small farms (Table 23). A discussion of the effects of changes in the net returns to family labor available follows in a later section on income distribution.

Some factors contributing to the ever-diverging differences in labor productivity by farm size are: (1) the choice of different technologies on the different farm size groups, (2) the intra-farm differences in labor employment associated with the cropping history and

technological change, and (3) different levels of commercial inputs used which in turn affect the total net revenues for farms of different size.

Capital Productivity

Net capital productivity, defined as the ratio of net revenue to total annual cash outlay where net revenue is as previously defined and total annual cash outlay includes outlays on variable and quasi-fixed inputs, does not follow a uniform growth pattern over farm sizes (Graph 26). Capital productivity on small farms declined by 7.6 percent, at an almost constant rate, over the decade suggesting that the growth rate in net output is slightly less than that of capital used on small farms during the sample period (Table 43). Medium farms also showed a declining trend, with minor fluctuations except for the initial years (again a problem caused by the initial conditions), with a reduction of 11 percent in capital productivity between 1961 and 1970. Large farms, however, show an upward trend in capital productivity to the mid-sixties, but a declining path in the late sixties.[5] Yet the index in 1970 was 114 percent higher than that in 1961. The decreasing trend of capital productivity in the late sixties is likely to continue as the region approaches capital satiation with capital outlays growing faster than output.

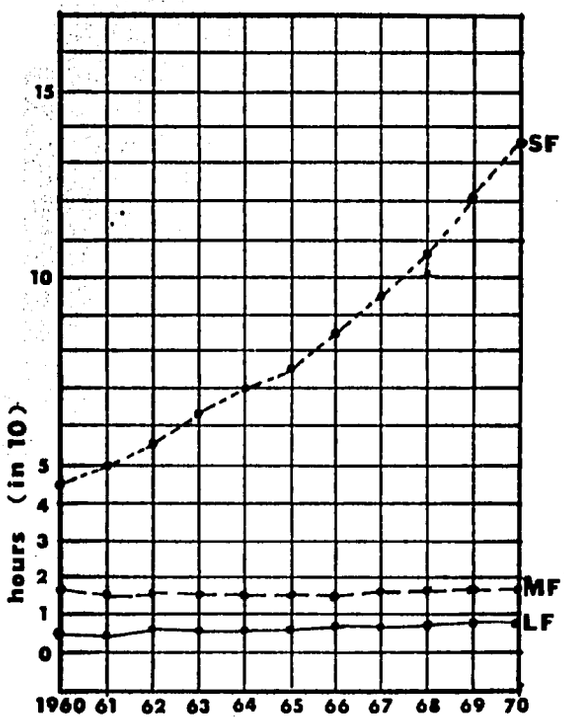
[5]The capital productivity on large farms is slightly underestimated because the total cash outlays defined for the denominator of the productivity index includes cash expenses on wage labors. However, the proportion accrued to wage labor is not significant.

In contrast to the intra-farm comparison of the labor productivity, the net capital productivity is a decreasing function of farm size through time. Small farms' capital productivity was generally 125 to 140 percent greater than on medium farms which in turn was 3 fold greater than on large farms. This substantially lower level of the capital productivity on large farms relative to either small or medium farms is closely associated with (1) a unique investment pattern for modern farm power only on large farms and (2) accelerated use of a commercial input mix over time. Both factors lead to greater total cash outlays on large farms than on the other farms. But the higher total cash outlays were not accompanied by the correspondingly higher level of net output on large farms; thus a relatively low capital productivity resulted.

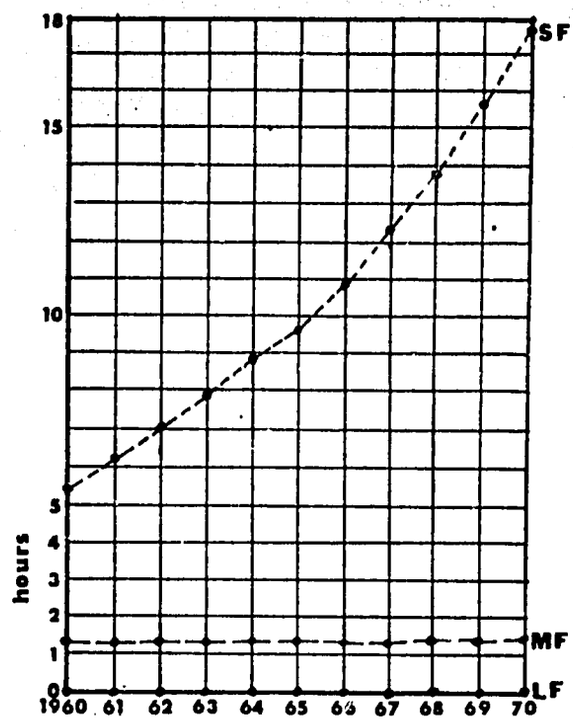
## VI.4) Factor Proportions

One of the basic features of the model formulation is the differences in factor endowment among farms of different sizes initially and over time. These differences in factor endowments are accentuated and result in differences in factor proportions through time. Most of the discussions of factor proportions are presented below only on the per hectare basis. However, a series of tables showing the dynamics of various factor/labor ratios are contained in Appendix D.

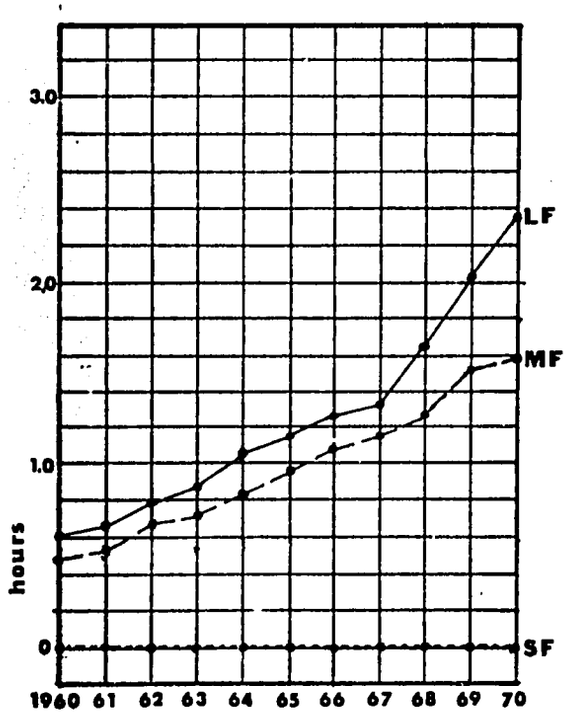
The differences in labor/land ratios by farm size are evident in Graph 27, with small farms showing an upward trend while medium and large farms exhibit a constant ratio over time. The labor hours employed per hectare is a strictly decreasing function of farm size.



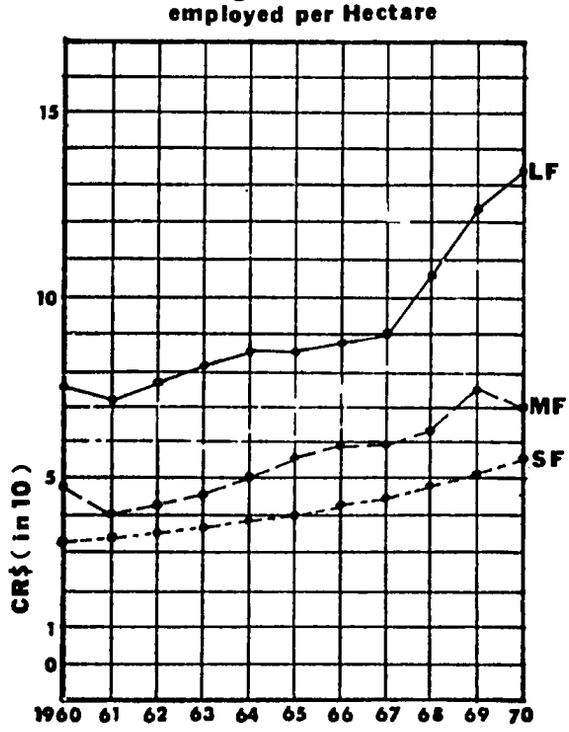

GRAPH 27: Average Labor Hours per Hectare




GRAPH 28: Average Draft Animal Hours employed per Hectare




GRAPH 29: Average Tractror Hours employed per Hectare




GRAPH 30: Total Annual Capital Expenditures per Hectare

S F: Small Farms M F: Medium Farms L F: Large Farms

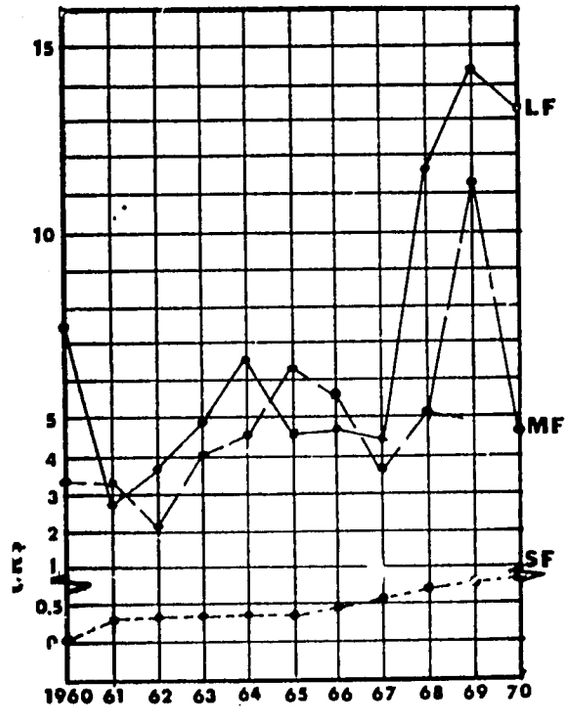
Source: Model Results

Wheat Region in the State of Rio Grande Do Sul, Southern Brazil (1960-1970)

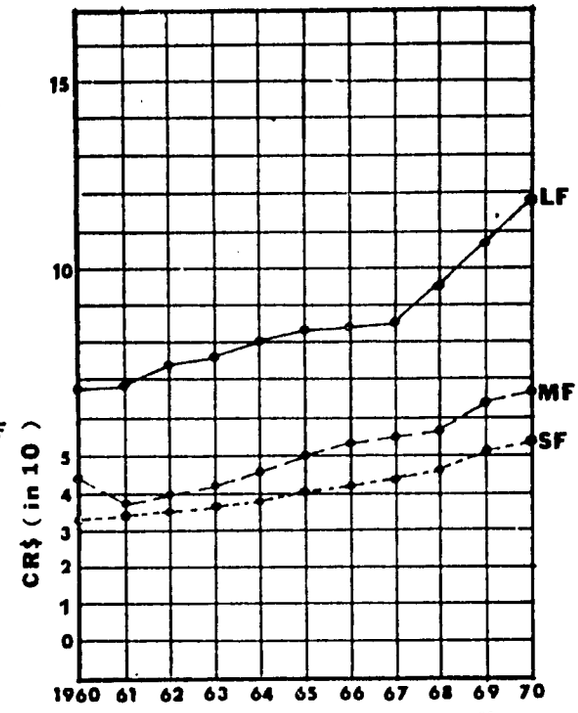
Combined with the dynamic path of the labor/land ratios are the trends in both the draft animal/land (Graph 28) and tractor/land (Graph 29) ratios. These establish a complementarity between human labor and draft animal power on small farms and a substitutability between labor and mechanical power on other farms. Obviously, the significantly increasing trend of labor per hectare on small farms is associated with a similar trend in draft animals per hectare as they use labor-intensive traditional technology. However, increasing labor requirements per hectare on medium farms with relative labor scarcity brings about an ever-increasing use of relatively labor-saving tractor technologies, thus displacing labor in the long run. The same holds true for large farms in a much stronger way, primarily because large farms have an even greater labor scarcity and do not employ draft animal technologies because of their complementary labor requirements.

The degree of capitalization accompanying the regional transformation are manifested in Graphs 31-33. Between 1960 and 1970, per hectare total cash outlays grew by 170-180 percent on all the farm size groups (Table 51). However, per hectare cash expenditures on large farms are roughly 1.7 times higher than on medium farms over time which in turn are about 1.2 times greater than on small farms over the same period.

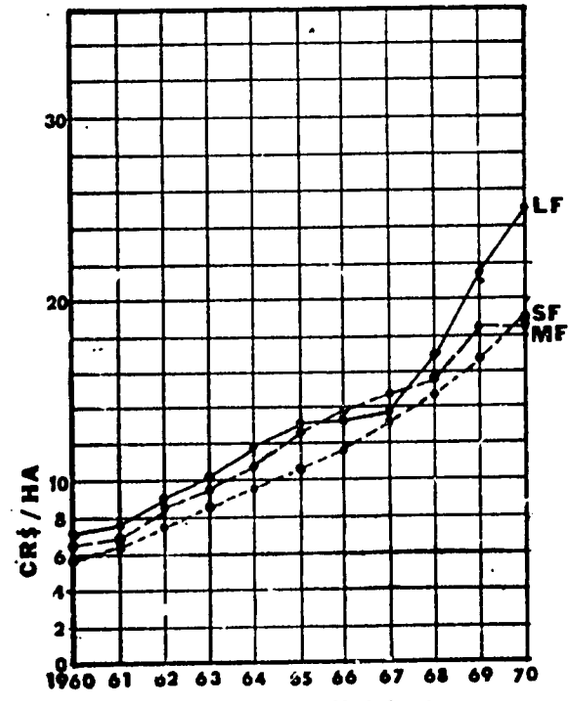
As total cash outlays are broken down into investment and working capital, per hectare total cash outlays are decomposed in the same way. For both components greater capital use per hectare is associated with an increase in farm size, and these differences increase over time (Graphs 31 and 32).



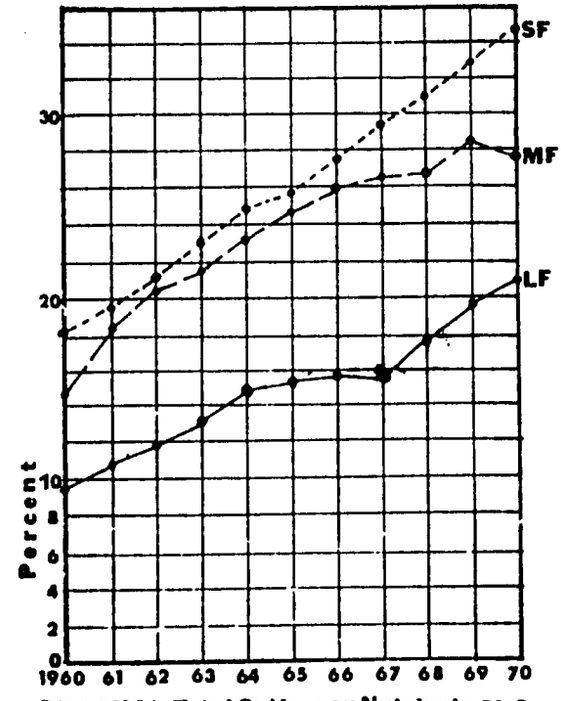

GRAPH 31: Gross New Investment Capital per Hectare




GRAPH 32: Average Working Capital Use per Hectare




GRAPH 33: Total Outlays on Nutrients per Hectare




GRAPH 34: Total Outlays on Nutrients as a Percentage of Total Working Capital

SF: Small Farms MF: Medium Farms LF: Large Farms

Source: Model Results

Wheat Region in the State of Rio Grande Do Sul, Southern Brazil (1960-1970)

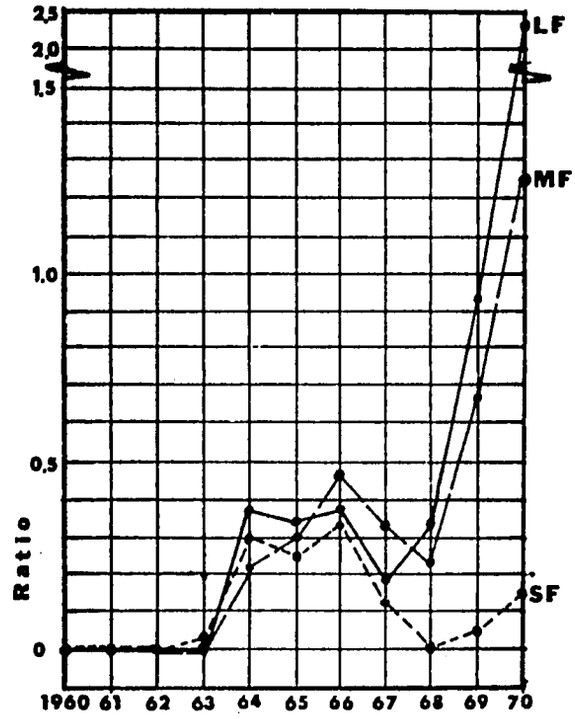
Some caution is required in interpreting total outlays on nutrients per hectare as a principal component of total working capital (Graph 33). The upward sloping trends on all the farm size groups do not imply an increased application of nutrients on crop land. It merely reflects the reduction in natural pasture land which received no fertilizer and an increase in crop land that uses larger amounts of nutrients per hectare. This is the reason why nutrient use per hectare grows the fastest on large farms reflecting their faster rate of transition to wheat crop land use.

## VI.5) Credit Use

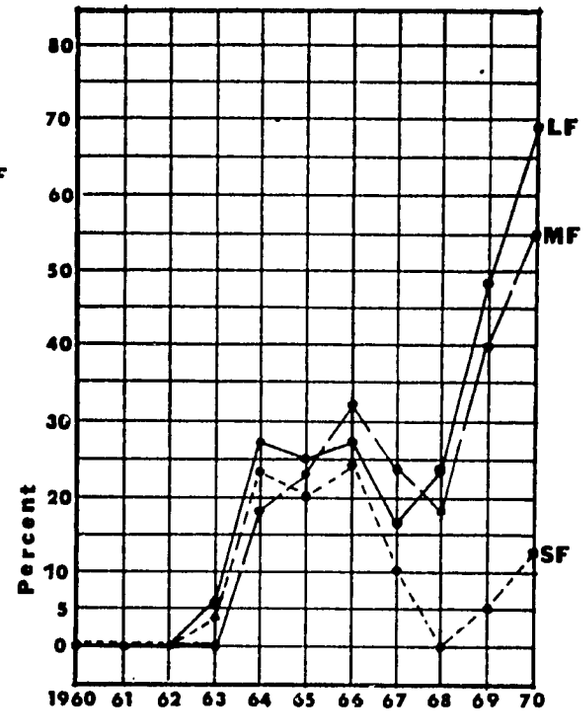
It has already been emphasized (section VI.2) that the regional demand for debt has undergone a remarkable growth. The importance of the role that credit has played during the transition period is most convincingly displayed in Graphs 35 and 36.

Considering the important facilitating function of the working cash constraint in the model, the entire spectrum of the dynamic paths of transition would have presented an entirely different picture without the increased availability of credit to finance farm operations, especially after the wheat pricing and credit subsidy programs came into effect in 1963-1964. Borrowing as a percentage of total outlays increased from 0-5 percent in 1963 to 28-34 percent in 1966 for all the farms in the region but declined to zero borrowing on small farms, 18 percent on medium farms, and 28 percent on large farms in 1968. From 1968 the percentages of the borrowed money accelerated to a very high

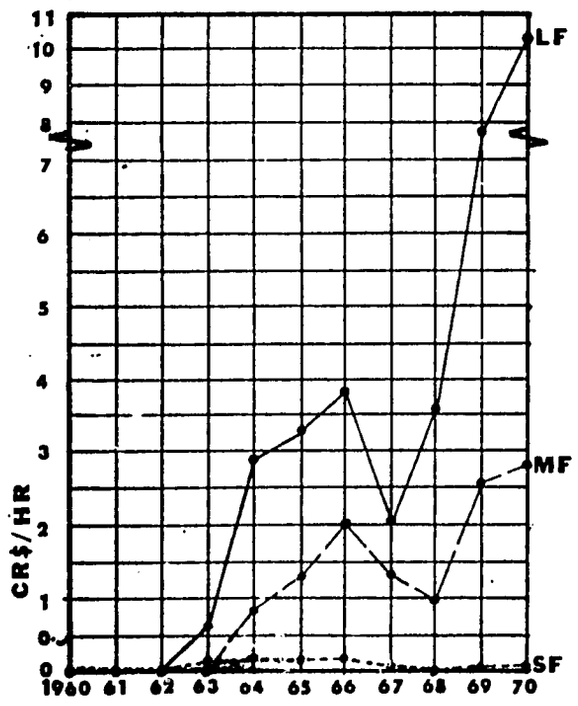
# CREDIT USE BY FARM SIZE



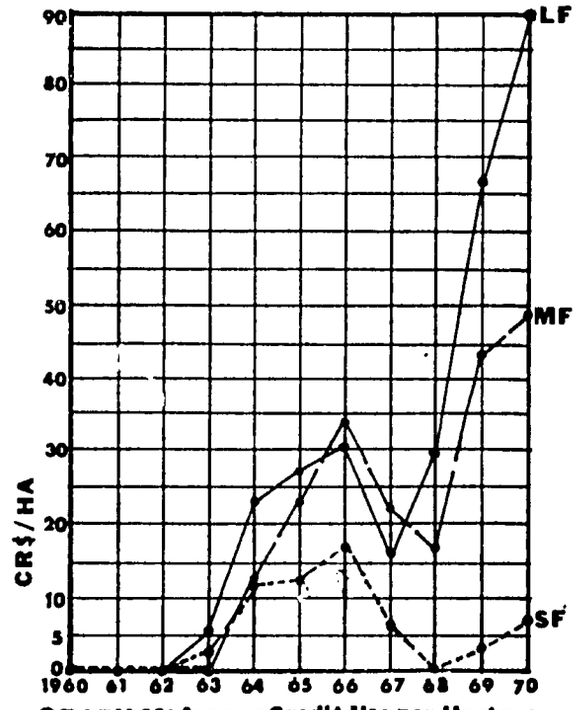

GRAPH 35: Borrowing/Internal Capital Financing Ratio




GRAPH 36: Total Credit Use as a Percentage of Total Cash Outlays




GRAPH 37: Average Credit Use/Labor Hour Ratio




GRAPH 38: Average Credit Use per Hectare

S F: Small Farms M F: Medium Farms L F: Large Farms

Source: Model Results

Wheat Region in the State of Rio Grande Do Sul, Southern Brazil (1960-1970)

69 percent on large farms and 50 percent on medium farms by 1970. Small farms, however, show a very small increase to 13 percent by 1970.

The credit/labor and credit/land ratios present dynamic trends similar to the total credit use as a percentage of total cash outlays, but adjusted slightly according to the trends of labor employment and double cropped land (Graphs 37 and 38). Since the increasing pattern of regional labor employment was mainly due to the activation of "surplus" family labor available on small farms, the time path of credit/labor ratio on small farms crawls along the horizontal axis at a zero level. Labor employment on all the farm size groups together with their unique patterns on technological choice further intensified widening gaps of credit use per labor hour between farm size groups. Of course, the ratio of credit/labor on larger farms is substantially higher than on smaller farms in the entire 1963-1970 period.

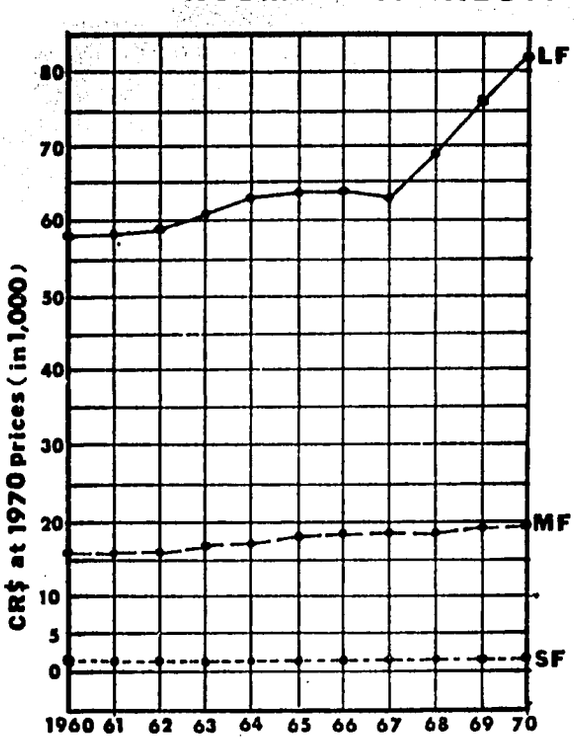
Unlike the ratio of credit/labor, the intra-farm paths of credit use per hectare show a somewhat different picture (Graph 38). There exist substantial differences on all farms in credit use per hectare in 1963-1967, but the intra-farm differences became further reinforced during the last three years of the decade. Credit use per hectare on large farms in 1970 is more than 20 fold greater than on small farms while 10 times higher than on medium farms. This increased dependence on credit to finance farm operations on medium and large farms is directly related to the credit policies which have enabled the purchase of both variable and quasi-fixed inputs with credit at nominal rates of interest far below the on-going rate of inflation, and a credit rule that allocates capital not due to its productivity but due to

requirements expressed as a function of the volume of market sales. Thus small farms with higher capital productivity end up with a smaller share of credit than large farms with a higher volume of gross sales.

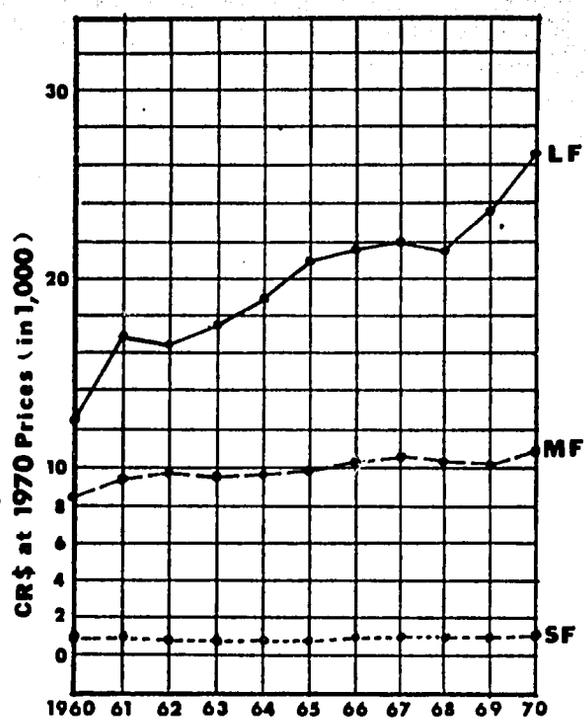
## VI.6) Income Distribution

The discussion that follows is centered around two broad income concepts. They are (1) farm incomes which are estimated on a gross or net basis by dividing the aggregate gross or net incomes of the size group by the number of farms in that farm size group and (2) returns to available family labor that are estimated by dividing the aggregate gross and net incomes by total family labor available. The number of farms is estimated exogenously, whereas the total family labor available is endogenously generated in the model. The data on the number of farms are presented in Appendix B.

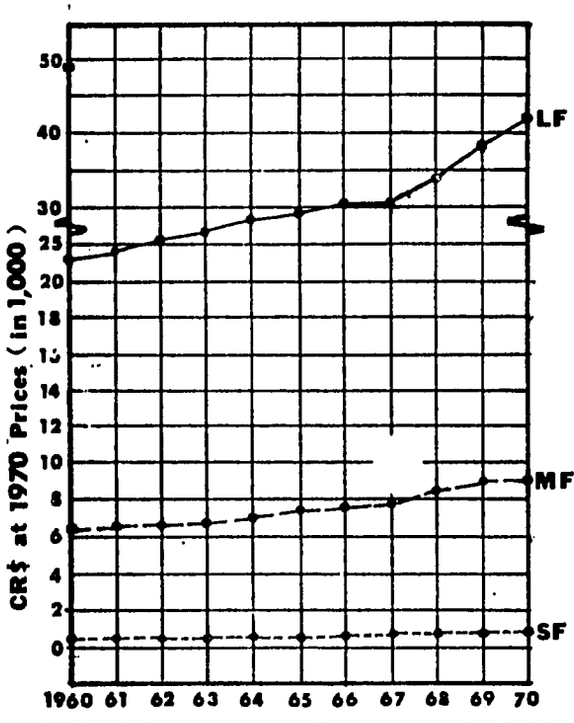
Accompanied by the rapidly changing economic history in the wheat region is a substantial growth in the regional agricultural output described in a previous section. The dramatic growth in total output is distributed most unevenly over different farm size groups (Graphs 39 and 40). Both gross and net farm incomes on small farms remained almost constant in the decade, the former at approximately Cr.$1,600 and the latter at about Cr.$1,000. Those on medium farms have grown at a slow but steady rate but are at least 8 fold greater than on small farms through the years. Most disturbing is the growth of incomes on large farms, with gross farm income increasing by 141 percent and net farm income by 212 percent between 1960-1970. Gross and net farm incomes, respectively, on large farms are 3.4 and 1.5 folds greater than on



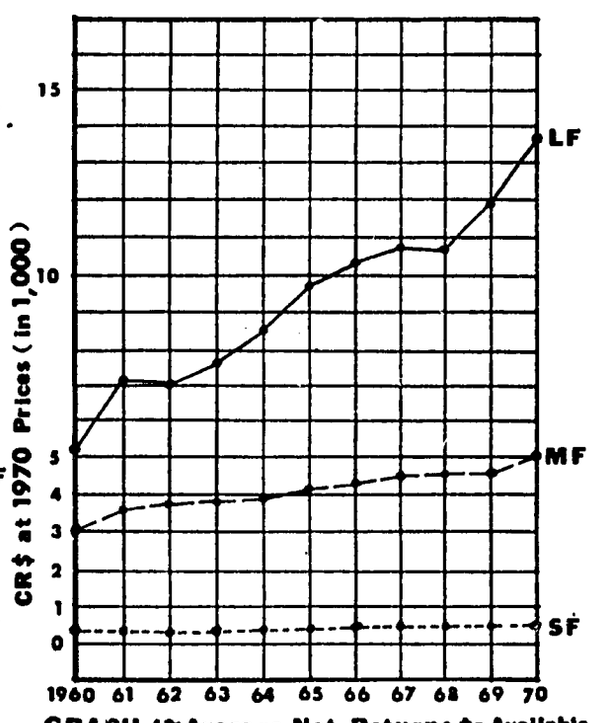

GRAPH 39: Average Gross Farm Income




GRAPH 40: Average Net Farm Income




GRAPH 41: Average Gross Returns to Available Family Labor per Hour




GRAPH 42: Average Net Returns to Available Family Labor per Hour

S F: Small Farms M F: Medium Farms L F: Large Farms

Source: Model Results

'heat Region in the State of Rio Grande De Sul, Southern Brazil (1960-1970)

medium farms in 1960. However, by 1970 gross farm incomes on large farms are 4.2 times higher than on medium farm whereas net farm incomes are 2.4 times greater than on medium farms. This suggests that inequalities in farm incomes have substantially increased over time.

Looking at the income distribution in terms of gross and net returns to available family labor per hour during (1960-1970) as shown in Graphs 41 and 42, the diverging income inequalities are further intensified mainly due to a surplus of family labor on small farms and deduction of hired labor from total labor employment on large farms to arrive at their available family labor. The inequalities of gross returns to available family labor per hour between small and large farms grew, expressed in returns to labor on large farms as a multiple of that on small farms from 44.5 fold in 1960 to 57 fold in 1970. The inequalities, on the net return basis, between small and large farms increased from 15 fold in 1960 to 29 fold in 1970. The same sort of comparison between medium and large farms would show a diverging trend of income distribution but at a substantially lower rate than between small and large farms.

## VI.7) Model Evaluation

The purpose of this section is to evaluate how "good" the model is in simulating the quantitative economic history of the wheat region during 1960-1970. Once the simulation model has been estimated for a historical time period, the model solutions should be compared with the historical observations in order to test the "goodness of fit" of

the model. Recently, as systems models have become a new tool for economic analysis, increasing attention is being given to verification and validation of specific simulation models.[6]

In general, the systems models are constructed with a view to evaluating the effects of alternative economic policy programs. Therefore, a prerequisite for both the interpretations of the model results and its policy implications under different model parameters is the model's ability to predict the behavior of the actual economic system.

In this section, we review briefly various evaluation methods of a simulation model and discuss the predictive performance of the model of this study with the help of graphical display of both observed and predicted time paths of some major endogenous variables in the model and by comparing the model results with related evidence found in a series of studies that provide auxiliary information.

## A Review of the Alternative Evaluation Methods

In order to test the degree to which the systems model solutions conform to observed historical data, Naylor suggests two alternative verifications--"historical verification" and "verification by forecasting."[7] The former is concerned with retrospective predictions, that is, expost simulations over the sample period, while the latter is

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[6]A few works related to the problem of the verification of simulation models include Naylor (1970), Van Horn (1971), Johnson and Rausser (1972), Day and Singh (1971), and Miller (1971). The last two focus on recursive programming models.

[7]Naylor (1970), p. 263.

concerned with prospective predictions, that is exante simulations beyond the sample period. Limiting ourselves to the historical verification, several specific measures and techniques have been suggested for testing the "goodness of fit" of simulation results, i.e., the degree of conformity of simulated series to observed data. Some of these measures for a given systems model have been discussed recently while leaving aside the difficult questions of validating and comparing alternative systems models.[8]

For example, using the criteria groups classified by Johnson and Rausser, Day and Singh applied the following methods to evaluate the Punjab model:[9]

a. The Regression Method

b. Theil's Inequality Coefficient

[8]As Johnson and Rausser points out, the question of validating alternative system models revolves around which model representation is the best in explaining the sample data. Beyond economic theories involved in specifying the alternative systems models, they argue that the question of ranking alternative system models in terms of their predictive power is difficult since some model representatives may perform well on the basis of one or more criteria but poorly on the basis of other criteria. In general, the validity of any particular model representation will increase with the number of positive results registered when the selected criteria are applied. Johnson and Rausser classify evaluation criteria into four groups for investigating both the explanatory and forecasting power of systems models--(a) point criteria, (b) tracking criteria, (c) error criteria, (d) spectral criteria. For the detailed discussions on those criteria, see Johnson and Rausser (1972), pp. 5-7.

[9]Day and Singh (1971), pp. 34-51.

The regression method explains the absolute levels of a historical (observed) series by regressing each observed series on the corresponding model series under the assumption that the observed series

c. Theil's Information Statistics

d. Directions of Change

e. Correct Turning Point

For the evaluation of the simulation result of a recursive programming model, ideally one would need a pairwise data series of model-predicted values and their corresponding historical values for the entire set of variables in the model.[10] As evident in the measurable

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contains a systematic part represented by the model and a random error and testing the null hypotheses of regression coefficients.

Theil's "inequality coefficient" is expressed in terms of the "U" statistic where U is defined as $U^2 = \frac{\Sigma(Pi-Ai)^2}{\Sigma\ Ai^2}$ where (Pi, Ai) stands for a pair of predicted and observed changes. (For discussions on $U^2$, see Theil (1966), pp. 28.)

The discussions and derivation of the Theil's information statistic is somewhat lengthy and hence the reader is referred to Theil (1966), pp. 256-282.

The discussions on both "directions of change" and "correct turning point" are associated with the concept of the information statistic. Both deal with a qualitative performance of the model. The reader is referred to Day and Singh (1971) for a brief discussion.

[10]As an important point in evaluating the predictive performance of the recursive programming models, Miller emphasizes the effects of alternative estimation procedures in deriving flexibility constraints discussed in Chapter IV. Since year-to-year changes in crop hectarages are bounded by the flexibility constraints, the predictive accuracy of recursive programming models rests on the estimation procedure of flexibility bounds. This is particularly true if the model solutions are hitting either upper or lower bounds continuously. Miller points out that the particular magnitude of the flexibility coefficients has a two-way effect on the total expected error of the model through (1) changes in the bias of the particular bound, and in some instances through (2) changes in the amount of free play the recursive programming model is given, compared with its ability to choose the correct bound. Therefore it is highly desirable to choose the best estimation procedure of the flexibility constraints in order to improve the predictive power of the recursive programming models. (Miller (1972), pp. 68-74.)

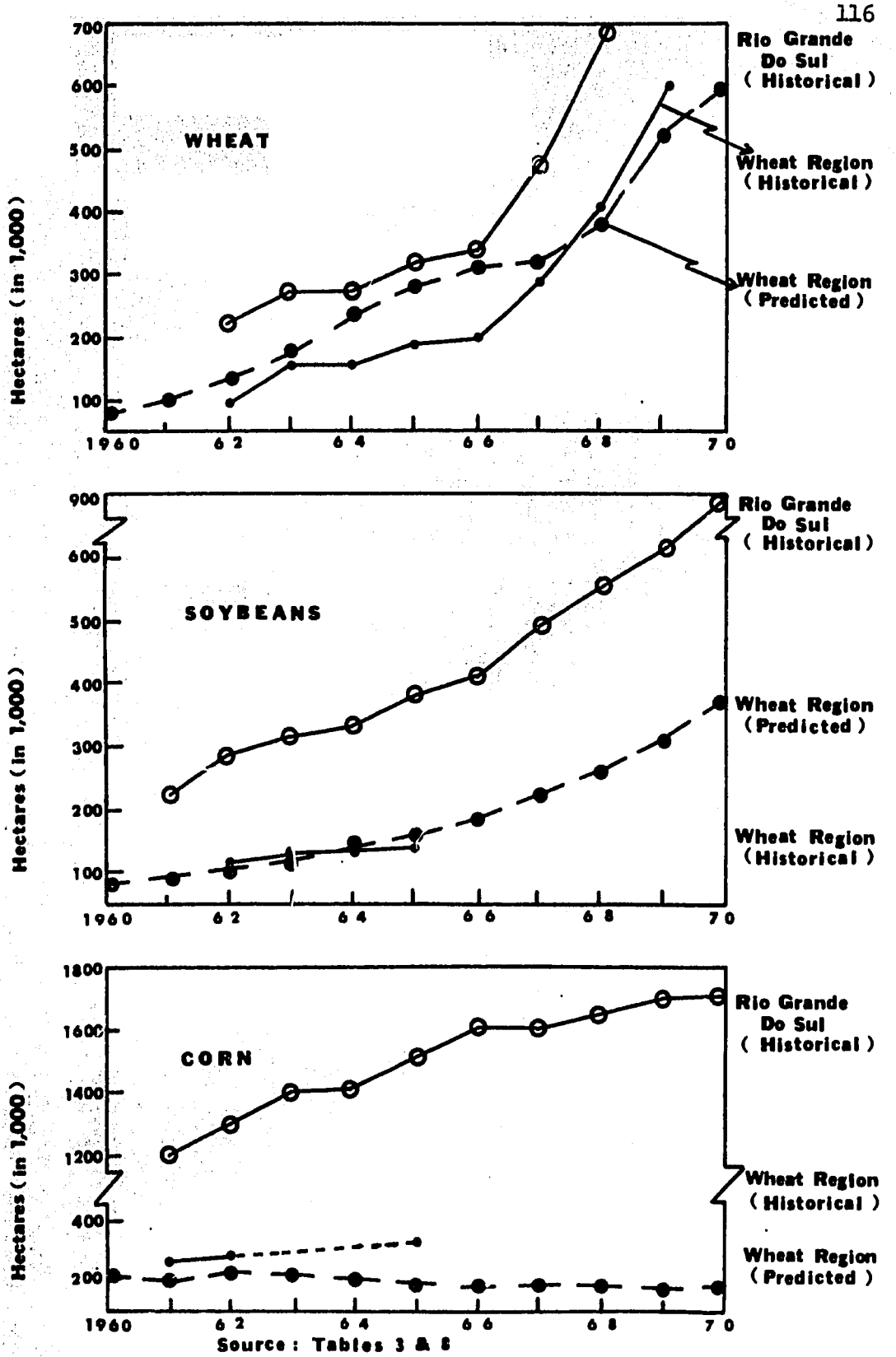
statistics introduced above for testing the predictive power of a simulation model, a sufficient number of observations for a given historical series is necessary to obtain proper degrees of freedom for statistical inference.

Unfortunately, very little data are available for the model evaluation purposes in this study. Even the available series of observed data does not cover the entire period of 1960-1970. Due to these data limitations, a simple evaluation technique is attempted below, utilizing a graphical display of predicted and observed series and verifying some model results with major findings in other related studies of agricultural development in Southern Brazil.

Evaluation of Model Simulation Results

In order to evaluate properly the model performance in this study, the historical regional data of a given variable by farm size is desired. However, only regional data on crop hectarages for Rio Grande do Sul and in some cases for the wheat region are available. They are presented in Graphs 43 and 44 along with corresponding model-predicted values. It is important to recognize in Graphs 43 and 44 that there exists a proportional relationship between the time paths of the statewise (Rio Grande do Sul) and its sub-regional (wheat region) data. Based on this relationship, the available statewise and sub-regional data can be used to the maximum for an "indirect" evaluation of the model.

First, the predicted time path of the regional wheat hectarage is fairly close to the corresponding historical path for the years




Source: Tables 3 & 8

GRAPH 43: HISTORICAL AND MODEL PREDICTED HECTARAGE OF FIELD CROPS IN THE WHEAT REGION AND RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960 1970)

NOTE: The Historical Hectarage Data are not Available for Missing Observations.

1962-1969. However, the model over-predicts slightly for the three years 1964, 1965, and 1966 while it under-predicts a little for 1969.

Second, the visual display of both predicted and observed hectarage for soybeans, the former covering the wheat region and the latter covering Rio Grande do Sul, suggests that the model performs better for soybeans than for wheat. Actual historical data of soybean hectarage in the wheat region are available only for the years 1962, 1963, and 1965 and each of them is paired very accurately with its predicted counterpart.

Third, the historical data availability of corn hectarage are the same as for soybeans and are under-predicted by the model. The time path predicted by the model depicts a situation of "steady state" (stagnation) in the growth of corn hectarages. A slight upward trend is apparent in the three observed data points for the wheat region while the historical path of the state data shows an increasing trend with tapering off during the second half of the last decade compared to wheat and soybeans.

Fourth, both the rapidly increasing trends for wheat and soybean hectarages and the stable trend for corn hectarage suggest that the natural pasture land has undergone a substantially declining trend. This is so because the model assumes a fixed total hectarage of regional land, and the residue of land after accounting for the crop land is attributed to natural and improved pastures but the proportion of improved pasture is very small (see the initial conditions in Appendix C). This declining time path of natural pasture predicted by the model is displayed on Graph 6.

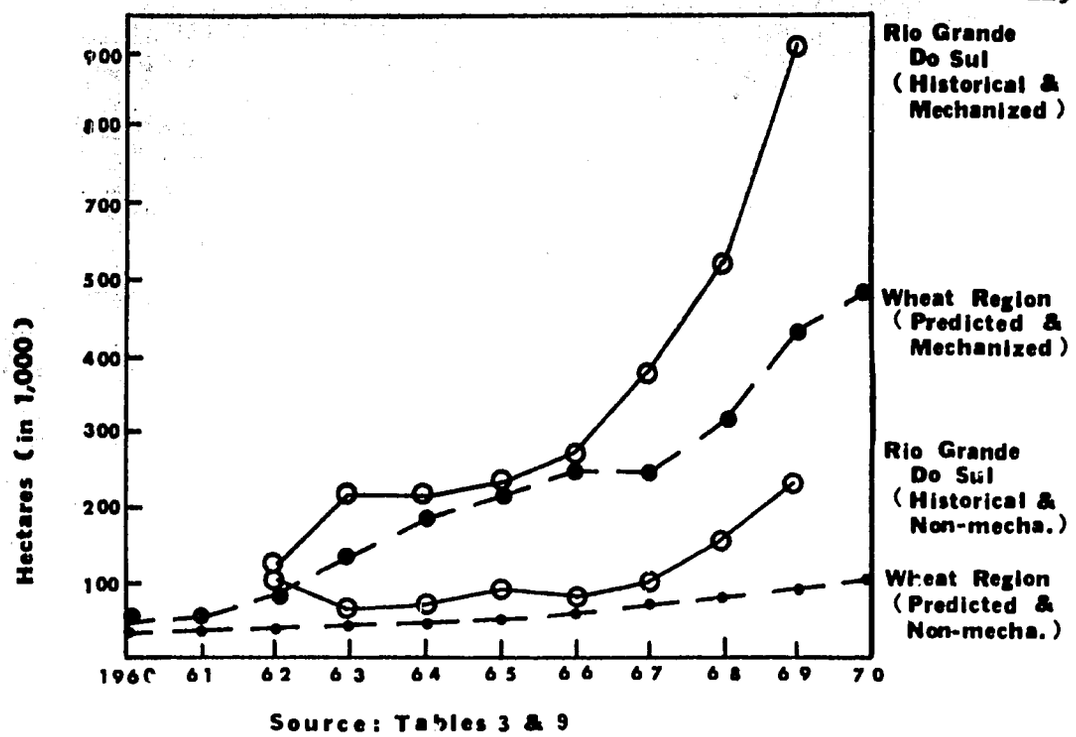
Although there are not adequate data to make more rigorous tests, it is clear that the model captures substantially the regional trends for the major crops over the simulation period, 1960-1970.

In Chapter II it was pointed out that the most important regional crop in this study is wheat. Presented in Graphs 44 and 45 is the historical data on wheat hectarage of Rio Grande do Sul during 1962-1969 classified by mechanized and non-mechanized farms and credit and non-credit use areas. The two time paths of mechanized and non-mechanized wheat hectarages in the wheat region, that are predicted by the model, are superimposed in Graph 44.

Bearing in mind that the wheat hectarages of Rio Grande do Sul and the wheat region (see the graph for wheat in Graph 43) are not directly comparable, the model prediction for mechanized and non-mechanized wheat hectarages captures most convincingly the general regional trend over the years 1962-1969. As shown in Table 11, the increasing trend of mechanized wheat hectarages is dominated by the large farm size group with much smaller contribution from the medium farm size group. This predicted trend is verified by the sample farm record data.[11] To a substantial extent, the soybean and corn predicted values and their trends are also verified

An increased use of credit over time (Graph 45) is also captured model as evident in Tables 60 and 63. A major concentration of

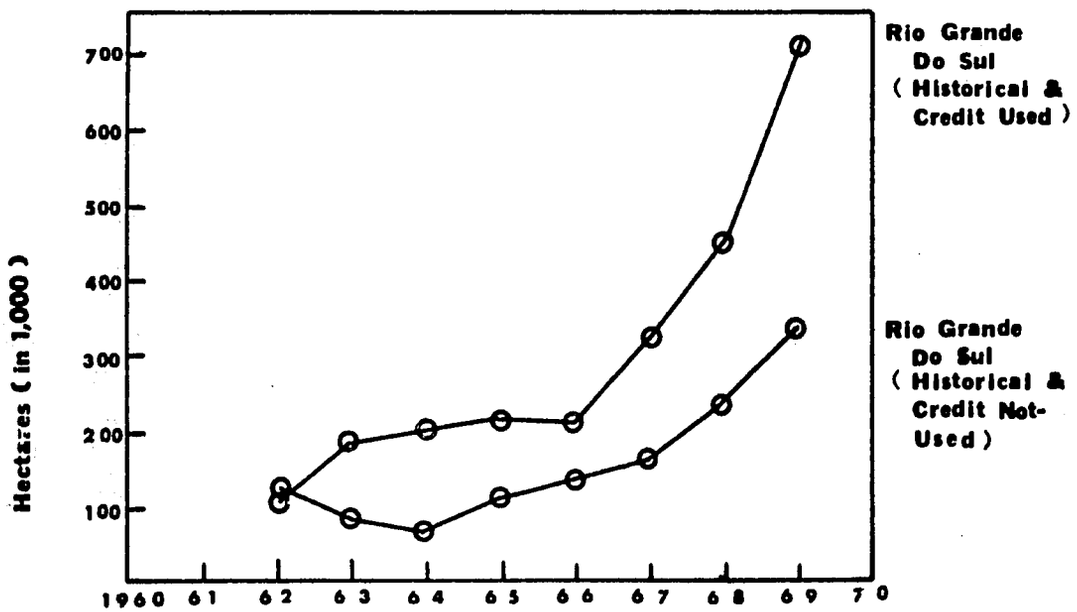
[11] Rask (1969), p. 33.




Source: Tables 3 & 9

**GRAPH 44: HISTORICAL WHEAT HECTARAGE OF RIO GRANDE DO SUL AND PREDICTED WHEAT HECTARAGE OF THE WHEAT REGION BY MECHANIZATION, SOUTHERN BRAZIL (1960—1970)**

**NOTE: The Data are not Available for the Missing Historical Observations.**




Source: Tables 3 & 10

**GRAPH 45: HISTORICAL WHEAT HECTARAGE OF RIO GRANDE DO SUL BY CREDIT USE, SOUTHERN BRAZIL (1960—1970)**

**NOTE: The Data are not Available for the Missing Historical Observations.**

credit use on larger size farms predicted by the model (Table 63) is verified by Rao's agricultural credit study in Southern Brazil.[12]

The general picture of both predicted and historical time paths involving crop hectarages and mechanization in view of traditional technology and modern technology by farm size also sheds lights on investment patterns. The historical data on larger mechanized farms and non-mechanized small farms imply that larger farms use modern farm power, and hence tend to invest in tractors and combines, while small farms stay with traditional work animals. This is precisely what the model captures as shown in Tables 29, 30, 31, 33, and 34.

The intra-farm comparisons of working capital expenses per hectare predicted by the model (Tables 53 and 54) have a strong support from the sample data for 1965.[13] The consistency of mechanization by farm size between the model prediction and observed data infers that investment capital expenditures predicted by the model would be supported by observed data if available.

The labor employment predicted by farm size (Table 23) generally agrees with the sample data in 1965.[14] Small farm's family labor is

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[12]Rao (1970), p. 149. Some of Rao's findings are: (1) the use of credit is very limited in traditional farming and (2) all farms, except large mechanized farms, are facing credit rationing and this problem is more acute on smaller farms among other types.

[13]As an indication of this support, the sample data shows that mechanized large crop farms with adequate financing in 1965 have committed roughly $17.00 per hectare for specific crop inputs such as seed, fertilizer and insecticides whereas small crop farms have omitted only $5.00 per hectare (Rask (1969), p. 80).

[14]Rask (1969), pp. 65-66.

in surplus supply while larger farms employ wage labor. The sample data suggest that, as farm size increases, there is a substantial increase in the number of hectares per man equivalent, ranging from about one hectare of cultivated land per man equivalent on a small farm to over 42 hectares of cultivated land per man equivalent on the largest farms.

With regard to productivity of land by farm size, the model prediction for 1965 (Table 41) confirms in general the findings for the year 1965 by Rask. He reports that the evidence of diminishing average returns to the land resource are very evident as farm size increases. Farms with land equivalents from one to 3.9 have an average output per unit of total land operated which is four times that of the farms with 50 or more hectares.[15]

Although the net farm cash receipts per hectare decrease very rapidly as farm size increases, the sample data indicates that net farm income is positively correlated with farm size.[16] This agrees strongly with the net farm income distribution predicted by the model as shown in Tables 64 and 65. This condition together with the evidence on the labor employment per hectare over farm sizes supports the model results on the average gross and net returns to available family labor (Tables 66 and 67).

[15] *Ibid.*, p. 63.

[16] *Ibid.*, p. 47 (see the part of "All Farms" in the table).

Due to limited amounts of historical data the model evaluation is not as complete as one would like. However, at this point the model has captured fairly well and consistently the transition of agriculture in this region.

# CHAPTER VII

# CONCLUSION

The main objectives of this study were twofold: (1) to develop an operational model of regional agricultural development that incorporates the details of interdependence and decision making in a firm-household, of technology, of the policy environment and of farm size, and (2) to test the general hypothesis that given similar economic opportunities and faced with a similar policy environment, differences in farm size as reflected in differences in relative on-farm resource endowments, lead to dissimilar dynamic paths of development. To a large extent this study has succeeded in fulfilling both these objectives.

The first objective was fulfilled by utilizing a recursive programming methodology which incorporated the elements of decision-making, technology and policy choices and which through the use of the decomposition principle was extended to account for differences in farm size and resource endowments. The resulting model was able, with reasonable accuracy, to capture not only the aggregate path of regional development, but also the path for each farm size. The model enables one to trace the patterns of resource use, factor productivity, factor proportions and income distribution by farm size, thus unfolding the economic history of regional development through time.

In fulfillment of the second objective the model predicted in general the path of development which had been hypothesized for, not only do differences in resource endowments lead to different factor proportions and output mix, but they are crucial to the choice of technology. Thus given similar economic opportunities and faced with a similar policy environment, farmers make technological choices, within limits of their relative factor scarcities, leading to different rates of adoption and investment and different paths of development.

In view of the success of the model as an operational tool capable of simulating regional development in a dynamic framework, several conclusions can be drawn concerning (1) the process of agricultural development in the wheat region of Rio Grande do Sul, (2) the role policies may have played in directing (distorting) this process, and (3) some conjectures about the future of regional development. This chapter is concluded by suggesting policy applications as well as some theoretical and operational extensions of this study as an agenda for future research.

## VII.1) The Dynamics of Regional Transformation

The dynamics of regional development in the wheat region, predicted by the model for the decade of the sixties revolves around the continuing transformation from extensive range livestock production on natural pasture to intensive crop farming with wheat, soybeans, corn in a double cropping system along with intensive livestock production on improved pasture systems. This changing pattern of land, which accelerated substantially after 1963 when subsidized price and credit

policies came into affect, lends a strong validity to the major conclusions and implications that stem from this study. These can be summarized as follows:

1. The accelerated agricultural transformation has brought about a substantial growth in regional real output between 1960-70. The growth in real regional output, however, has been uneven with both total and net output growing fastest on large farms and slowest on small farms. Consequently, the share of large farms in both total and net regional output has increased at the expense of small farms over the decade.

2. The transformation from extensive livestock to intensive crop production has not meant a decline in beef production, since decline in production on natural pasture has been more than offset by production on improved pasture systems. Thus, although an increasing amount of land is being converted to the production of wheat and soybeans, the increased conversion to improved (cropped) pasture systems has meant a moderate increase in livestock production, especially after 1963-64.

3. This increased intensity of land use has entailed a substantial growth in on-farm regional employment. The growth in employment has been mainly on small farms where underemployment of family labor has been reduced from 74 to 34 percent over the decade. Only small increases in employment on medium and large farms was predicted. The growth in employment on medium and large farms however has been enough to provide full employment of family labor. Large farms provide the only demand for hired labor, a demand which has remained fairly constant, declining somewhat between 1960-67 and increasing slightly

between 1968-70. Not only aggregate employment, but labor use per hectare on medium and large farms, has increased only very slightly. A nearly threefold increase on small farms accounted for most of the regional change.

4. The regional transformation to intensive land use has been accompanied by a large but uneven growth in capital utilization and capital stock in the region. Increases in aggregate capital use and capital stock are positively related to farm size with large farms showing the greatest increase. The main items of capitalization have been investments in farm power--draft animal power on small farms and mechanical sources of power such as tractors and combines on medium and large farms--and expenditures on fertilizer nutrients. Although a large percentage of total outlays is accounted for by nutrients on small farms, the growth in nutrient use per hectare has been fairly even for all farms and is related not to increasing nutrient use per hectare for any given crop but to the steady increase in the crop to natural pasture ratio.

5. The main component of technological change has been the rapid adoption of mechanized power which occurred on medium and large farms. The choice of technology with regard to farm power depends upon relative costs, as well as relative factor endowments. Most tasks are cheaper to perform with labor intensive techniques provided family labor, which represented a fixed cost to the farms, is available. However, if labor has to be hired at the going wage rate, labor-saving technology becomes more efficient and mechanical farm power begins to displace labor. Thus small farms with an abundance of family labor

continue to expand production using labor-intensive technology while medium and large farms, after fully employing family labor, switch to labor-saving technology. Family labor on large farms is so relatively scarce that even the complementary demand for labor due to the adoption of labor-saving technology is not met so additional labor is hired. On medium farms however the rate of adoption of labor-saving technology is such that, after satisfying this complementary demand for labor, enough family labor is left to allow some use of the lower cost labor-intensive technology. Thus medium farms, using a mix of technologies continually show full employment of family labor, hiring no labor, and switching to labor-saving technology as far as the exogenous constraints on their adoption permit. These results are a simplification because a more detailed breakdown of seasonal labor use (say on a weekly basis) would likely show critical periods of shortage on medium farms when they would resort to hiring labor; but, they do emphasize the critical importance of relative factor proportions for technological choice. These proportions, in turn, depend not only upon relative factor costs but upon relative factor scarcities. As long as this transition is in process the investments in farm power will continue to increase and follow a similar pattern of technological change.

6. The changes in relative factor productivities reflect the changing relative factor scarcities and the rate of transition. Thus, land productivities are inversely related to farm size while labor productivities are directly related. Both land and labor productivities have grown on all farms except for labor productivity which has

declined slowly on small farms as the demand for labor has increased at a faster rate than output.

7. The trends in capital productivity predicted suggest that capital is relatively more productive (because it is relatively more scarce) resource on small farms than on medium and large farms. However, when one compares capital productivity with increases in capital and credit it is seen that medium and large farms not only have had greater access to credit but have continued to increase their dependence on external funding. This result suggests very strongly that there has been a misallocation of scarce capital resources in the region. Part of this misallocation is related to the greater rate of transition to crop farming evidenced on larger farms, where demand for credit increased substantially, but the major cause is to be found in a credit policy in which access to credit is related not to its productivity but to requirements. This is the outcome of a credit limit tied to the volume of gross sales rather than to effective rates of return to capital outlays.

8. The uneven rates of growth of output in the region have increased the problems of income inequalities with a continually widening gap between large farms and medium and small farms. This unevenness in intra-farm growth and incomes is all the more alarming if one considers the fact that the future adoption of biological technologies is likely to increase these disparities, given the growing evidence that the impact of the "green revolution package" (new seeds, fertilizers and water) tends to favor larger farms, vis-a-vis smaller farms.

## VII.2) Some Policy Considerations

### For the Wheat Region

Although further research is necessary to separate and establish the direct and indirect impact of major policies upon regional development during the period of the study, some tentative conclusions can be drawn.

1. The wheat price subsidy program coupled with the availability of liberal credit probably accelerated the rate of regional transition from extensive livestock to crop farming. Whereas the wheat subsidies provided the incentives for the transition, liberal credit provided the means for it.

2. The wheat support program although providing incentives to shift out of extensive livestock production also provided an incentive for improvement in livestock production; for the latter, using land intensively, continued to compete effectively. This also suggests that, were wheat subsidies to be reduced, the transition would be to intensive livestock production instead of the old range livestock systems. Furthermore, the increased capitalization on medium and large farms, especially in farm power, will allow this transition to occur relatively smoothly.

3. There is little doubt that the liberal credit at negative real rates of interest has enabled excessive capitalization, especially through increasing investments in farm machinery on medium and large farms. In addition an examination of the shadow prices of the working capital constraint over the period suggest that higher nominal

rates of interest (rates in the range of 35-40 percent to offset the impact of inflation and set the real opportunity cost of capital between 5-10 percent during the period) would have significantly reduced credit use, and hence the rate of capitalization on medium and large farms. Furthermore, even at these higher nominal rates small farms would have increased their capital use if their credit limits were raised and set free from criteria based on volume of gross sales.

For Regional Agricultural Development

In addition to these conclusions specific to the region of study some general implications about the methodology and development in a broader content are appropriate.

1. This research has shown the usefulness of this methodology in analyzing regional agricultural development where the outcome depends upon the ability of the model to incorporate dynamically and in detail such diverse criteria as on-farm resource endowments and decision rules, the regional physical, economic and policy environment and vast differences in intial conditions attributable to farm size. Only by accounting for the "complex interaction system" in an agricultural region, can its development be effectively understood and planned.

2. The differences and disparities in the process of development, even within a fairly homogeneous region suggest that development policy should be fully cognizant of them and take them into account. In this context the study is in conformity with the major findings of

the vast literature on regional and dualistic development that emphasizes disparities of growth.

3. The study has made one aware of the fact that development is a much broader concept than can be encompassed by one discipline--in this case, economics. The interplay of social, cultural and political forces with the economic forces is what finally determines the path of development. Thus one is not surprised if economic principles (even as broadly and comprehensively perceived as in this study) do not predict the path of wheat hectarage fully. The disagreement between historical and predicted series of regional wheat hectarages (Graph 44) could very well be due to the exclusion of such factors as neighborhood and information effects that are the subject matter of the theory of spatial and social distribution. One should be aware that the access of large farms to credit can also be explained by the interplay of power and economics. Therefore this is perceived as an incomplete but essential attempt to explain regional development. The conclusions are modified accordingly.

## VII.3) Further Research

Although the model captures in detail and with substantial accuracy the main features of transformation in the region, it can be improved and extended in several aspects. Even in its current stage it can be used for various analytic and policy applications. The most important model improvements and applications as an agenda for future research are briefly reviewed.

The model can be extended theoretically and improved operationally. Theoretically, the most useful extensions include:

1. a specification in the model structure of inter-farm activities and resource transfers, especially the renting and hiring of land and quasi-fixed (machine) capacities between farms of different size. There is some evidence that a rental market for farm equipment and machinery may be in the nascent stages of development in the region. The inclusion of such resource transfers between farms of different size will reduce the discontinuities and differences in the investments and factor proportions and introduce an additional motive for investment. Land rental transactions also have important implications for regional analysis; for by changing the operational size of holdings, they change the relative factor proportions found to be so crucial in the current study;

2. a more detailed treatment of adoption and adjustment behavior including alternative specifications for flexibility and adoption constraints to account for spatial and temporal diffusion and the importance of on- and off-farm wealth upon investment decisions;

3. a detailed treatment of stochastic elements in the model, especially yield and price expectations to more fully deal with risk and uncertainty;

4. the specification of demand equations for farm outputs, which jointly with the model estimates of supply could determine market clearing prices thus making output price expectations endogenous;

5. the extension of the model to include more than one region, using the decomposition framework to account for inter-regional competition, specialization and diversity;

6. the extension of the model to include rural processing and distributive industries to account more carefully for the nexus of rural linkages that focus on the farm sector;

7. the inclusion of a set of activities to account for investments in infrastructure by policy makers in the region.

Operationally, given adequate data the model can be easily extended to include:

1. a detailed breakdown of expected biochemical technologies through a specification of a set of intermediate fertilizing activities that could account for ranging levels of nutrient use for current as well as expected new varieties as done by Singh (1971) in his Punjab study;

2. a more detailed classification of seasonal labor use on a weekly basis and a clearer specification of regional labor supply at varying wage rates;

3. a specification of regional in- and out-migration of labor between the rural and urban sector and between different regions;

4. a detailed set of activities to take into account investment in land improvements, building and livestock inventories;

5. a more exact specification of the cash expenditures for non-farm durable and non-durable consumer goods using econometrically estimated expenditure functions;

6. a more detailed analysis of credit restrictions specifying the source, cost and limits of both formal and informal credit availability.

Although the operational model improvements listed above would go a long way in making the model a more effective analytic tool, even in its current state it can be used for policy analysis. Among the expected model applications the three most important are:

1. the projection of exogenous input and output prices and land and labor supplies to allow conditional forecasts of the model into the 1980's, thus providing a projection of the transformation underway into the future;

2. forward (future) and backward (past) simulations of the model to determine the specific past and expected impact of alternative policies in the long run and over time;

3. the use of the model, by means of price and resource parametrics, to trace in a comparative static framework the impact of changes in key policy variables in the short run for any given year or between two specified time periods, and in a comparative dynamic analysis for entire simulation periods.

It is contended that each of these applications can yield useful analytic insights helpful for the evaluation of alternative policies and programs. Research in this direction is already under way.

# APPENDIX A

## NAMES AND DEFINITIONS OF COLUMN AND ROW VARIABLES USED IN THE MODEL MATRIX

The purpose of Appendix A is to list variable names, computer codes, and their descriptions for both activities (columns) and constraints (rows) of the model sub-matrix for one farm size group.

## Activity List and Variable Names

| Column (Activity) Variable Name | Computer Code | Description of Activity |
|---|---|---|
| **Production Activities** | | |
| $X_1$ | W1 | : One hectare sown to wheat with traditional technology |
| $X_2$ | W2 | : One hectare sown to wheat with modern technology |
| $X_3$ | WS1 | : One hectare sown to soybeans following wheat with traditional technology |
| $X_4$ | WS2 | : One hectare sown to soybeans following wheat with modern technology |
| $X_5$ | WI1 | : One hectare sown to soybeans independent of wheat with traditional technology |
| $X_6$ | WI2 | : One hectare sown to soybeans independent of wheat with modern technology |
| $X_7$ | C1 | : One hectare sown to corn with traditional technology |
| $X_8$ | C2 | : One hectare sown to corn with modern technology |
| $X_9$ | NAP | : One hectare of range natural pasture land |
| $X_{10}$ | SPA1 | : One hectare sown to summer-improved pasture with traditional technology |

| Column (Activity) Variable Name | Computer Code | | Description of Activity |
|---|---|---|---|
| $X_{11}$ | SPA2 | : | One hectare sown to summer-improved pasture with modern technology |
| $X_{12}$ | WPA1 | : | One hectare sown to winter-improved pasture with traditional technology |
| $X_{13}$ | WPA2 | : | One hectare sown to winter-improved pasture with modern technology |
| $X_{14}$ | BNP | : | One cow unit of beef cattle (cow-calf fattening) using natural pasture |
| $X_{15}$ | BSP | : | One cow unit of beef cattle (cow-calf fattening) using summer-improved pasture |
| $X_{16}$ | BSWP | : | One cow unit of beef cattle (cow-calf fattening) |
| $X_{17}$ | BNWP | : | One cow unit of beef cattle (cow-calf fattening) using a combination 75% natural pasture and 25% winter-improved pasture |
| **Investment Activities** | | | |
| $X_{18}$ | IVTR | : | Investment in a 50 horse power tractor |
| $X_{19}$ | IVCO | : | Investment in a 50 horse power combine |
| $X_{20}$ | IVDA | : | Investment in a draft animal |
| **Purchasing Activities** | | | |
| $X_{21}$ | OCTR | : | Operation of 50 horse power tractor (hours) |
| $X_{22}$ | OCCO | : | Operation of 50 horse power combine (hours) |
| $X_{23}$ | OCDA | : | Operation of a draft animal (hours) |

| Column (Activity) Variable Name | Computer Code | Description of Activity |
|---|---|---|
| $X_{24}$ | HL1 | : Hiring wage labor during November (hours) |
| $X_{25}$ | HL2 | : Hiring wage labor during March-April (hours) |
| $X_{26}$ | HL3 | : Hiring of wage labor for the rest of the months (hours) |
| **Financial Activities** | | |
| $X_{27}$ | BORR | : Borrowing for short term (Cr$) |
| $X_{28}$ | SAV | : Saving Deposits (Cr$) |
| $X_{29}$ | TRCA | : Activity transferring cash for investment outlays (Cr$) |

Note:[1]

1. In order to reduce the number of columns, each crop production activity includes the purchase of seeds, fertilizer, and transportation; while beef cattle fattening activities include the purchase of bone meal, salt, medicine and vaccines, replacement of bulls and fencing.
2. Since both summer and winter improved pasture systems require land preparation, seeding, and fertilizing, they are regarded as cropping activities.
3. Natural pasturing activity involves only the maintenance and repairs of fences.
4. Three seasonal classifications for hiring wage labor are considered: Season 1 (November) is the peak load labor period during which wheat is harvested and land prepared for soybeans. Season 2 (March and April) is the harvesting season for corn and soybeans independent of wheat. Season 3 covers the rest of the year.

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[1]For a detailed discussion on cropping practices, beef cattle enterprises, and related farm budgets, see Engler (1971).

## Constraint List and Variable Names Used

| Row (Constraint) Variable Name | Computer Code | | Description of Constraint |
|---|---|---|---|
| **Land Constraints** | | | |
| $B_1$ | LA1 | : | Total hectares of land available during May to mid-November (in 1,000,000 ha.) |
| $B_2$ | LA2 | : | Total hectares of land available during mid-November to April (in 1,000,000 ha.) |
| $B_3$ | NP | : | Balance equation transferring total hectares of natural pasture into use |
| $B_4$ | SP | : | Balance equation transferring total hectares of summer improved pasture into use |
| $B_5$ | WP | : | Balance equation transferring winter improved pasture into use |
| $B_6$ | WL1 | : | Balance equation transferring total hectares of wheat adopting traditional technology into use to grow soybeans in crop rotation by the traditional technology |
| $B_7$ | WL2 | : | Balance equation transferring total hectares of wheat adopting modern technology into use to grow soybeans in crop rotation by the modern technology |
| **Labor Constraints** | | | |
| $B_8$ | FL1 | : | Family labor hours available during November (in 10,000,000 hours) |
| $B_9$ | FL2 | : | Family labor hours available during March-April (in 10,000,000 hours) |
| $B_{10}$ | FL3 | : | Family labor hours available for the rest of the months (in 10,000,000 hours) |

| Row (Constraint) Variable Name | Computer Code | | Description of Constraint |
|---|---|---|---|
| **Quasi-fixed Capacity Constraints** | | | |
| $B_{11}$ | TRO | : | Balance equation transferring tractor availability into use to account for operation cost |
| $B_{12}$ | CBO | : | Balance equation transferring combine availability into use to account for operation cost |
| $B_{13}$ | DANO | : | Balance equation transferring draft animal availability into use to account for operation cost |
| $B_{14}$ | TRH | : | Total tractor capacity hours available (in 1,000,000 hours) |
| $B_{15}$ | CBH | : | Total combine capacity hours available (in 100,000 hours) |
| $B_{16}$ | DANH | : | Total draft animal capacity hours available (in 10,000,000 hours) |
| **Financial Constraints** | | | |
| $B_{17}$ | WCA | : | Working cash availability at the beginning of the year (in 1,000,000 Cr$) |
| $B_{18}$ | ICA | : | Balance equation transferring cash into investments and outlays |
| **Behavioral Constraints** | | | |
| $B_{19}$ | WU | : | The upper bound on wheat hectarge |
| $B_{20}$ | WL | : | The lower bound on wheat hectarage |
| $B_{21}$ | SU | : | The upper bound on soybean hectarage following wheat |
| $B_{22}$ | SL | : | The lower bound on soybean hectarage following wheat |

| Row (Constraint) Variable Name | Computer Code | | Description of Constraint |
|---|---|---|---|
| $B_{23}$ | SIU | : | The upper bound on soybean hectarage independent of wheat |
| $B_{24}$ | SIL | : | The lower bound on soybean hectarage independent of wheat |
| $B_{25}$ | CU | : | The upper bound on corn hectarage |
| $B_{26}$ | CL | : | The lower bound on corn hectarage |
| $B_{27}$ | BNPU | : | The upper bound on natural pasture hectarage used for beef enterprise |
| $B_{28}$ | BNPL | : | The lower bound on natural pasture hectarage used for beef enterprise |
| $B_{29}$ | BIPU | : | The upper bound on improved pasture hectarage (summer and winter pastures) used for beef enterprise |

Since the other two farm size groups have the identical 29 elements in their RHC vectors, the regional coupling constraints start from 88th rows of the RHS vector and they are specified as follows:

| | | | |
|---|---|---|---|
| $B_{88}$ | MTRU | : | The upper limit on regional market supply of tractors |
| $B_{89}$ | CRED | : | The upper limit on regional credit supply |
| $B_{90}$ | HLA1 | : | The upper limit on regional wage labor availability (in 10,000,000 hours) during November |
| $B_{91}$ | HLA2 | : | The upper limit on regional wage labor availability (in 10,000,000 hours) during March-April |
| $B_{92}$ | HLA3 | : | The upper limit on regional wage labor availability (in 10,000,000 hours) for the rest of the months |

# APPENDIX B

a) INPUT-OUTPUT PRICES EXOGENOUS TO THE MODEL

b) ESTIMATED NUMBER OF FARMS

c) FLEXIBILITY AND ADOPTION CONSTRAINTS

TABLE 5: PRICE VECTORS OF OUTPUTS AND INPUTS IN THE WHEAT REGION OF SOUTHERN BRAZIL (1960-1970)

| Year | Wheat Cr$/kg | Soybean Cr$/kg | Corn Cr$/kg | Beef Cr$/kg | Labor Hiring Cr$/hr. | Tractor Cr$/unit (50 hp) | Combine Cr$/unit | Trans. cost Cr$/10 kg | Gas & Oil for Tractor Cr$/hr. | Gas & Oil for Combine Cr$/hr. | Fert. for wheat & soybns Cr$/kg | Fert. for Rice Cr$/kg | Bone Meal Cr$/kg | Salt Cr$/kg | Seed for Sum. Past. Cr$/kg (Pensacola Bahia) | Seed for Win. Oats (Vegetfass) Cr$/kg. | Seed for Wheat Cr$/kg | Seed for Soybn Cr$/kg | Seed for Corn Cr$/kg | Interest of Saving | Interest of Credit | Draft Animal Unit Cr$/unit | Wholesale Agri. Price Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1960 | .0164 | .011 | .0057* | 0.072 | .025 | 876* | 2220* | .0075 | .11* | .28* | .011* | .010* | .012* | .005* | .016* | .062 | .025 | .016 | .03 | .06 | .10 | 13.5 | 100.0 |
| 1961 | .0228 | .0131 | .0076* | 0.104 | .040 | 1135* | 2820* | .005* | .18* | .44* | .022* | .020* | .019* | .007* | .024* | .096 | .034 | .019 | .038 | .06 | .10 | 17.5 | 137.46 |
| 1962 | .0400 | .0165 | .015* | 0.173 | .056 | 1717* | 4320* | .007* | .23* | .58* | .039* | .035* | .031* | .011* | .039* | .154 | .060 | .025 | .075 | .06 | .10 | 26.4 | 214.11 |
| 1963 | .0687 | .0332 | .017* | 0.291 | .091 | 2907* | 7260* | .014* | .45*, | 1.11* | .068* | .062* | .069* | .026* | .087* | .348 | .097 | .049 | .085 | .06 | .10 | 44.7 | 332.33 |
| 1964 | .1446 | .0662 | .040* | 0.533 | .183 | 5053* | 12660* | .026* | .86* | 2.15* | .137* | .124* | .114* | .043* | .144* | .562 | .217 | .099 | .200 | .06 | .10 | 77.7 | 745.74 |
| 1965 | .2060 | .1069 | .0507 | 0.627* | .300 | 8416* | 21180* | .050* | 1.63* | 4.08* | .252* | .228* | .158* | .059* | .198* | ..790 | .309 | .160 | .250 | .06 | .10 | 129.5 | 992.7 |
| 1966 | .2540* | .1577 | .1085 | 0.721* | .382 | 10733* | 25560* | .060* | 1.96* | 4.87* | .252* | .228* | .220* | .082* | .276* | 1.102 | .381 | .236 | .542 | .06 | .10 | 157.0 | 1178.33 |
| 1967 | .3505 | .2214 | .1280 | 0.815* | .479 | 13054* | 32640* | .074* | 2.41* | 6.00* | .263* | .238* | .190* | .071* | .233* | .952 | .450 | .332 | .640 | .06 | .10 | 200.0 | 1472.0 |
| 1968 | .3635* | .2644* | .1353* | 0.849* | .583 | 16055* | 40140* | .091* | 2.96* | 7.36* | .346* | .313* | .213* | .081* | .267* | 1.066 | .545 | .396 | .676 | .06 | .10 | 247.0 | 1909.9 |
| 1969 | .4265 | .3077 | .1426* | 0.995* | .708 | 20143* | 50340* | .119* | 3.87* | 9.62* | .396* | .356* | .312* | .117* | .391* | 1.562 | .640 | .461 | .713 | .06 | .10 | 310.0 | 2506.08 |
| 1970 | .4900 | .350 | .150 | 1.10 | .852 | 24000 | 60000 | .14 | 4.55 | 11.32* | .420* | .380 | .40* | .150 | .50* | 2.0 | .735 | .525 | .750 | .06 | .10 | 366.0 | 3830.65 |

SOURCE: A) All Non-starred figures are from:**

(1) "Anuario Estatistico Do Brasil," 1960-1970.
(2) "Anuario Estatistico Do Trigo," 1965-1969.
(3) "Conjuntura Economica," 1962-1971.
(4) "Anuario Agro-Pecuario," 1960-1969.
(5) "Anuario Estatistico do Rio Grande do Sul," 1970.
(6) "Projections of Supply and Demand for Agricultural Products in Brazil through 1975."

** The items (1) through (5) are Brazilian statistical publications. The item (6) is published by the Economic Research Service, U.S.D.A. All the figures are nominal prices.

B) All starred figures are estimated based on the various price indices contained in "Desenvolvimento de Agricultura Paulista, 2 Vol.," Instituto do Economia Agricola, Sao Paulo, Brasil.

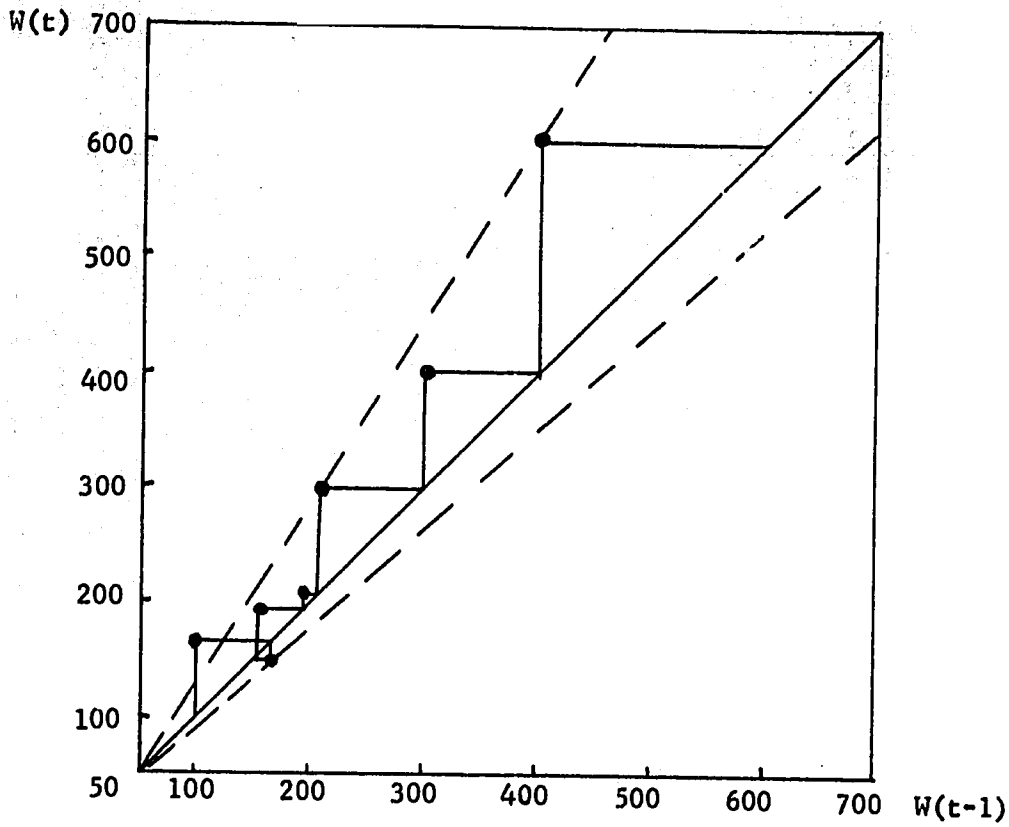
C) The Wholesale Agricultural Price Index in the Sao Paulo region is used. Source: Conjuctura Economica, Vol. 17, No. 9, 1970, p. 91.

TABLE 6: ESTIMATED NUMBER OF FARMS: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| Year | Small Farms | Medium Farms | Large Farms | Regional Farms |
|---|---|---|---|---|
| 1960 | 60121 | 8404 | 3304 | 71829 |
| 1961 | 62724 | 8768 | 3447 | 74939 |
| 1962 | 65440 | 9147 | 3597 | 78184 |
| 1963 | 68296 | 9544 | 3729 | 81569 |
| 1964 | 71230 | 9957 | 3914 | 85101 |
| 1965 | 74314 | 10388 | 4084 | 88786 |
| 1966 | 77531 | 10838 | 4261 | 92630 |
| 1967 | 80865 | 11264 | 4512 | 96641 |
| 1968 | 84391 | 11797 | 4638 | 100826 |
| 1969 | 88046 | 12308 | 4838 | 105192 |
| 1970 | 91858 | 12840 | 5049 | 109747 |

Source: The data for 1960 and 1967 are from (1) Brazil, IBGE - Servico Nacional de Recenseamento, Censo Agricola de 1960: Rio Grande do Sul, and (2) Estrutusa Fundiaria do Rio Grande do Sul (see Table 5). For the remaining years, an exponential growth rate in number of farms with fixed inter-farm ratios is assumed: From $71829\ (1+\rho)^7 = 96641$, $\hat{\rho} \cong 0.0433$.

Flexibility Constraints : Wheat




where W(t) : Wheat Hectarage in t. Source : Table 3.

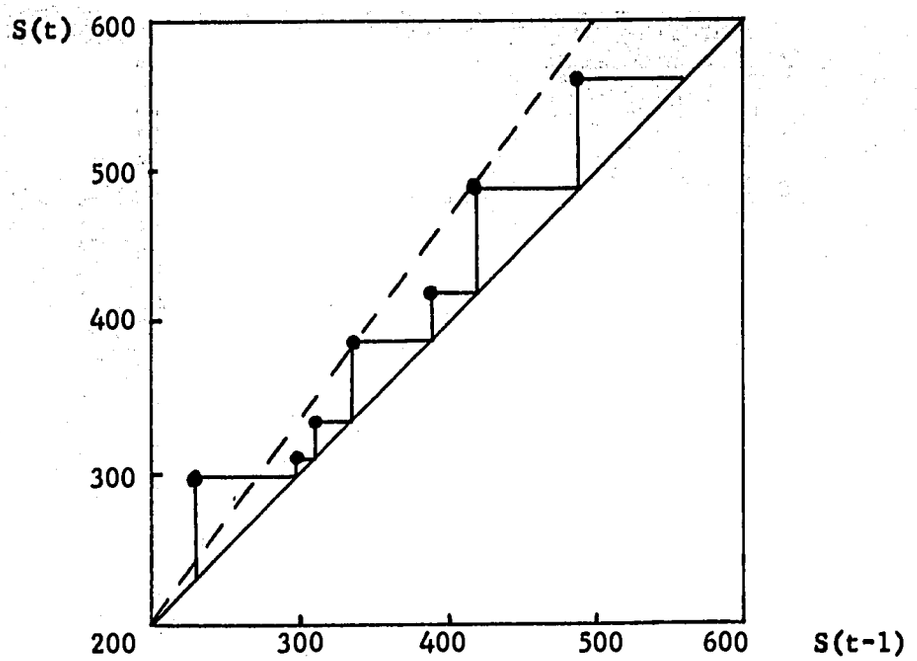
Figure 8 : Relationship of Wheat Hectarage in (t) and (t-1) in the Wheat Region of Rio Grande do Sul (t = 1963 to 1970, Unit = in 1000 Ha).

Both $\overline{\beta}$ and $\underline{\beta}$ for wheat are estimated by the method of select point , i.e., fitting a straight line on the point showing greater deviation from the previous year. Two points at t = 1966-1967, and 1968-1969, are selected to estimate $\overline{\beta}$ . One point at t = 1963-1964 is used to estimate $\underline{\beta}$ .

Results $\begin{cases} \text{Upper bound of } W(t),\ \overline{\beta} = 0.487 : W(t) \leq (1 + 0.487)\ W(t-1) \\ \text{Lower bound of } W(t),\ \underline{\beta} = 0.05 : -W(t) \leq -(1 - 0.05)\ W(t-1) \end{cases}$

Remarks : These estimates are used for medium farms. For large farms, the flexibility coefficients are greater by 5% than those on medium farms. But for small farms the coefficients are smaller by 5% than those on medium farms. This holds true for all other crops in order to take account for the risk aversion attitude on smaller farms.

Flexibility Constraints : Soybeans



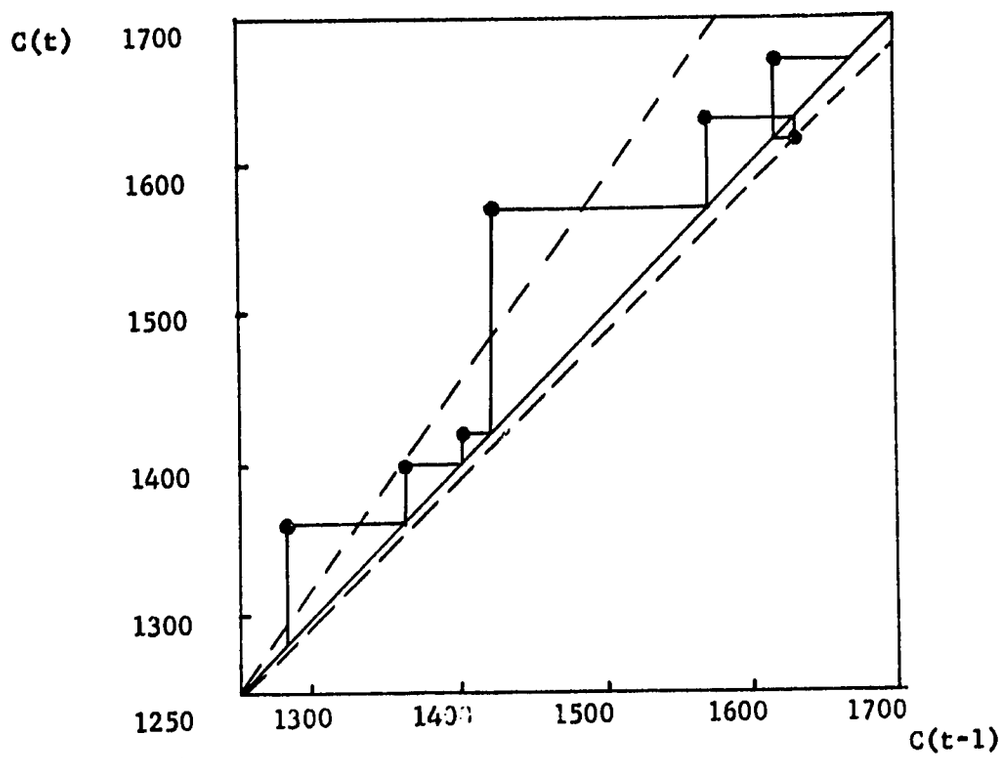

where S(t) = Soybean Hectarage in t. Source : Table 3.

Figure 9 : Relationship of Soybean Hectarage in (t) and (t-1) in Rio Grande do Sul (t = 1961 to 1968, Unit = in 1000 Ha).

The data for the soybean hectarage for the wheat region are not available. As a proxy, the statewise data are used. The $\beta$ for soybeans is estimated by the method of select point. Two points at t = 1964-65 and 1966-67 are selected to estimate $\overline{\beta}$. Although there is no point below the 45 degree line, $\underline{\beta}$ for soybeans is assumed to equal 0.05 of the lower bound of wheat as a "safety margin."

Results $\begin{cases} \text{Upper bound of } S(t),\ \overline{\beta} = 0.167 : S(t) \leq (1 + 0.167)\ S(t-1) \\ \text{Lower bound of } S(t),\ \underline{\beta} = 0.05 \ : -S(t) \leq -(1 - 0.05)\ S(t-1) \end{cases}$

**Flexibility Constraints : Corn**



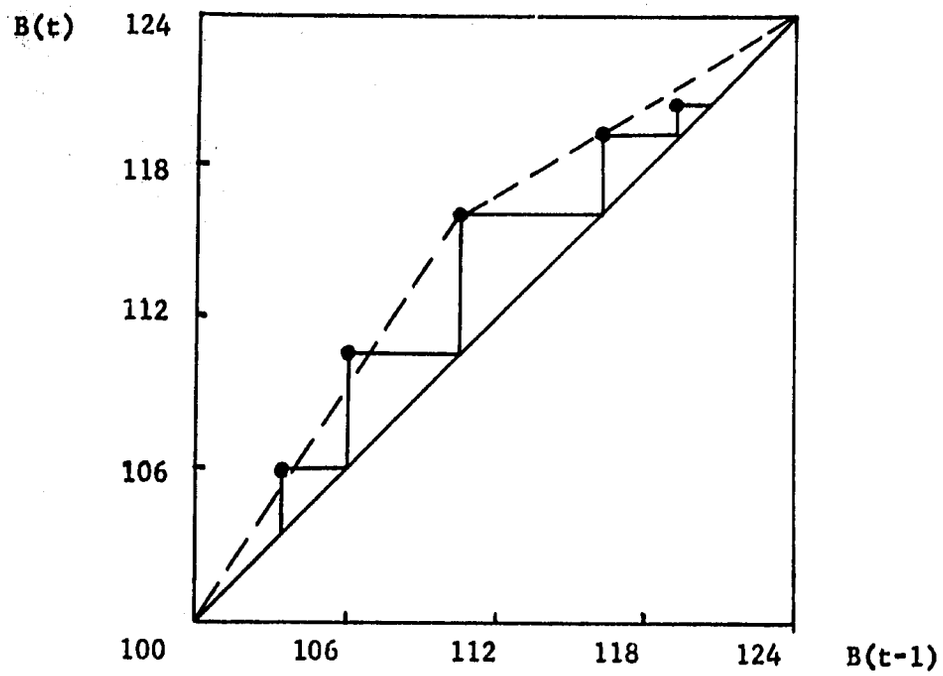

where C(t) = Corn Hectarage in t. Source : Table 3.

Figure 10 : Relationship of Corn Hectarage in (t) and (t-1) in Rio Grande do Sul (t = 1961 to 1968, Unit = in 1000 Ha).

The data for the corn hectarage for the wheat region are not available. As a proxy, the statewise data are used to estimate both $\overline{\beta}$ and $\underline{\beta}$ . One point at t = 1963-64 with origin is selected to estimate $\overline{\beta}$ . One point at t = 1966-67 is used to estimate $\underline{\beta}$ .

**Results** $\begin{cases} \text{Upper bound of } C(t),\ \overline{\beta} = 0.114 : C(t) \leq (1 + 0.114)\ C(t-1) \\ \text{Lower bound of } C(t),\ \underline{\beta} = 0.05 : -C(t) \leq -(1 - 0.05)\ C(t-1) \end{cases}$

Flexibility Constraint : Beef Production
Using Improved Pasture




where B(t) = Beef Production in year t. Source : Table 3.

Figure 11 : Relationship of Beef Production in (t) and (t-1) in Rio Grande do Sul (t = 1963 to 1968, Unit = in 100,000 Heads).

The data for the beef production for the wheat region are not available. The statewise data are used to estimate a proxy upper bound of beef production using improved pasture systems. Since the data also account for the beef production using natural pasture as well as improved pastures, it is impossible to estimate $\bar{\beta}$ for beef production using improved pasture with this data. However, considering the regional transition discussed in Chapter II, $\bar{\beta}$ for beef production utilizing improved pastures is substantially higher than the one obtainable from this data. Hence, $\bar{\beta}$ is guessed with other data to be 30% higher than the estimated value of $\bar{\beta}$ based on this data. Three points at t = 1963-64, 1965-66, and 1966-67 are used.

Result : Upper bound of B(t), $\beta = 0.12$ : $B(t) \leq (1 + 0.12)\ B(t-1)$

## Adoption Constraints on Tractor

The only data available on the numbers of tractors actually used is for Brazil as a whole. The number of tractors used in Brazil for the two years of 1950 and 1960 are 8,372 and 63,493 respectively.[1] Using this information a simple exponential function is used to derive a proxy adoption coefficient of tractors for the wheat region:

$$63{,}493 = (1 + \rho)^{10}\ 8.372$$

$$10 \log (1 + \rho) \cong \log 7.583$$

$$\hat{\rho} \cong 0.225$$

The covers the adoption phase.

The adjustment coefficient can be derived from the equation (7) which has already been discussed in section IV.2;

$$K_j(t) = \alpha(\overline{K}_j(t) - K_j(t-1)) + K_j(t-1)$$

The estimation of is not attempted because the wheat region as a whole is still far away from the long run desired capacity level, $\overline{K}_j(t)$. That is, range livestock farming still predominates in the region even in 1970.[2] Hence it is assumed that the adoption phase is still at lower level than the adjustment phase during 1960-1970. Therefore, following the equation (9), the adjustment constraint as specified in (9) becomes a redundant constraint.

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[1]See "Projections of Supply and Demand for Agricultural Products of Brazil through 1975," The Getulio Vargas Foundation, Brazil, 1968, p. 82.

[2]See Tables 3 and 4.

## APPENDIX C

a) MODEL MATRIX FOR THE INITIAL YEAR 1960

b) INPUT-OUTPUT COEFFICIENTS USED IN THE MODEL

c) INITIAL RESOURCE ENDOWMENTS IN THE RHS VECTOR OF THE MODEL

```
RECURSIVE-DECISION-SYSTEMS-PROCESSOR  FOR LINEAR DECISION-OPERATORS      **DATE : 23 FEB 7 TIME : 19:13:1500     PAGE   1

   DYNAMIC STORAGE ALLOCATION IS PROVIDED, BUT
   FOR THIS COLLECTION OF ELT-S
      MAXIMAL ROWS = 100
          COLUMNS = 120
          OBJ-FNS =   3
          RHSIDES =   4
          MEMORY  =   3
          LAG-VAR =  50
    PROGRAM USED SPECIFIC COMPILER AND COLLECTOR
    WHICH ARE NOT UWCC-SUPPORTED. SEE GERRIET P.MUELLER.


   MICRO COMMAND : START  EXECUTED, CPU-TIME DIFF.:     .033 : NEW MICRO : TITLE

    NEW TITLE *DYNAMIC DECOMPOSITION MODEL (S. BRAZIL 60-70)  CHGONG Y. AHN*

   MICRO COMMAND : TITLE  EXECUTED, CPU-TIME DIFF.:     .020 : NEW MICRO : LOAD

         INPUT.1
         ROW ID
                    DOBJ                 *SBIPU
                    *SLA1                *MLA1
                    *SLA2                *MLA2                    *MBIPU
                    *SNP                 *MNP                     *LLA1
                    *SSP                 *MSP                     *LLA2
                    *SWP                 *MWP                     *LNP
                    *SWL1                *MWL1                    *LSP
                    *SWL2                *MWL2                    *LWP
                    *SFL1                *MFL1                    *LWL1
                    *SFL2                *MFL2                    *LWL2
                    *SFL3                *MFL3                    *LFL1
                    OSTRO                OMTRO                    *LFL2
                    OSCBO                OMCBO                    *LFL3
                    OSDANO               OMDANO                   OLTRO
                    *SDANH               *MDANH                   OLCBO
                    *STRH                *MTRH                    OLDANO
                    *SCBH                *MCBH                    *LDANH
                    *SWCA                *MWCA                    *LTRH
                    *SICA                *MICA                    *LCBH
                    *SWU                 *MWU                     *LWCA
                    -SWL                 -MWL                     *LICA
                    *SSU                 *MSU                     *LWU
                    -SSL                 -MSL
                    *SSIU                *MSIU
                    -SSIL                -MSIL
                    *SCU                 *MCU
                    -SCL                 -MCL
                    *SBNPU               *MBNPU
                    -SBNPL               -MBNPL
```

-LWL
+LSU
-LSL
+LSIU
-LSIL
+LCU
-LCL
+LBNPU
-LBNPL
+LBIPU
+MTRU
+CRED
+HLA1
+HLA2
+HLA3

MATRIX

| | | | |
|---|---|---|---|
| SW1 | OBJ | - | 11.002 |
| SW1 | SLA1 | + | 1.0 |
| SW1 | SWL1 | - | 1.0 |
| SW1 | SFL1 | + | 11.84 |
| SW1 | SFL3 | + | 39.69 |
| SW1 | SDANO | + | 7.1 |
| SW1 | SWCA | + | 5.726 |
| SW1 | SWU | + | 1.0 |
| SW1 | SWL | + | 1.0 |
| SW2 | OBJ | - | 11.002 |
| SW2 | SLA1 | + | 1.0 |
| SW2 | SWL2 | - | 1.0 |
| SW2 | SFL1 | + | 0.315 |
| SW2 | SFL3 | + | 0.63 |
| SW2 | STRO | + | 7.35 |
| SW2 | SCBO | + | 10.5 |
| SW2 | SWCA | + | 5.726 |
| SW2 | SWU | + | 1.0 |
| SW2 | SWL | + | 1.0 |
| SWS1 | OBJ | - | 9.353 |
| SWS1 | SLA2 | + | 1.0 |
| SWS1 | SWL1 | + | 1.0 |
| SWS1 | SFL1 | + | 10.62 |
| SWS1 | SFL2 | + | 11.84 |
| SWS1 | SFL3 | + | 21.24 |
| SWS1 | SDANO | + | 5.9 |
| SWS1 | SWCA | + | 1.969 |
| SWS1 | SSU | + | 1.0 |
| SWS1 | SSL | + | 1.0 |
| SWS2 | OBJ | - | 9.353 |
| SWS2 | SLA2 | + | 1.0 |
| SWS2 | SWL2 | + | 1.0 |
| SWS2 | SFL1 | + | 1.157 |
| SWS2 | SFL2 | + | 0.315 |
| SWS2 | SFL3 | + | 0.315 |
| SWS2 | STRO | + | 4.725 |
| SWS2 | SCBO | + | 10.5 |
| SWS2 | SWCA | + | 1.969 |
| SWS2 | SSU | + | 1.0 |
| SWS2 | SSL | + | 1.0 |
| SIS1 | OBJ | - | 11.598 |
| SIS1 | SLA1 | + | 1.0 |
| SIS1 | SLA2 | + | 1.0 |
| SIS1 | SFL2 | + | 17.1 |
| SIS1 | SFL3 | + | 37.0 |
| SIS1 | SDANO | + | 7.6 |
| SIS1 | SWCA | + | 4.386 |
| SIS1 | SSIU | + | 1.0 |
| SIS1 | SSIL | + | 1.0 |
| SIS2 | OBJ | - | 11.598 |
| SIS2 | SLA1 | + | 1.0 |
| SIS2 | SLA2 | + | 1.0 |
| SIS2 | SFL2 | + | 0.319 |
| SIS2 | SFL3 | + | 0.682 |
| SIS2 | STRO | + | 7.35 |
| SIS2 | SCBO | + | 10.5 |
| SIS2 | SWCA | + | 4.386 |
| SIS2 | SSIU | + | 1.0 |
| SIS2 | SSIL | + | 1.0 |
| SC1 | OBJ | - | 4.116 |
| SC1 | SLA1 | + | 1.0 |
| SC1 | SLA2 | + | 1.0 |
| SC1 | SFL2 | + | 5.0 |
| SC1 | SFL3 | + | 46.2 |
| SC1 | SDANO | + | 7.1 |
| SC1 | SWCA | + | 3.408 |
| SC1 | SCU | + | 1.0 |
| SC1 | SCL | + | 1.0 |
| SC2 | OBJ | - | 4.116 |
| SC2 | SLA1 | + | 1.0 |
| SC2 | SLA2 | + | 1.0 |
| SC2 | SFL2 | + | 5.0 |
| SC2 | SFL3 | + | 0.945 |
| SC2 | STRO | + | 7.35 |
| SC2 | SWCA | + | 3.408 |
| SC2 | SCU | + | 1.0 |
| SC2 | SCL | + | 1.0 |
| SNPA | OBJ | + | 0.288 |
| SNPA | SLA1 | + | 1.0 |
| SNPA | SLA2 | + | 1.0 |
| SNPA | SNP | - | 1.0 |
| SNPA | SWCA | + | 0.288 |
| SSPA1 | OBJ | + | 1.894 |
| SSPA1 | SLA1 | + | 1.0 |
| SSPA1 | SLA2 | + | 1.0 |
| SSPA1 | SSP | - | 100.0 |
| SSPA1 | SFL3 | + | 39.7 |
| SSPA1 | SDANO | + | 4.74 |
| SSPA1 | SWCA | + | 1.894 |
| SSPA2 | OBJ | + | 1.894 |
| SSPA2 | SLA1 | + | 1.0 |
| SSPA2 | SLA2 | + | 1.0 |
| SSPA2 | SSP | - | 100.0 |
| SSPA2 | SFL3 | + | 0.735 |
| SSPA2 | STRO | + | 6.3 |
| SSPA2 | SWCA | + | 1.894 |
| SWPA1 | OBJ | + | 2.958 |
| SWPA1 | SLA1 | + | 1.0 |
| SWPA1 | SLA2 | + | 1.0 |
| SWPA1 | SWP | - | 100.0 |
| SWPA1 | SFL2 | + | 46.2 |
| SWPA1 | SDANO | + | 4.74 |
| SWPA1 | SWCA | + | 2.958 |
| SWPA2 | OBJ | + | 2.958 |
| SWPA2 | SLA1 | + | 1.0 |
| SWPA2 | SLA2 | + | 1.0 |
| SWPA2 | SWP | - | 100.0 |
| SWPA2 | SFL2 | + | 0.735 |
| SWPA2 | STRO | + | 6.3 |
| SWPA2 | SWCA | + | 2.958 |
| SBNP | OBJ | - | 8.1 |
| SBNP | SNP | + | 2.0 |
| SBNP | SFL1 | + | 0.09 |
| SBNP | SFL2 | + | 0.18 |
| SBNP | SFL3 | + | 0.73 |
| SBNP | SWCA | + | 0.936 |
| SBNP | SBNPU | + | 1.0 |
| SBNP | SBNPL | + | 1.0 |
| SBSP | OBJ | - | 12.791 |
| SBSP | SSP | + | 125.0 |
| SBSP | SFL1 | + | 0.1 |
| SBSP | SFL2 | + | 0.2 |
| SBSP | SFL3 | + | 0.8 |
| SBSP | SWCA | + | 0.936 |
| SBSP | SBIPU | + | 1.0 |
| SBSWP | OBJ | - | 17.736 |
| SBSWP | SSP | + | 67.5 |
| SBSWP | SWP | + | 22.5 |
| SBSWP | SFL1 | + | 0.1 |
| SBSWP | SFL2 | + | 0.2 |
| SBSWP | SFL3 | + | 0.8 |

| | | | |
|---|---|---|---|
| SBSWP | SWCA | + | 0.936 |
| SBSWP | SBIPU | + | 1.0 |
| SBNWP | OBJ | - | 14.276 |
| SBNWP | SNP | + | 1.25 |
| SBNWP | SWP | + | 42.0 |
| SBNWP | SFL1 | + | 0.09 |
| SBNWP | SFL2 | + | 0.18 |
| SBNWP | SFL3 | + | 0.73 |
| SBNWP | SWCA | + | 0.936 |
| SBNWP | SBIPU | + | 1.0 |
| SIVTR | OBJ | + | 0.876 |
| SIVTR | STRH | - | 20.0 |
| SIVTR | SICA | + | 8.76 |
| SIVTR | MTRU | + | 1.0 |
| SIVCO | OBJ | + | 2.22 |
| SIVCO | SCBH | - | 25.0 |
| SIVCO | SICA | + | 22.2 |
| SIVDA | OBJ | + | 2.7 |
| SIVDA | SNP | + | 2.5 |
| SIVDA | SDANH | - | 240.0 |
| SIVDA | SICA | + | 13.5 |
| SOCTR | OBJ | + | 0.11 |
| SOCTR | STRO | - | 1.0 |
| SOCTR | STRH | + | 1.0 |
| SOCTR | SWCA | + | 0.11 |
| SOCCO | OBJ | + | 0.28 |
| SOCCO | SCBO | - | 1.0 |
| SOCCO | SCBH | + | 1.0 |
| SOCCO | SWCA | + | 0.28 |
| SOCDA | SDANO | - | 1.0 |
| SOCDA | SDANH | + | 1.0 |
| SHL1 | OBJ | + | 0.25 |
| SHL1 | SFL1 | - | 1.0 |
| SHL1 | SWCA | + | 0.25 |
| SHL1 | HLA1 | + | 1.0 |
| SHL2 | OBJ | + | 0.25 |
| SHL2 | SFL2 | - | 1.0 |
| SHL2 | SWCA | + | 0.25 |
| SHL2 | HLA2 | + | 1.0 |
| SHL3 | OBJ | + | 0.25 |
| SHL3 | SFL3 | - | 1.0 |
| SHL3 | SWCA | + | 0.25 |
| SHL3 | HLA3 | + | 1.0 |
| SBORP | OBJ | + | 0.15 |
| SBORP | SWCA | - | 1.0 |
| SBORR | CRED | + | 1.0 |
| SSAV | OBJ | - | 0.06 |
| SSAV | SWCA | + | 1.0 |
| STRCA | SWCA | + | 1.0 |

| | | | |
|---|---|---|---|
| STRCA | SICA | - | 1.0 |
| MW1 | OBJ | - | 11.002 |
| MW1 | MLA1 | + | 1.0 |
| MW1 | MWL2 | - | 1.0 |
| MW1 | MFL1 | + | 11.84 |
| MW1 | MFL3 | + | 36.69 |
| MW1 | MDANO | + | 7.1 |
| MW1 | MWCA | + | 5.726 |
| MW1 | MWU | + | 1.0 |
| MW1 | MWL | + | 1.0 |
| MW2 | OBJ | - | 11.002 |
| MW2 | MLA1 | + | 1.0 |
| MW2 | MWL2 | - | 1.0 |
| MW2 | MFL1 | + | 0.3 |
| MW2 | MFL3 | + | 0.6 |
| MW2 | MTRO | + | 7.0 |
| MW2 | MCBO | + | 10.0 |
| MW2 | MWCA | + | 5.726 |
| MW2 | MWU | + | 1.0 |
| MW2 | MWL | + | 1.0 |
| MWS1 | OBJ | - | 9.353 |
| MWS1 | MLA2 | + | 1.0 |
| MWS1 | MWL1 | + | 1.0 |
| MWS1 | MFL1 | + | 10.62 |
| MWS1 | MFL2 | + | 11.84 |
| MWS1 | MFL3 | + | 21.24 |
| MWS1 | MDANO | + | 5.9 |
| MWS1 | MWCA | + | 1.969 |
| MWS1 | MSU | + | 1.0 |
| MWS1 | MSL | + | 1.0 |
| MWS2 | OBJ | - | 9.353 |
| MWS2 | MLA2 | + | 1.0 |
| MWS2 | MWL2 | + | 1.0 |
| MWS2 | MFL1 | + | 0.15 |
| MWS2 | MFL2 | + | 0.3 |
| MWS2 | MFL3 | + | 0.3 |
| MWS2 | MTRO | + | 4.5 |
| MWS2 | MCBO | + | 10.0 |
| MWS2 | MWCA | + | 1.969 |
| MWS2 | MSU | + | 1.0 |
| MWS2 | MSL | + | 1.0 |
| MIS1 | OBJ | - | 11.598 |
| MIS1 | MLA1 | + | 1.0 |
| MIS1 | MLA2 | + | 1.0 |
| MIS1 | MFL2 | + | 17.1 |
| MIS1 | MFL3 | + | 37.0 |
| MIS1 | MDANO | + | 7.6 |
| MIS1 | MWCA | + | 4.386 |
| MIS1 | MSIU | + | 1.0 |

| | | | |
|---|---|---|---|
| MIS1 | MSIL | + | 1.0 |
| MIS2 | OBJ | - | 11.598 |
| MIS2 | MLA1 | + | 1.0 |
| MIS2 | MLA2 | + | 1.0 |
| MIS2 | MFL2 | + | 0.3 |
| MIS2 | MFL3 | + | 0.65 |
| MIS2 | MTRO | + | 7.0 |
| MIS2 | MCBO | + | 10.0 |
| MIS2 | MWCA | + | 4.386 |
| MIS2 | MSIU | + | 1.0 |
| MIS2 | MSIL | + | 1.0 |
| MC1 | OBJ | - | 4.116 |
| MC1 | MLA1 | + | 1.0 |
| MC1 | MLA2 | + | 1.0 |
| MC1 | MFL2 | + | 5.0 |
| MC1 | MFL3 | + | 46.2 |
| MC1 | MDANO | + | 7.1 |
| MC1 | MWCA | + | 3.408 |
| MC1 | MCU | + | 1.0 |
| MC1 | MCL | + | 1.0 |
| MC2 | OBJ | - | 4.116 |
| MC2 | MLA1 | + | 1.0 |
| MC2 | MLA2 | + | 1.0 |
| MC2 | MFL2 | + | 5.0 |
| MC2 | MFL3 | + | 0.9 |
| MC2 | MTRO | + | 7.0 |
| MC2 | MWCA | + | 3.406 |
| MC2 | MCU | + | 1.0 |
| MC2 | MCL | + | 1.0 |
| MNPA | OBJ | + | 0.288 |
| MNPA | MLA1 | + | 1.0 |
| MNPA | MLA2 | + | 1.0 |
| MNPA | MNP | - | 1.0 |
| MNPA | MWCA | + | 0.288 |
| MSPA1 | OBJ | + | 1.894 |
| MSPA1 | MLA1 | + | 1.0 |
| MSPA1 | MLA2 | + | 1.0 |
| MSPA1 | MSP | - | 100.0 |
| MSPA1 | MFL3 | + | 39.7 |
| MSPA1 | MDANO | + | 4.74 |
| MSPA1 | MWCA | + | 1.894 |
| MSPA2 | OBJ | + | 1.894 |
| MSPA2 | MLA1 | + | 1.0 |
| MSPA2 | MLA2 | + | 1.0 |
| MSPA2 | MSP | - | 100.0 |
| MSPA2 | MFL3 | + | 0.7 |
| MSPA2 | MTRO | + | 6.0 |
| MSPA2 | MWCA | + | 1.894 |
| MWPA1 | OBJ | + | 2.958 |

| | | | |
|---|---|---|---|
| MWPA1 | MLA1 | + | 1.0 |
| MWPA1 | MLA2 | + | 1.0 |
| MWPA1 | MWP | - | 100.0 |
| MWPA1 | MFL2 | + | 46.2 |
| MWPA1 | MDANO | + | 4.74 |
| MWPA1 | MWCA | + | 2.958 |
| MWPA2 | OBJ | + | 2.958 |
| MWPA2 | MLA1 | + | 1.0 |
| MWPA2 | MLA2 | + | 1.0 |
| MWPA2 | MWP | - | 100.0 |
| MWPA2 | MFL2 | + | 0.7 |
| MWPA2 | MTRO | + | 0.6 |
| MWPA2 | MWCA | + | 2.958 |
| MBNP | OBJ | - | 8.1 |
| MBNP | MNP | + | 2.0 |
| MBNP | MFL1 | + | 0.09 |
| MBNP | MFL2 | + | 0.18 |
| MBNP | MFL3 | + | 0.73 |
| MBNP | MWCA | + | 0.936 |
| MBNP | MBNPU | + | 1.0 |
| MBNP | MBNPL | + | 1.0 |
| MBSP | OBJ | - | 12.791 |
| MBSP | MSP | + | 125.0 |
| MBSP | MFL1 | + | 0.1 |
| MBSP | MFL2 | + | 0.2 |
| MBSP | MFL3 | + | 0.8 |
| MBSP | MWCA | + | 0.936 |
| MBSP | MBIPU | + | 1.0 |
| MBSWP | OBJ | - | 17.736 |
| MBSWP | MSP | + | 67.5 |
| MBSWP | MWP | + | 22.5 |
| MBSWP | MFL1 | + | 0.1 |
| MBSWP | MFL2 | + | 0.2 |
| MBSWP | MFL3 | + | 0.8 |
| MBSWP | MWCA | + | 0.936 |
| MBSWP | MBIPU | + | 1.0 |
| MBNWP | OBJ | - | 14.276 |
| MBNWP | MNP | + | 1.25 |
| MBNWP | MWP | + | 42.0 |
| MBNWP | MFL1 | + | 0.09 |
| MBNWP | MFL2 | + | 0.18 |
| MBNWP | MFL3 | + | 0.73 |
| MBNWP | MWCA | + | 0.936 |
| MBNWP | MBIPU | + | 1.0 |
| MIVTR | OBJ | + | 0.876 |
| MIVTR | MTRH | - | 20.0 |
| MIVTR | MICA | + | 8.76 |
| MIVTR | MTRU | + | 1.0 |
| MIVCO | OBJ | + | 2.22 |

| | | | |
|---|---|---|---|
| MIVCO | MCBH | - | 25.0 |
| MIVCO | MICA | + | 22.2 |
| MIVDA | OBJ | + | 2.7 |
| MIVDA | MNP | + | 2.5 |
| MIVDA | MDANH | - | 240.0 |
| MIVDA | MICA | + | 13.5 |
| MOCTR | OBJ | + | 0.11 |
| MOCTR | MTRO | - | 1.0 |
| MOCTR | MTRH | + | 1.0 |
| MOCTR | MWCA | + | 0.11 |
| MOCCO | OBJ | + | 0.28 |
| MOCCO | MCBO | - | 1.0 |
| MOCCO | MCBH | + | 1.0 |
| MOCCO | MWCA | + | 0.28 |
| MOCDA | MDANO | - | 1.0 |
| MOCDA | MDANH | + | 1.0 |
| MHL1 | OBJ | + | 0.25 |
| MHL1 | MFL1 | - | 1.0 |
| MHL1 | MWCA | + | 0.25 |
| MHL1 | MLA1 | + | 1.0 |
| MHL2 | OBJ | + | 0.25 |
| MHL2 | MFL2 | - | 1.0 |
| MHL2 | MWCA | + | 0.25 |
| MHL2 | MLA2 | + | 1.0 |
| MHL3 | OBJ | + | 0.25 |
| MHL3 | MFL3 | - | 1.0 |
| MHL3 | MWCA | + | 0.25 |
| MHL3 | MLA3 | + | 1.0 |
| MBORR | OBJ | + | 0.15 |
| MBORR | MWCA | - | 1.0 |
| MBORR | CRED | + | 1.0 |
| MSAV | OBJ | - | 0.05 |
| MSAV | MWCA | + | 1.0 |
| MTRCA | MWCA | + | 1.0 |
| MTRCA | MICA | - | 1.0 |
| LW1 | OBJ | - | 11.002 |
| LW1 | LLA1 | + | 1.0 |
| LW1 | LWL1 | - | 1.0 |
| LW1 | LFL1 | + | 11.84 |
| LW1 | LFL2 | + | 39.69 |
| LW1 | LDANO | + | 7.1 |
| LW1 | LWCA | + | 5.726 |
| LW1 | LWU | + | 1.0 |
| LW1 | LWL | + | 1.0 |
| LW2 | OBJ | - | 11.002 |
| LW2 | LLA1 | + | 1.0 |
| LW2 | LWL2 | - | 1.0 |
| LW2 | LFL1 | + | 0.285 |
| LW2 | LFL3 | + | 0.57 |
| LW2 | LTRO | + | 6.65 |
| LW2 | LCBO | + | 9.5 |
| LW2 | LWCA | + | 5.726 |
| LW2 | LWU | + | 1.0 |
| LW2 | LWL | + | 1.0 |
| LWS1 | OBJ | - | 9.353 |
| LWS1 | LLA2 | + | 1.0 |
| LWS1 | LWL1 | + | 1.0 |
| LWS1 | LFL1 | + | 10.62 |
| LWS1 | LFL2 | + | 11.84 |
| LWS1 | LFL3 | + | 21.24 |
| LWS1 | LDANO | + | 5.9 |
| LWS1 | LWCA | + | 1.969 |
| LWS1 | LSU | + | 1.0 |
| LWS1 | LSL | + | 1.0 |
| LWS2 | OBJ | - | 9.353 |
| LWS2 | LLA2 | + | 1.0 |
| LWS2 | LWL2 | + | 1.0 |
| LWS2 | LFL1 | + | 0.143 |
| LWS2 | LFL2 | + | 0.285 |
| LWS2 | LFL3 | + | 0.285 |
| LWS2 | LTRO | + | 4.275 |
| LWS2 | LCBO | + | 9.5 |
| LWS2 | LWCA | + | 1.969 |
| LWS2 | LSU | + | 1.0 |
| LWS2 | LSL | + | 1.0 |
| LIS1 | OBJ | - | 11.598 |
| LIS1 | LLA1 | + | 1.0 |
| LIS1 | LLA2 | + | 1.0 |
| LIS1 | LFL2 | + | 17.1 |
| LIS1 | LFL3 | + | 37.0 |
| LIS1 | LDANO | + | 7.6 |
| LIS1 | LWCA | + | 4.386 |
| LIS1 | LSIU | + | 1.0 |
| LIS1 | LSIL | + | 1.0 |
| LIS2 | OBJ | - | 11.598 |
| LIS2 | LLA1 | + | 1.0 |
| LIS2 | LLA2 | + | 1.0 |
| LIS2 | LFL2 | + | 0.285 |
| LIS2 | LFL3 | + | 0.618 |
| LIS2 | LTRO | + | 6.65 |
| LIS2 | LCBO | + | 9.5 |
| LIS2 | LWCA | + | 4.386 |
| LIS2 | LSIU | + | 1.0 |
| LIS2 | LSIL | + | 1.0 |
| LC1 | OBJ | - | 4.115 |
| LC1 | LLA1 | + | 1.0 |
| LC1 | LLA2 | + | 1.0 |
| LC1 | LFL2 | + | 5.0 |
| LC1 | LFL3 | + | 46.2 |
| LC1 | LDANO | + | 7.1 |
| LC1 | LWCA | + | 3.408 |
| LC1 | LCU | + | 1.0 |
| LC1 | LCL | + | 1.0 |
| LC2 | OBJ | - | 4.116 |
| LC2 | LLA1 | + | 1.0 |
| LC2 | LLA2 | + | 1.0 |
| LC2 | LFL2 | + | 5.0 |
| LC2 | LFL3 | + | 0.855 |
| LC2 | LTRO | + | 6.65 |
| LC2 | LWCA | + | 3.408 |
| LC2 | LCU | + | 1.0 |
| LC2 | LCL | + | 1.0 |
| LNPA | OBJ | + | 0.288 |
| LNPA | LLA1 | + | 1.0 |
| LNPA | LLA2 | + | 1.0 |
| LNPA | LNP | - | 1.0 |
| LNPA | LWCA | + | 0.288 |
| LSPA1 | OBJ | + | 1.894 |
| LSPA1 | LLA1 | + | 1.0 |
| LSPA1 | LLA2 | + | 1.0 |
| LSPA1 | LSP | - | 100.0 |
| LSPA1 | LFL3 | + | 39.7 |
| LSPA1 | LDANO | + | 4.74 |
| LSPA1 | LWCA | + | 1.894 |
| LSPA2 | OBJ | + | 1.894 |
| LSPA2 | LLA1 | + | 1.0 |
| LSPA2 | LLA2 | + | 1.0 |
| LSPA2 | LSP | - | 100.0 |
| LSPA2 | LFL3 | + | 0.665 |
| LSPA2 | LTRO | + | 5.65 |
| LSPA2 | LWCA | + | 1.894 |
| LWPA1 | OBJ | + | 2.958 |
| LWPA1 | LLA1 | + | 1.0 |
| LWPA1 | LLA2 | + | 1.0 |
| LWPA1 | LWP | - | 100.0 |
| LWPA1 | LFL2 | + | 46.2 |
| LWPA1 | LDANO | + | 4.74 |
| LWPA1 | LWCA | + | 2.958 |
| LWPA2 | OBJ | + | 2.958 |
| LWPA2 | LLA1 | + | 1.0 |
| LWPA2 | LLA2 | + | 1.0 |
| LWPA2 | LWP | - | 100.0 |
| LWPA2 | LFL2 | + | 0.665 |
| LWPA2 | LTRO | + | 5.7 |
| LWPA2 | LWCA | + | 2.958 |
| LBNP | OBJ | - | 8.1 |
| LBNP | LNP | + | 2.2 |
| LBNP | LFL1 | + | 0.09 |
| LBNP | LFL2 | + | 0.18 |
| LBNP | LFL3 | + | 0.73 |
| LBNP | LWCA | + | 0.936 |
| LBNP | LBNPU | + | 1.0 |
| LBNP | LBNPL | + | 1.0 |
| LBSP | OBJ | - | 12.791 |
| LBSP | LSP | + | 125.0 |
| LBSP | LFL1 | + | 0.1 |
| LBSP | LFL2 | + | 0.2 |
| LBSP | LFL3 | + | 0.8 |
| LBSP | LWCA | + | 0.936 |
| LBSP | LBIPU | + | 1.0 |
| LBSWP | OBJ | - | 17.736 |
| LBSWP | LSP | + | 67.5 |
| LBSWP | LWP | + | 22.5 |
| LBSWP | LFL1 | + | 0.1 |
| LBSWP | LFL2 | + | 0.2 |
| LBSWP | LFL3 | + | 0.8 |
| LBSWP | LWCA | + | 0.936 |
| LBSWP | LBIPU | + | 1.0 |
| LBNWP | OBJ | - | 14.276 |
| LBNWP | LNP | + | 1.25 |
| LBNWP | LWP | + | 42.0 |
| LBNWP | LFL1 | + | 0.09 |
| LBNWP | LFL2 | + | 0.18 |
| LBNWP | LFL3 | + | 0.73 |
| LBNWP | LWCA | + | 0.936 |
| LBNWP | LBIPU | + | 1.0 |
| LIVTR | OBJ | + | 0.876 |
| LIVTR | LTRH | - | 20.0 |
| LIVTR | LICA | + | 8.76 |
| LIVTR | MTRU | + | 1.0 |
| LIVCO | OBJ | + | 2.22 |
| LIVCO | LCBH | - | 25.0 |
| LIVCO | LICA | + | 22.2 |
| LIVDA | OBJ | + | 2.7 |
| LIVDA | LNP | + | 2.5 |
| LIVDA | LDANH | - | 240.0 |
| LIVDA | LICA | + | 13.5 |
| LOCTR | OBJ | + | 0.11 |
| LOCTR | LTRO | - | 1.0 |
| LOCTR | LTRH | + | 1.0 |
| LOCTR | LWCA | + | 0.11 |
| LOCCO | OBJ | + | 0.28 |
| LOCCO | LCBO | - | 1.0 |
| LOCCO | LCBH | + | 1.0 |
| LOCCO | LWCA | + | 0.28 |
| LOCDA | LDANO | - | 1.0 |

| | | | |
|---|---|---|---|
| LOCDA | LDANH | + | 1.0 |
| LHL1 | OBJ | + | 0.25 |
| LHL1 | LFL1 | - | 1.0 |
| LHL1 | LWCA | + | 0.25 |
| LHL1 | HLA1 | + | 1.0 |
| LHL2 | OBJ | + | 0.25 |
| LHL2 | LFL2 | - | 1.0 |
| LHL2 | LWCA | + | 0.25 |
| LHL2 | HLA2 | + | 1.0 |
| LHL3 | OBJ | + | 0.25 |
| LHL3 | LFL3 | - | 1.0 |
| LHL3 | LWCA | + | 0.25 |
| LHL3 | HLA3 | + | 1.0 |
| LBCRR | OBJ | + | 0.15 |
| LBCRR | LWCA | - | 1.0 |
| LBCRR | CRED | + | 1.0 |
| LSAV | OBJ | - | 0.06 |
| LSAV | LWCA | + | 1.0 |
| LTRCA | LWCA | + | 1.0 |
| LTRCA | LICA | - | 1.0 |

FIRST 8

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| SLA1 | + | 1.049 | MTRH | + | 0.55 | LSIU | + | 0.015 | | |
| SLA2 | + | 1.049 | MCBH | + | 0.042 | LSIL | + | 0.01 | | |
| SNP | - | 0.036 | MWCA | + | 1.314 | LCU | + | 0.135 | | |
| SFL1 | + | 2.000 | MWU | + | 0.03 | LCL | + | 0.09 | | |
| SFL2 | + | 4.000 | MWL | + | 0.023 | LBNPU | + | 0.94 | | |
| SFL3 | + | 12.000 | MSU | + | 0.02 | LBNPL | + | 0.94 | | |
| SDANH | + | 0.550 | MSL | + | 0.016 | LBIPU | + | 0.033 | | |
| STRH | + | 0.128 | MSIU | + | 0.01 | MTRU | + | 0.025 | | |
| SCBH | + | 0.017 | MSIL | + | 0.007 | CRED | + | 9.0 | | |
| SWCA | + | 0.788 | MCU | + | 0.099 | HLA1 | + | 0.877 | | |
| SWU | + | 0.015 | MCL | + | 0.066 | HLA2 | + | 0.877 | | |
| SWL | + | 0.01 | MBNPU | + | 0.705 | HLA3 | + | 0.877 | | |
| SSU | + | 0.01 | MBNPL | + | 0.63 | | | | | |
| SSL | + | 0.007 | MBIPU | + | 0.023 | | | | | |
| SSIU | + | 0.005 | LLA1 | + | 1.95 | | | | | |
| SSIL | + | 0.003 | LLA2 | + | 1.95 | | | | | |
| SCU | + | 0.066 | LNP | - | 0.02 | | | | | |
| SCL | + | 0.044 | LFL1 | + | 0.075 | | | | | |
| SBNPU | + | 0.47 | LFL2 | + | 0.16 | | | | | |
| SBNPL | + | 0.42 | LFL3 | + | 0.569 | | | | | |
| SBIPU | + | 0.015 | LDANH | + | 0.116 | | | | | |
| HLA1 | + | 1.472 | LTRH | + | 0.85 | | | | | |
| HLA2 | + | 1.472 | LCBH | + | 0.110 | | | | | |
| HNP | - | 0.028 | LWCA | + | 1.879 | | | | | |
| HFL1 | + | 0.28 | LWU | + | 0.045 | | | | | |
| HFL2 | + | 0.55 | LWL | + | 0.035 | | | | | |
| HFL3 | + | 1.449 | LSU | + | 0.03 | | | | | |
| HDANH | + | 0.233 | LSL | + | 0.025 | | | | | |

INPUTS REQUIREMENTS FOR VARIOUS CROPPING ACTIVITIES IN WHEAT REGION, RIO GRANDE DO SUL, SOUTHERN BRAZIL

| | Seeds (kg) | Fertilizer (kg) | Insecticide (kg) | Soil Fumigant (Cr$) | Trans-portation (kg) | Land (ha) | Labor Use: Land Preparation (hour) | Labor Use: Harvesting (hour) | Cash: Modern Inputs (Cr$) | Cash: Operating Cost (Cr$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Wheat | 90 | 250 | 8.11 | 5.43 | 1360 | 1.0 (May.-Nov.15) | 6.0 (May-Jun.) | 3.0 (Nov.1-15) | 181.54 | 54.15 |
| Soyb-W | 70 | | 15.00 | | 1090 | 1.0 (Nov.15-Apr.) | 4.5 (Nov.15-Dec.) | 3.0 (Apr.) | 43.37 | 43.37 |
| Soyb-I | 70 | 200 | 15.00 | | 1710 | 1.0 (Sep.-Mar.) | 6.5 (Sep.-Oct.) | 3.0 (Mar.) | 137.50 | 61.33 |
| Corn | 12 | 200 | 10.00 | | 1532 | 1.0 (Sep.-Apr.) | 7.0 (Sep.-Oct.) | 5.0 (Mar.-Apr.) | 95.60 | 49.79 |
| Nat-Pas | | | | | | 1.0 | | | | 1.54 |
| Sum-Pas | 20 | 100 | | | 120 | 1.0 | 3.0 (Jul.-Aug.) | | 53.00 | 14.29 |
| Win-Pas | 20 | 100 | | | 120 | 1.0 | 6.0 | | 126.00 | 30.34 |

Note : Soyb-W = Soybeans following wheat
Soyb-I = Soybeans independent of wheat
Nat-Pas = Natural Pasture
Sum-Pas = Summer Pasture
Win-Pas = Winter Pasture

All the input values are in 1970 prices.

Source : Engler (1971)

INPUT REQUIREMENTS FOR BEEF PRODUCTION PER COW UNIT

| | Land (kg) | Labor (Hour) | Bone Meal (kg) | Salt (kg) | Medicine (Cr$) | Modern Inputs (Cr$) | Operating Cost (Cr$) |
|---|---|---|---|---|---|---|---|
| Beef (Nat-Pas) | 2.5 | 10 | 8.0 | 12.0 | 5.0 | 10.0 | 9.60 |
| Beef (Sum-Pas) | 1.25 | 11 | 8.0 | 12.0 | 6.0 | 11.0 | 9.6 |
| Beef (Win+Nat) | 1.07(Nat)<br>0.62(Win) | 12 | 14.0 | 10.0 | 6.0 | 13.10 | 9.6 |
| Beef (Sum+Win) | 0.71(Sum)<br>0.25(Win) | 12 | 14.0 | 10.0 | 6.0 | 13.10 | 9.6 |

Note: Beef (Nat-Pas) = Beef production using natural pasture
Beef (Sum-Pas) = Beef production using summer pasture
Beef (Win+Nat) = Beef production using both natural and winter pastures
Beef (Sum+Win) = Beef production using both summer and winter pastures

Nat = Natural Pasture
Sum = Summer Pasture
Win = Winter Pasture

Source: Engler (1971)

FARM POWER REQUIREMENTS FOR VARIOUS CROPPING ACTIVITIES PER HECTARE

| | Modern Farm Power | | Traditional Farm Power | |
|---|---|---|---|---|
| | Land Preparation (Tractor Hours) | Harvesting (Combine Hours) | Land Preparation (Draft Animal Hours) | Harvesting (Manual Labor Hours) |
| Wheat | 5.0 | 1.0 | 71.0 | 118.4 |
| Soybean-W | 3.5 | 1.0 | 59.0 | 82.8 |
| Soybean-I | 5.5 | 1.0 | 76.0 | 130.2 |
| Corn | 6.0 | | 84.0 | 50.0 |
| Summer-Pas | 5.0 | | 23.7 | |
| Winter-Pas | 5.0 | | 47.4 | |

Note: Soybean-W = Soybeans following wheat
Soybean-I = Soybeans independent of wheat
Summer-Pas = Summer pasturing activity
Winter-Pas = Winter pasturing activity
Economies of scale in machine operation is allowed on larger farms (see Chap. V). Mechanization has not been introduced for corn harvesting in the wheat region during 1960- 1970. (See Engler [1971])

Source: For modern farm power, see Engler (1971)
For traditional farm power, see Singh (1971a), p. 300
Also see Singh, et al. (1968). Singh derived draft animal hour requirements per acre. The per acre requirements are converted to per hectare.

TABLE 7 : INITIAL RESOURCE ENDOWMENTS (RIGHT HAND SIDE VALUES) BY FARM SIZE IN THE MODEL MATRIX

| Resources | Small Farms | Medium Farms | Large Farms |
|---|---|---|---|
| Land (in 1000,000 Ha) | 1.0490 | 1.4720 | 1.9500 |
| Monthly Family Labor (in 1000,000 Hrs.) | 2.8000 | 2.8000 | 0.7500 |
| Tractors (in 1000,000 Hrs.) | 0.1280 | 0.5500 | 0.8500 |
| Combines (in 1000,000 Hrs.) | 0.0017 | 0.0042 | 0.0110 |
| Draft Animal (in 1000,000 Hrs.) | 5.5000 | 2.3300 | 0.1160 |
| Working Cash (in 1000,000 Cr$) | 7.8800 | 13.1400 | 18.7900 |

Estimation Procedures:

1) Land ; the land by farm size is estimated from Table 4 after accounting for 20 percent of non-cultivable land from the total farm area. Table 4 provides the direct estimate for small farms but does not have data for 50-300 and 300+ ha. size groups. Using the sample farm record data on the number of farms and farm area, 65 % of the 50-1000 size group in Table 4 is estimated to belong to the 50-300 ha. size group (medium farms). This then gives an estimate for large farm size group.

2) Family labor ; for the data on family labor by farm size are estimated based on (a) the census 1960, Rio Grande do Sul, (b) number of farms (Table 6), and (c) the sample data description (Rask (1969), p.36). The servicable family hours are based on 8 hours per day and 25 days per month.

The census of the wheat region in 1960 is as follows:

| | | |
|---|---|---|
| total number of farms | : | 71,586 |
| total farm population | : | 244,839 |
| total farm family labor | : | 188,586 |
| total hired family labor | : | 30,338 |

3) Tractors ; the deviation of tractor capacity hours is based on an auxiliary information. It is reported that Southern Brazil had one tractor for every 58 farms, 4,180 hectares of total area, 469 hectares of crop land and 246 persons employed (see U.S.D.A. Projections of Supply and Demand for Agricultural Products in Brazil Through 1975. Center for Agricultural Studies, Brazilian Institute of Economics, July 1968, p.82). For simplicity, all the tractors are assumed to have 50 horse power capacity.

4) Combines ; since the model treats combine capacity hours as a scalar multiple of tractors, the initial capacity hours of combine by farm size is deduced from the initial tractor capacity hours. All the combines are assumed to have 65 horse power capacity.

5) Draft animals ; 1.2 pair of oxen per farm was suggested by Brazilian in estimating initial draft animal capacity hours. 1.2 pair of oxen per farm was suggested by Brazilian students.

6) Working cash ; the sample data description on cash flow by Rask (see Rask (1969), pp.42-48) and the index of average farm income (Conjuntura Economica 1962-1970) are used to estimate the initial working cash availability by farm size.

In addition to the items listed above, the sample farm record data and the census in 1960 are used to estimate regional wage labor and credit availability. The initial flexibility bounds of cropping activity are estimated from Table 3 and interfarm ratios of the farm size groups.

# APPENDIX D

a) SOME HISTORICAL DATA ON WHEAT PRODUCTION IN THE WHEAT REGION OF RIO GRANDE DO SUL, SOUTHERN BRAZIL

b) VARIOUS TABLES PERTAINING TO MODEL RESULTS

TABLE 8 : CROPPING HISTORY OF WHEAT IN THE WHEAT REGION, RIO GRANDE DO SUL AND BRAZIL (1962-1971): NUMBER OF FARMS, AREA, PRODUCTION, AND FERTILIZER USED

| Year | NUMBER OF FARMS | | | | | AREA | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wheat Region | | R. G. D. S. | | Brazil | Wheat Region | | | | R. G. D. S. | | | Brazil | |
| | Number (in 1000) | % of National | Number (in 1000) | % of National | Number (in 1000) | Hectares (in 1000) | % of Total LA* of wheat region | % of National wheat (ha.) | Ave. Size | Hectares (in 1000) | % of National | Ave. Size | Hectares (in 1000) | Ave. Size |
| 1962 | 5.5 | 28 | 29.5 | 80 | 36.9 | 94.4 | 1.71 | 32 | 19.22 | 226.6 | 88 | 7.67 | 258.2 | 7.0 |
| 1963 | 4.0 | 32 | 12.1 | 77 | 15.8 | 161.9 | 2.93 | 58 | 39.05 | 278.9 | 92 | 22.98 | 302.1 | 19.10 |
| 1954 | 5.3 | 26 | 17.4 | 79 | 22.0 | 155.4 | 2.82 | 57 | 28.4 | 271.9 | 91 | 15.62 | 300.5 | 13.62 |
| 1965 | 7.4 | 31 | 23.5 | 84 | 27.9 | 188.9 | 3.42 | 58 | 24.8 | 325.4 | 92 | 13.84 | 354.7 | 12.70 |
| 1966 | 7.8 | 29 | 26.9 | 81 | 33.6 | 199.6 | 3.61 | 58 | 24.9 | 343.5 | 89 | 12.77 | 384.9 | 11.46 |
| 1967 | 11.0 | 35 | 31.9 | 74 | 43.1 | 292.9 | 5.31 | 60 | 27.6 | 487.7 | 87 | 15.29 | 562.0 | 13.05 |
| 1968 | 15.0 | 33 | 45.5 | 68 | 67.4 | 399.2 | 7.23 | 59 | 27.1 | 689.1 | 82 | 15.14 | 845.7 | 12.54 |
| 1969 | 21.7 | 34 | 65.8 | 70 | 93.7 | 602.2 | 10.91 | 60 | 28.7 | 1044.7 | 80 | 15.88 | 1299.5 | 13.81 |
| 1970** | N.A. | N.A. | 80.0 | 70 | 115.0 | N.A. | N.A. | N.A. | N.A. | 1500.0 | 81 | 16.0 | 1810.0 | 13.95 |
| 1971** | N.A. | N.A. | 100.0 | 70 | 143.0 | N.A. | N.A. | N.A. | N.A. | 1800.0 | 82 | 18.0 | 2210.0 | 15.65 |

* LA = Land Area  ** Data for 1970 and 1971 are estimated by the Brazilian statistics agency referred to below.

SOURCE: Anuario Estatistico do Trigo - SAFRA 69/70, CCLEF - Ministerio da Agricultura
Estado do Rio Grande do Sul

Note: N.A. = Not Available

TABLE 8 : CROPPING HISTORY OF WHEAT IN THE WHEAT REGION, RIO GRANDE DO SUL AND BRAZIL (1962-1971): NUMBER OF FARMS, AREA, PRODUCTION, AND FERTILIZER USE (cont.)

| Year | PRODUCTION | | | | | | | | FERTILIZER USED | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wheat Region | | | R. G. D. S. | | | Brazil | | Wheat Region | | | R. G. D. S. | | | Brazil | |
| | Tons (in 1000) | % of National | Yield Kg/Ha | Tons (in 1000) | % of National | Yield Kg/Ha | Tons (in 1000) | Yield Kg/Ha | Tons (in 1000) | % of National | Per Ha use Kg/Ha | Tons (in 1000) | % of National | Per Ha use Kg/Ha | Tons (in 1000) | Per Ha use Kg/Ha |
| 1962 | 129.0 | 47 | 1.27 | 274.2 | 91 | 1.21 | 303.4 | 1.17 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |
| 1963 | 63.9 | 62 | 0.40 | 103.6 | 89 | 0.37 | 115.7 | 0.38 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |
| 1964 | 128.8 | 57 | 0.85 | 225.7 | 90 | 0.83 | 250.5 | 0.83 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |
| 1965 | 136.8 | 58 | 0.73 | 236.9 | 92 | 0.73 | 256.7 | 0.72 | 38.6 | 70 | 192 | 55.1 | 95 | 169 | 58.3 | 164 |
| 1966 | 178.8 | 59 | 0.91 | 296.0 | 89 | 0.86 | 333.5 | 0.87 | 42.9 | 68 | 207 | 62.6 | 94 | 182 | 66.5 | 173 |
| 1967 | 195.8 | 58 | 0.68 | 339.6 | 84 | 0.69 | 405.7 | 0.72 | 60.5 | 68 | 195 | 89.5 | 93 | 183 | 95.9 | 170 |
| 1968 | 363.9 | 59 | 0.94 | 618.7 | 81 | 0.89 | 765.1 | 0.90 | 82.5 | 66 | 197 | 125.8 | 90 | 182 | 139.7 | 165 |
| 1969 | 664.1 | 64 | 1.06 | 1090.1 | 83 | 1.043 | 1303.4 | 1.00 | 12.95 | 68 | 202 | 192.8 | 87 | 184 | 221.4 | 170 |
| 1970** | N.A. | N.A. | N.A. | 1500.0 | 82 | 1.0 | 1784.0 | 0.98 | N.A. | N.A. | N.A. | 236.8 | 87 | 185 | 272.2 | 171 |
| 1971** | N.A. | N.A. | N.A. | 1800.0 | 82 | 1.0 | 2198.8 | 0.99 | N.A. | N.A. | N.A. | 333.0 | 87 | 185 | 383.8 | 173 |

** Data for years 1970 and 1971 are estimated by the Brazilian statistics agency referred to below.

SOURCE: Anuario Estatistico do Trigo - SAFRA 69/70, CCLEF - Ministerio da Agricultura
Estado do Rio Grande do Sul

Note: N.A. - Not Available

TABLE 9 : CROPPING HISTORY OF WHEAT IN RIO GRANDE DO SUL BY MECHANIZATION (1962-1971)

| Year | NUMBER OF FARMS | | | | AREA | | | | | | PRODUCTION | | | | | | FERTILIZER USE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mechanized | | Non-Mechan. | | Mechanized | | | Non-Mechanized | | | Mechanized | | | Non-Mechanized | | | Mechanized | | | Non-Mechanized | | |
| | Number (in 1000) | % of Total | Number (in 1000) | % of Total | Ha. (in 1000) | % of Total | Ave. Size | Ha. (in 1000) | % of Total | Ave. Size | Tons (in 1000) | % of Total | Yield Kg/Ha | Tons (in 1000) | % of Total | Yield Kg/Ha | Tons (in 1000) | % of Total | Per Ha use Kg/Ha | Tons (in 1000) | % of Total | Per Ha use Kg/Ha |
| 1962 | 2.47 | 8 | 27.05 | 92 | 125.4 | 55 | 50.7 | 101.2 | 45 | 3.7 | 166.8 | 61 | 1.33 | 107.4 | 39 | 1.21 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |
| 1963 | 3.13 | 26 | 9.01 | 74 | 218.2 | 78 | 69.8 | 60.6 | 22 | 6.7 | 79.5 | 78 | 0.36 | 22.9 | 22 | 0.37 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |
| 1964 | 3.33 | 19 | 14.08 | 81 | 206.4 | 76 | 62.1 | 65.5 | 24 | 4.6 | 173.2 | 77 | 0.84 | 52.5 | 23 | 0.83 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |
| 1965 | 3.96 | 17 | 19.56 | 83 | 229.8 | 71 | 58.0 | 95.6 | 29 | 4.9 | 167.7 | 71 | 0.73 | 69.3 | 29 | 0.73 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |
| 1966 | 5.64 | 21 | 21.26 | 79 | 264.2 | 77 | 46.8 | 79.2 | 23 | 3.8 | 233.9 | 79 | 0.79 | 62.1 | 21 | 0.78 | 60.2 | 96 | 228 | 2.4 | 4 | 30 |
| 1967 | 6.77 | 21 | 25.13 | 79 | 381.0 | 78 | 56.3 | 106.7 | 22 | 4.2 | 263.2 | 77 | 0.79 | 76.5 | 23 | 0.73 | 84.7 | 94 | 222 | 4.9 | 6 | 45 |
| 1968 | 9.21 | 20 | 36.27 | 80 | 531.3 | 77 | 57.7 | 157.8 | 23 | 4.2 | 484.4 | 78 | 0.84 | 34.3 | 22 | 0.85 | 117.5 | 93 | 221 | 8.3 | 7 | 53 |
| 1969 | 14.83 | 22 | 50.92 | 78 | 813.3 | 79 | 54.8 | 231.44 | 21 | 4.4 | 881.8 | 82 | 0.91 | 208.3 | 18 | 0.90 | 176.1 | 92 | 216 | 16.7 | 8 | 75 |
| 1970 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |

SOURCE: Anuario Estatistico do Trigo - SAFRA 69/70, CCLEP - Ministerio da Agricultura
Estado do Rio Grande do Sul

NOTE: N.A. - Not Available.

TABLE 10 : CROPPING HISTORY OF WHEAT IN RIO GRANDE DO SUL BY CREDIT USE (1962 - 1969)

| | NUMBER OF FARMS | | | | AREA | | | | | | PRODUCTION | | | | | | FERTILIZER USE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Credit Used | | Credit Non-used | | Credit Used | | | Credit Non-Used | | | Credit Used | | | Credit Non-Used | | | Credit Used | | | Credit Non-Used | | |
| Year | Number (in 1000) | % of Total | Number (in 1000) | % of Total | Ha. (in 1000) | % of Total | Ave. Size | Ha. (in 1000) | % of Total | Ave. Size | Tons (in 1000) | % of Total | Yield Kg/Ha | Tons (in 1000) | % of Total | Yield Kg/Ha | Tons (in 1000) | % of Total | Per Ha use Kg/Ha | Tons (in 1000) | % of Total | Per Ha use Kg/Ha |
| 1962 | 2.21 | 7 | 27.31 | 93 | 106.5 | 47 | 48.1 | 120.1 | 53 | 4.4 | 140.3 | 51 | 1.32 | 133.9 | 49 | 1.317 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |
| 1963 | 3.54 | 29 | 8.59 | 71 | 191.7 | 69 | 54.1 | 87.1 | 31 | 10.1 | 68.4 | 67 | 0.36 | 33.9 | 33 | 0.357 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |
| 1964 | 5.10 | 29 | 12.30 | 71 | 202.4 | 74 | 39.6 | 69.5 | 26 | 5.7 | 166.6 | 74 | 0.82 | 59.1 | 26 | 0.823 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |
| 1965 | 5.25 | 22 | 18.27 | 78 | 213.4 | 66 | 40.6 | 111.9 | 34 | 6.1 | 152.7 | 64 | 0.72 | 84.2 | 36 | 0.716 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |
| 1966 | 4.91 | 18 | 21.99 | 82 | 213.7 | 62 | 43.5 | 129.8 | 38 | 5.9 | 189.5 | 64 | 0.89 | 106.5 | 36 | 0.887 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |
| 1967 | 7.19 | 23 | 24.70 | 77 | 321.9 | 66 | 44.8 | 165.8 | 34 | 6.7 | 223.1 | 66 | 0.69 | 116.6 | 34 | 0.692 | 69.7 | 78 | 216 | 19.8 | 22 | 119 |
| 1968 | 9.84 | 22 | 35.65 | 78 | 454.2 | 66 | 46.2 | 234.9 | 34 | 6.6 | 410.0 | 66 | 0.90 | 208.7 | 34 | 0.902 | 99.2 | 79 | 218 | 26.7 | 21 | 113 |
| 1969 | 16.82 | 25 | 48.94 | 75 | 710.4 | 69 | 42.2 | 334.3 | 31 | 6.8 | 762.7 | 70 | 1.07 | 327.5 | 30 | 1.073 | 150.5 | 79 | 211 | 42.3 | 21 | 126 |
| 1970 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |

SOURCE: Anuario Estatistico do Trigo -SAFRA 69/70, CCLRF - Ministerio da Agricultura
Estado do Rio Grande do Sul

NOTE: N.A. - Not Available.

## Various Tables Pertaining to Model Results

Symbols and Definitions Used in Tables 11-69:

WHEAT1: Hectarage sown to wheat adopting draft animal technology

WHEAT2: Hectarage sown to wheat adopting tractor technology

SOYBW1: Hectarage sown to soybean following wheat adopting draft animal technology

SOYBW2: Hectarage sown to soybean following wheat adopting tractor technology

SOYBI1: Hectarage sown to soybean independent of wheat adopting draft animal technology

SOYBI2: Hectarage sown to soybean independent of wheat adopting tractor technology

CORN1: Hectarage sown to corn adopting draft animal technology

CORN2: Hectarage sown to corn adopting tractor technology

NATPAS: Hectarage used for natural pasture

SUPAS1: Hectarage sown to summer-improved pasture adopting draft animal technology

SUPAS2: Hectarage sown to summer-improved pasture adopting tractor technology

WIPAS1: Hectarage sown to winter-improved pasture adopting draft animal technology

WIPAS2: Hectarage sown to winter-improved pasture adopting tractor technology

WHEAT = WHEAT1 + WHEAT2
SOYBN = SOYBN1 + WOYBN2 + SOYBI1 + SOYBI2
CORN = CORN1 + CORN2
NAPAS = NATPAS
SUPAS = SUPAS1 + SUPAS2
WIPAS = WIPAS1 + WIPAS2

Remarks: a) Both summer pasture and winter pasture are improved pasture systems which require the tasks of land preparation, seeding, and fertilizing.

b) In Table 20, the hectarages for double cropping activities, i.e. wheat and soybeans following wheat are explicitly accounted for in computing total land use.

Average Net Land Productivity per Hectare (t) = {Gross Revenue (t)-Total Cost (t)}/Total Labor in Use (t) : (Table 41)

Average Net Labor Productivity per Hour (t) = {Gross Revenue (t)-Total Cost (t)}/Total Labor Hours Employed (t) : (Table 42)

Average Net Productivity of Annual Cash Outlays (t) = {Gross Revenue (t)-Total Cost (t)}/Total Cost (t) : (Table 43)

Average Net Productivity of Total Capital Stock (t) = {Gross Revenue (t)-Total Cost (t)}/Estimated Value of Total Capital Stock (t), where Total Capital Stock includes quasi-fixed capital plus value of land in use as defined in Tables 25 and 26. : (Table 44)

Average Net Productivity of Working Capital (t) = {Gross Revenue (t)-Total Cost (t)}/Total Working Capital (t), where total cost consists of working capital plus investment capital. : (Table 47)

Total Capital Expenditures in Table 51 includes both investment capital and working capital. The investment capital in Table 52 covers the purchase outlays on farm power sources such as draft animals, tractors and combines. The working capital in Table 53 refers to cash outlays on machine operations, labor hiring, nutrients use (see Table 54), seeds used in cropping activities, transportation, and bone meal and salts for beef enterprises.

Total cash outlays in Table 61 includes both investment capital and working capital as defined in Table 51. Credit use refers to short term borrowings (one crop year) at a nominal rate of 15 percent per annum.

Average Gross Farm Income (t) =
Gross Revenue (t) / Number of Farms (t) : (Table 64)

Average Net Farm Income (t) =
{Gross Revenue (t)-Total Cost (t)}/Number of Farms (t) : (Table 65)

SMALL FARM = Small farms with 0- 50 hectares
MEDIUM FARM = Medium farms with 51-300 hectares
LARGE FARM = Large farms with above 300 hectares

Classification of Tables

1. Regional Resource Use . . . . . Tables 11-39
2. Factor Productivities . . . . . Tables 40-47
3. Factor Proportions . . . . . Tables 48-59
4. Credit Use . . . . . Tables 60-63
5. Income Distribution . . . . . Tables 64-69

TABLE 11: REGIONAL LAND USE BY FARM SIZE AND TECHNOLOGY: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | WHEAT1 | WHEAT2 | SOYBW1 | SOYBW2 | SOYBI1 | SOYBI2 | CORN1 | CORN2 | NATPAS | SUPAS1 | SUPAS2 | WIPAS1 | WIPAS2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LAND USE ON SMALL FARMS (IN 1000 HA) | | | | | | | | | | | | | |
| 1960 | 15.0 | 0.0 | 10.0 | 0.0 | 5.0 | 0.0 | 44.0 | 0.0 | 971.5 | 10.1 | 0.0 | 3.4 | 0.0 |
| 1961 | 18.0 | 0.0 | 11.7 | 0.0 | 5.7 | 0.0 | 47.5 | 0.0 | 952.2 | 11.6 | 0.0 | 3.8 | 0.0 |
| 1962 | 21.0 | 0.0 | 13.7 | 0.0 | 6.6 | 0.0 | 51.3 | 0.0 | 934.3 | 13.4 | 0.0 | 4.5 | 0.0 |
| 1963 | 25.9 | 0.0 | 16.0 | 0.0 | 7.6 | 0.0 | 55.4 | 0.0 | 917.7 | 15.4 | 0.0 | 5.1 | 0.0 |
| 1964 | 31.1 | 0.0 | 18.7 | 0.0 | 8.7 | 0.0 | 59.9 | 0.0 | 902.3 | 17.7 | 0.0 | 5.9 | 0.0 |
| 1965 | 37.3 | 0.0 | 21.9 | 0.0 | 10.1 | 0.0 | 58.1 | 0.0 | 887.3 | 20.4 | 0.0 | 6.8 | 0.0 |
| 1966 | 44.8 | 0.0 | 25.7 | 0.0 | 11.6 | 0.0 | 62.7 | 0.0 | 873.8 | 23.4 | 0.0 | 7.8 | 0.0 |
| 1967 | 53.7 | 0.0 | 30.0 | 0.0 | 13.3 | 0.0 | 67.7 | 0.0 | 861.0 | 26.9 | 0.0 | 9.0 | 0.0 |
| 1968 | 64.5 | 0.0 | 35.1 | 0.0 | 15.3 | 0.0 | 73.1 | 0.0 | 849.0 | 31.0 | 0.0 | 10.3 | 0.0 |
| 1969 | 77.4 | 0.0 | 41.1 | 0.0 | 17.6 | 0.0 | 79.0 | 0.0 | 827.5 | 35.6 | 0.0 | 11.9 | 0.0 |
| 1970 | 91.9 | 0.0 | 48.1 | 0.0 | 20.2 | 0.0 | 84.4 | 0.0 | 796.9 | 41.0 | 0.0 | 13.7 | 0.0 |
| LAND USE ON MEDIUM FARMS (IN 1000 HA) | | | | | | | | | | | | | |
| 1960 | 16.9 | 8.6 | 11.4 | 8.6 | 0.0 | 7.0 | 0.0 | 66.6 | 1352.8 | 0.0 | 15.5 | 0.0 | 5.2 |
| 1961 | 14.4 | 19.3 | 4.3 | 19.3 | 3.6 | 4.8 | 0.0 | 59.7 | 1327.3 | 0.0 | 18.6 | 0.0 | 6.2 |
| 1962 | 19.1 | 25.4 | 0.0 | 25.4 | 5.7 | 2.3 | 0.0 | 67.9 | 1303.5 | 0.0 | 22.4 | 0.0 | 7.5 |
| 1963 | 18.2 | 40.5 | 0.4 | 29.5 | 6.9 | 2.6 | 0.0 | 64.5 | 1281.1 | 0.0 | 26.8 | 0.0 | 8.9 |
| 1964 | 17.3 | 60.2 | 1.4 | 33.9 | 7.8 | 1.3 | 0.0 | 61.3 | 1259.5 | 0.0 | 32.2 | 0.0 | 10.7 |
| 1965 | 16.3 | 86.0 | 2.2 | 39.4 | 8.6 | 0.0 | 0.0 | 58.2 | 1238.7 | 0.0 | 38.6 | 0.0 | 12.9 |
| 1966 | 17.3 | 102.7 | 1.0 | 48.1 | 8.4 | 0.0 | 0.0 | 63.1 | 1218.6 | 0.0 | 46.4 | 0.0 | 15.5 |
| 1967 | 18.6 | 102.4 | 0.0 | 58.0 | 8.1 | 2.0 | 0.0 | 67.6 | 1199.1 | 0.0 | 55.6 | 0.0 | 18.5 |
| 1968 | 17.8 | 108.5 | 1.1 | 67.4 | 8.7 | 3.5 | 0.0 | 64.2 | 1180.2 | 0.0 | 66.8 | 0.0 | 22.2 |
| 1969 | 16.6 | 150.2 | 1.8 | 79.0 | 9.5 | 5.0 | 0.0 | 61.0 | 1122.8 | 0.0 | 80.1 | 0.0 | 26.7 |
| 1970 | 16.0 | 147.0 | 2.8 | 92.5 | 9.8 | 7.7 | 0.0 | 58.0 | 1105.3 | 0.0 | 96.1 | 0.0 | 32.0 |
| LAND USE ON LARGE FARMS (IN 1000 HA) | | | | | | | | | | | | | |
| 1960 | 0.0 | 35.0 | 0.0 | 30.0 | 0.0 | 10.0 | 0.0 | 90.0 | 1785.3 | 0.0 | 22.3 | 0.0 | 7.4 |
| 1961 | 0.0 | 48.3 | 0.0 | 35.7 | 0.0 | 12.5 | 0.0 | 83.7 | 1754.8 | 0.0 | 27.8 | 0.0 | 9.3 |
| 1962 | 0.0 | 66.7 | 0.0 | 42.5 | 0.0 | 11.6 | 0.0 | 90.9 | 1725.5 | 0.0 | 34.8 | 0.0 | 11.6 |
| 1963 | 0.0 | 92.0 | 0.0 | 50.6 | 0.0 | 10.8 | 0.0 | 84.5 | 1697.3 | 0.0 | 43.5 | 0.0 | 14.5 |
| 1964 | 0.0 | 126.9 | 0.0 | 60.2 | 0.0 | 10.1 | 0.0 | 78.6 | 1661.9 | 0.0 | 54.4 | 0.0 | 18.1 |
| 1965 | 0.0 | 141.5 | 0.0 | 72.6 | 0.0 | 9.4 | 0.0 | 73.1 | 1635.4 | 0.0 | 68.0 | 0.0 | 22.7 |
| 1966 | 0.0 | 150.3 | 0.0 | 85.2 | 0.0 | 8.7 | 0.0 | 68.0 | 1609.7 | 0.0 | 85.0 | 0.0 | 28.3 |
| 1967 | 0.0 | 149.7 | 0.0 | 101.4 | 0.0 | 10.9 | 0.0 | 63.2 | 1584.6 | 0.0 | 106.2 | 0.0 | 35.4 |
| 1968 | 0.0 | 206.6 | 0.0 | 120.6 | 0.0 | 13.6 | 0.0 | 58.8 | 1494.0 | 0.0 | 132.8 | 0.0 | 44.3 |
| 1969 | 0.0 | 283.0 | 0.0 | 143.6 | 0.0 | 17.0 | 0.0 | 54.7 | 1374.1 | 0.0 | 166.0 | 0.0 | 55.3 |
| 1970 | 0.0 | 337.5 | 0.0 | 170.8 | 0.0 | 21.2 | 0.0 | 50.9 | 1263.8 | 0.0 | 207.5 | 0.0 | 69.2 |

SOURCE: MODEL RESULTS

TABLE 12: LAND USE BY FARM SIZE AND BY TECHNOLOGY AS A PERCENTAGE OF REGIONAL LAND USE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | WHEAT1 | WHEAT2 | SOYBW1 | SOYBW2 | SOYBI1 | SOYBI2 | CORN1 | CORN2 | NATPAS | SUPAS1 | SUPAS2 | WIPAS1 | WIPAS2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LAND USE ON SMALL FARMS AS A PERCENTAGE OF REGIONAL LAND USE | | | | | | | | | | | | | |
| 1960 | 47.0 | 0.0 | 46.7 | 0.0 | 100.0 | 0.0 | 100.0 | 0.0 | 23.6 | 100.0 | 0.0 | 100.0 | 0.0 |
| 1961 | 55.6 | 0.0 | 73.1 | 0.0 | 61.3 | 0.0 | 100.0 | 0.0 | 23.6 | 100.0 | 0.0 | 100.0 | 0.0 |
| 1962 | 52.4 | 0.0 | 100.0 | 0.0 | 53.7 | 0.0 | 100.0 | 0.0 | 23.6 | 100.0 | 0.0 | 100.0 | 0.0 |
| 1963 | 58.7 | 0.0 | 97.0 | 0.0 | 52.4 | 0.0 | 100.0 | 0.0 | 23.6 | 100.0 | 0.0 | 100.0 | 0.0 |
| 1964 | 64.3 | 0.0 | 93.0 | 0.0 | 52.7 | 0.0 | 100.0 | 0.0 | 23.6 | 100.0 | 0.0 | 100.0 | 0.0 |
| 1965 | 69.6 | 0.0 | 90.9 | 0.0 | 54.0 | 0.0 | 100.0 | 0.0 | 23.6 | 100.0 | 0.0 | 100.0 | 0.0 |
| 1966 | 72.1 | 0.0 | 96.3 | 0.0 | 58.0 | 0.0 | 100.0 | 0.0 | 23.6 | 100.0 | 0.0 | 100.0 | 0.0 |
| 1967 | 74.3 | 0.0 | 100.0 | 0.0 | 62.1 | 0.0 | 100.0 | 0.0 | 23.6 | 100.0 | 0.0 | 100.0 | 0.0 |
| 1968 | 78.4 | 0.0 | 97.0 | 0.0 | 63.7 | 0.0 | 100.0 | 0.0 | 24.1 | 100.0 | 0.0 | 100.0 | 0.0 |
| 1969 | 82.3 | 0.0 | 95.8 | 0.0 | 64.9 | 0.0 | 100.0 | 0.0 | 24.9 | 100.0 | 0.0 | 100.0 | 0.0 |
| 1970 | 85.3 | 0.0 | 94.5 | 0.0 | 67.3 | 0.0 | 100.0 | 0.0 | 25.2 | 100.0 | 0.0 | 100.0 | 0.0 |
| LAND USE ON MEDIUM FARMS AS A PERCENTAGE OF REGIONAL LAND USE | | | | | | | | | | | | | |
| 1960 | 53.0 | 19.7 | 53.3 | 22.3 | 0.0 | 41.2 | 0.0 | 42.5 | 32.9 | 0.0 | 41.0 | 0.0 | 41.3 |
| 1961 | 44.4 | 28.6 | 26.9 | 35.1 | 38.7 | 27.7 | 0.0 | 41.6 | 32.9 | 0.0 | 40.1 | 0.0 | 40.3 |
| 1962 | 47.6 | 27.6 | 00.0 | 37.4 | 46.3 | 16.5 | 0.0 | 42.8 | 32.9 | 0.0 | 39.2 | 0.0 | 39.3 |
| 1963 | 41.3 | 30.6 | 2.4 | 36.8 | 47.6 | 19.4 | 0.0 | 43.3 | 32.9 | 0.0 | 38.1 | 0.0 | 38.0 |
| 1964 | 35.7 | 32.2 | 7.0 | 36.0 | 47.3 | 11.4 | 0.0 | 43.8 | 32.9 | 0.0 | 37.2 | 0.0 | 37.2 |
| 1965 | 30.4 | 37.8 | 9.1 | 35.5 | 46.0 | 0.0 | 0.0 | 44.3 | 32.9 | 0.0 | 36.2 | 0.0 | 36.2 |
| 1966 | 27.9 | 40.6 | 3.7 | 36.1 | 42.0 | 0.0 | 0.0 | 48.1 | 32.9 | 0.0 | 35.3 | 0.0 | 35.4 |
| 1967 | 25.7 | 40.6 | 0.0 | 36.4 | 37.9 | 15.5 | 0.0 | 51.7 | 32.9 | 0.0 | 34.4 | 0.0 | 34.3 |
| 1968 | 21.6 | 34.4 | 3.0 | 35.9 | 36.2 | 20.5 | 0.0 | 52.2 | 33.5 | 0.0 | 33.5 | 0.0 | 33.4 |
| 1969 | 17.7 | 34.7 | 4.2 | 35.5 | 35.1 | 22.7 | 0.0 | 52.7 | 33.8 | 0.0 | 32.5 | 0.0 | 32.6 |
| 1970 | 14.7 | 30.3 | 5.5 | 35.1 | 32.7 | 26.6 | 0.0 | 53.3 | 34.9 | 0.0 | 31.7 | 0.0 | 31.6 |
| LAND USE ON LARGE FARMS AS A PERCENTAGE OF REGIONAL LAND USE | | | | | | | | | | | | | |
| 1960 | 0.0 | 80.3 | 0.0 | 77.7 | 0.0 | 58.8 | 0.0 | 57.5 | 43.4 | 0.0 | 59.0 | 0.0 | 58.7 |
| 1961 | 0.0 | 71.4 | 0.0 | 64.9 | 0.0 | 72.3 | 0.0 | 58.4 | 43.5 | 0.0 | 59.9 | 0.0 | 60.0 |
| 1962 | 0.0 | 72.4 | 0.0 | 62.6 | 0.0 | 83.5 | 0.0 | 57.2 | 43.5 | 0.0 | 60.8 | 0.0 | 60.7 |
| 1963 | 0.0 | 69.4 | 0.0 | 63.2 | 0.0 | 80.6 | 0.0 | 56.7 | 43.6 | 0.0 | 61.9 | 0.0 | 62.0 |
| 1964 | 0.0 | 67.8 | 0.0 | 64.0 | 0.0 | 88.6 | 0.0 | 56.2 | 43.5 | 0.0 | 62.8 | 0.0 | 62.8 |
| 1965 | 0.0 | 62.2 | 0.0 | 64.5 | 0.0 | 100.0 | 0.0 | 55.7 | 43.5 | 0.0 | 63.8 | 0.0 | 63.8 |
| 1966 | 0.0 | 59.4 | 0.0 | 63.9 | 0.0 | 100.0 | 0.0 | 51.9 | 43.5 | 0.0 | 64.7 | 0.0 | 64.6 |
| 1967 | 0.0 | 59.4 | 0.0 | 63.6 | 0.0 | 84.5 | 0.0 | 48.3 | 43.5 | 0.0 | 65.6 | 0.0 | 65.7 |
| 1968 | 0.0 | 65.6 | 0.0 | 64.1 | 0.0 | 79.5 | 0.0 | 47.8 | 42.4 | 0.0 | 66.5 | 0.0 | 66.6 |
| 1969 | 0.0 | 65.4 | 0.0 | 64.5 | 0.0 | 77.3 | 0.0 | 47.3 | 41.3 | 0.0 | 67.5 | 0.0 | 67.4 |
| 1970 | 0.0 | 69.7 | 0.0 | 64.9 | 0.0 | 73.4 | 0.0 | 46.7 | 39.9 | 0.0 | 68.3 | 0.0 | 68.4 |

SOURCE: MODEL RESULTS

TABLE 13: CROPPING PATTERN BY FARM SIZE AND BY TECHNOLOGY: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | WHEAT1 | WHEAT2 | SOYBW1 | SOYBW2 | SOYBI1 | SOYBI2 | CORN1 | CORN2 | NATPAS | SUPAS1 | SUPAS2 | WIPAS1 | WIPAS2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CROPPING PATTERN ON SMALL FARMS AS A PERCENTAGE OF TOTAL LAND USE ON SMALL FARMS | | | | | | | | | | | | | |
| 1960 | 1.42 | 0.0 | 0.94 | 0.0 | 0.47 | 0.0 | 4.15 | 0.0 | 91.74 | 0.95 | 0.0 | 0.32 | 0.0 |
| 1961 | 1.71 | 0.0 | 1.11 | 0.0 | 0.54 | 0.0 | 4.52 | 0.0 | 90.64 | 1.10 | 0.0 | 0.36 | 0.0 |
| 1962 | 1.01 | 0.0 | 1.31 | 0.0 | 0.63 | 0.0 | 4.91 | 0.0 | 89.42 | 1.28 | 0.0 | 0.43 | 0.0 |
| 1963 | 2.48 | 0.0 | 1.53 | 0.0 | 0.73 | 0.0 | 5.31 | 0.0 | 87.98 | 1.48 | 0.0 | 0.49 | 0.0 |
| 1964 | 2.98 | 0.0 | 1.79 | 0.0 | 0.83 | 0.0 | 5.74 | 0.0 | 86.40 | 1.69 | 0.0 | 0.56 | 0.0 |
| 1965 | 3.58 | 0.0 | 2.10 | 0.0 | 0.97 | 0.0 | 5.58 | 0.0 | 85.16 | 1.96 | 0.0 | 0.65 | 0.0 |
| 1966 | 4.27 | 0.0 | 2.45 | 0.0 | 1.10 | 0.0 | 5.97 | 0.0 | 83.23 | 2.23 | 0.0 | 0.74 | 0.0 |
| 1967 | 5.06 | 0.0 | 2.83 | 0.0 | 1.25 | 0.0 | 6.38 | 0.0 | 81.10 | 2.53 | 0.0 | 0.85 | 0.0 |
| 1968 | 5.98 | 0.0 | 3.26 | 0.0 | 1.42 | 0.0 | 6.78 | 0.0 | 78.74 | 2.87 | 0.0 | 0.96 | 0.0 |
| 1969 | 7.10 | 0.0 | 3.77 | 0.0 | 1.61 | 0.0 | 7.25 | 0.0 | 75.96 | 3.27 | 0.0 | 1.09 | 0.0 |
| 1970 | 8.47 | 0.0 | 4.38 | 0.0 | 1.84 | 0.0 | 7.69 | 0.0 | 72.63 | 3.74 | 0.0 | 1.25 | 0.0 |
| CROPPING PATTERN ON MEDIUM FARMS AS A PERCENTAGE OF TOTAL LAND USE ON MEDIUM FARMS | | | | | | | | | | | | | |
| 1960 | 1.13 | 0.58 | 0.76 | 0.58 | 0.0 | 0.47 | 0.0 | 4.46 | 90.63 | 0.0 | 1.04 | 0.0 | 0.35 |
| 1961 | 0.97 | 1.31 | 0.29 | 1.31 | 0.24 | 0.32 | 0.0 | 4.04 | 89.83 | 0.0 | 1.26 | 0.0 | 0.42 |
| 1962 | 1.29 | 1.72 | 0.0 | 1.72 | 0.39 | 0.16 | 0.0 | 4.59 | 88.12 | 0.0 | 1.51 | 0.0 | 0.51 |
| 1963 | 1.23 | 2.74 | 0.03 | 1.99 | 0.47 | 0.18 | 0.0 | 4.36 | 86.60 | 0.0 | 1.81 | 0.0 | 0.60 |
| 1964 | 1.16 | 4.05 | 0.09 | 2.28 | 0.53 | 0.09 | 0.0 | 4.13 | 84.78 | 0.0 | 2.17 | 0.0 | 0.72 |
| 1965 | 1.09 | 5.73 | 0.15 | 2.63 | 5.07 | 0.0 | 0.0 | 3.88 | 82.53 | 0.0 | 2.57 | 0.0 | 0.86 |
| 1966 | 1.14 | 6.75 | 0.07 | 3.16 | 0.55 | 0.0 | 0.0 | 4.15 | 80.11 | 0.0 | 3.05 | 0.0 | 1.02 |
| 1967 | 1.22 | 6.69 | 0.0 | 3.79 | 0.53 | 0.13 | 0.0 | 4.42 | 78.38 | 0.0 | 3.63 | 0.0 | 1.21 |
| 1968 | 1.16 | 7.04 | 0.07 | 4.38 | 0.56 | 0.23 | 0.0 | 4.17 | 76.62 | 0.0 | 4.34 | 0.0 | 1.44 |
| 1969 | 1.07 | 9.67 | 0.12 | 5.09 | 0.61 | 0.32 | 0.0 | 3.93 | 72.31 | 0.0 | 5.16 | 0.0 | 1.72 |
| 1970 | 1.02 | 9.38 | 0.18 | 5.90 | 0.63 | 0.49 | 0.0 | 3.70 | 70.53 | 0.0 | 6.13 | 0.0 | 2.04 |
| CROPPING PATTERN ON LARGE FARMS AS A PERCENTAGE OF TOTAL LAND USE ON LARGE FARMS | | | | | | | | | | | | | |
| 1960 | 0.0 | 1.77 | 0.0 | 1.52 | 0.0 | 0.51 | 0.0 | 4.5 | 90.17 | 0.0 | 1.13 | 0.0 | 0.37 |
| 1961 | 0.0 | 2.45 | 0.0 | 1.81 | 0.0 | 0.63 | 0.0 | 4.24 | 88.98 | 0.0 | 1.41 | 0.0 | 0.47 |
| 1962 | 0.0 | 3.36 | 0.0 | 2.14 | 0.0 | 0.58 | 0.0 | 4.58 | 86.99 | 0.0 | 1.75 | 0.0 | 0.58 |
| 1963 | 0.0 | 4.62 | 0.0 | 2.54 | 0.0 | 0.58 | 0.0 | 4.24 | 85.15 | 0.0 | 2.18 | 0.0 | 0.74 |
| 1964 | 0.0 | 6.31 | 0.0 | 2.99 | 0.0 | 0.50 | 0.0 | 3.91 | 82.67 | 0.0 | 2.71 | 0.0 | 0.90 |
| 1965 | 0.0 | 7.00 | 0.0 | 3.54 | 0.0 | 0.46 | 0.0 | 3.62 | 80.89 | 0.0 | 3.36 | 0.0 | 1.12 |
| 1966 | 0.0 | 7.39 | 0.0 | 4.19 | 0.0 | 0.43 | 0.0 | 3.34 | 79.09 | 0.0 | 4.18 | 0.0 | 1.39 |
| 1967 | 0.0 | 7.30 | 0.0 | 4.94 | 0.0 | 0.53 | 0.0 | 3.08 | 77.24 | 0.0 | 5.18 | 0.0 | 1.73 |
| 1968 | 0.0 | 9.98 | 0.0 | 5.82 | 0.0 | 0.66 | 0.0 | 2.84 | 72.15 | 0.0 | 6.41 | 0.0 | 2.14 |
| 1969 | 0.0 | 13.52 | 0.0 | 6.86 | 0.0 | 0.81 | 0.0 | 2.61 | 65.63 | 0.0 | 7.93 | 0.0 | 2.64 |
| 1970 | 0.0 | 15.91 | 0.0 | 8.05 | 0.0 | 1.00 | 0.0 | 2.40 | 59.59 | 0.0 | 9.78 | 0.0 | 3.26 |

SOURCE: MODEL RESULTS

TABLE 14: REGIONAL LAND USE BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | WHEAT | SOYBN | CORN | NAPAS | SUPAS | WIPAS |
|---|---|---|---|---|---|---|
| LAND USE BY CROP ON SMALL FARMS (IN 1000 HA) | | | | | | |
| 1960 | 15.00 | 15.00 | 44.00 | 971.50 | 10.10 | 3.40 |
| 1961 | 18.00 | 17.40 | 47.50 | 952.20 | 11.60 | 3.80 |
| 1962 | 21.00 | 20.30 | 51.30 | 934.30 | 13.40 | 4.50 |
| 1963 | 25.90 | 23.60 | 55.40 | 917.70 | 15.40 | 5.10 |
| 1964 | 31.10 | 27.40 | 59.90 | 902.30 | 17.70 | 5.90 |
| 1965 | 37.30 | 32.00 | 58.10 | 887.30 | 20.40 | 6.80 |
| 1966 | 44.80 | 37.30 | 62.70 | 873.80 | 23.40 | 7.80 |
| 1967 | 53.70 | 43.30 | 67.70 | 861.00 | 26.90 | 9.00 |
| 1968 | 64.50 | 50.40 | 73.10 | 849.00 | 31.00 | 10.30 |
| 1969 | 77.40 | 58.70 | 79.00 | 827.50 | 35.60 | 11.90 |
| 1970 | 92.90 | 68.30 | 84.40 | 796.90 | 41.00 | 13.70 |
| LAND USE BY CROP ON MEDIUM FARMS (IN 1000 HA) | | | | | | |
| 1960 | 25.50 | 27.00 | 66.60 | 1352.80 | 15.50 | 5.20 |
| 1961 | 33.70 | 32.00 | 59.70 | 1327.30 | 18.60 | 6.20 |
| 1962 | 44.50 | 33.40 | 67.90 | 1303.50 | 22.40 | 7.50 |
| 1963 | 58.70 | 39.40 | 64.50 | 1281.10 | 26.80 | 8.90 |
| 1964 | 77.50 | 44.40 | 61.30 | 1259.50 | 32.20 | 10.70 |
| 1965 | 102.30 | 50.20 | 58.20 | 1238.70 | 38.60 | 12.90 |
| 1966 | 120.00 | 57.50 | 63.10 | 1218.60 | 46.40 | 15.50 |
| 1967 | 121.00 | 68.10 | 67.60 | 1199.10 | 55.60 | 18.50 |
| 1968 | 126.30 | 80.70 | 64.20 | 1180.20 | 66.80 | 22.20 |
| 1969 | 166.80 | 95.30 | 61.00 | 1122.80 | 80.10 | 26.70 |
| 1970 | 163.00 | 112.80 | 58.00 | 1105.30 | 96.10 | 32.00 |
| LAND USE BY CROP ON LARGE FARMS (IN 1000 HA) | | | | | | |
| 1960 | 35.00 | 40.00 | 90.00 | 1785.30 | 22.30 | 7.40 |
| 1961 | 48.30 | 48.20 | 83.70 | 1754.80 | 27.80 | 9.30 |
| 1962 | 66.70 | 54.10 | 90.90 | 1725.50 | 34.80 | 11.60 |
| 1963 | 92.00 | 61.40 | 84.50 | 1697.30 | 43.50 | 14.50 |
| 1964 | 126.90 | 70.30 | 78.60 | 1661.90 | 54.40 | 18.10 |
| 1965 | 141.50 | 81.00 | 73.10 | 1635.40 | 68.00 | 22.70 |
| 1966 | 150.30 | 93.90 | 68.00 | 1609.70 | 85.00 | 28.30 |
| 1967 | 149.70 | 112.30 | 63.20 | 1584.60 | 106.20 | 35.40 |
| 1968 | 206.60 | 134.20 | 58.80 | 1494.00 | 132.80 | 44.30 |
| 1969 | 283.00 | 160.60 | 54.70 | 1374.10 | 166.00 | 55.30 |
| 1970 | 337.50 | 192.00 | 50.90 | 1263.80 | 207.50 | 69.20 |

SOURCE: MODEL RESULTS

TABLE 15: BEEF PRODUCTION USING NATURAL PASTURE (IN 1000 METRIC TONS): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM | REGIONAL TOTAL |
|---|---|---|---|---|
| 1960 | 64.7 | 91.6 | 122.1 | 278.4 |
| 1961 | 63.7 | 90.2 | 120.2 | 274.1 |
| 1962 | 62.7 | 88.9 | 118.4 | 270.0 |
| 1963 | 61.8 | 87.5 | 116.6 | 265.9 |
| 1964 | 60.5 | 86.2 | 113.5 | 260.6 |
| 1965 | 59.9 | 84.9 | 112.6 | 257.4 |
| 1966 | 59.0 | 83.7 | 110.9 | 253.6 |
| 1967 | 58.2 | 82.4 | 109.3 | 249.9 |
| 1968 | 57.3 | 81.2 | 103.1 | 241.6 |
| 1969 | 55.7 | 77.3 | 94.8 | 227.8 |
| 1970 | 53.5 | 76.1 | 87.2 | 216.6 |

TABLE 16: BEEF PRODUCTION USING IMPROVED PASTURE (IN 1000 METRIC TONS): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM | REGIONAL TOTAL |
|---|---|---|---|---|
| 1960 | 4.1 | 6.3 | 9.0 | 19.4 |
| 1961 | 4.7 | 7.5 | 12.5 | 24.7 |
| 1962 | 5.4 | 9.0 | 14.1 | 28.5 |
| 1963 | 6.2 | 10.8 | 17.6 | 34.6 |
| 1964 | 7.1 | 13.0 | 21.9 | 42.0 |
| 1965 | 8.2 | 15.6 | 27.3 | 51.1 |
| 1966 | 9.4 | 18.7 | 34.3 | 62.4 |
| 1967 | 10.9 | 22.5 | 42.9 | 76.3 |
| 1968 | 12.5 | 26.9 | 53.6 | 93.0 |
| 1969 | 14.4 | 32.3 | 67.0 | 113.7 |
| 1970 | 16.5 | 38.8 | 83.7 | 139.0 |

TABLE 17: TOTAL BEEF PRODUCTION (IN 1000 METRIC TONS): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM | REGIONAL TOTAL |
|---|---|---|---|---|
| 1960 | 68.8 | 97.9 | 131.1 | 297.8 |
| 1961 | 68.4 | 97.7 | 132.7 | 298.8 |
| 1962 | 68.1 | 97.9 | 132.5 | 298.5 |
| 1963 | 68.0 | 98.3 | 134.2 | 300.5 |
| 1964 | 68.0 | 99.2 | 135.4 | 302.6 |
| 1965 | 68.1 | 100.5 | 139.9 | 308.5 |
| 1966 | 68.4 | 102.4 | 145.2 | 316.0 |
| 1967 | 69.1 | 104.9 | 152.2 | 326.2 |
| 1968 | 69.8 | 108.1 | 156.7 | 334.6 |
| 1969 | 70.1 | 109.6 | 161.8 | 341.5 |
| 1970 | 70.0 | 114.9 | 170.9 | 355.8 |

SOURCE: MODEL RESULTS

TABLE 18: LAND USE BY FARM SIZE AS A PERCENTAGE OF REGIONAL LAND USE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | WHEAT | SOYBN | CORN | NAPAS | SUPAS | WIPAS |
|---|---|---|---|---|---|---|
| CROPPING PATTERN ON SMALL FARMS | | | | | | |
| 1960 | 19.87 | 18.29 | 21.93 | 23.64 | 21.09 | 21.25 |
| 1961 | 18.00 | 17.03 | 24.88 | 23.60 | 20.00 | 19.69 |
| 1962 | 15.89 | 18.83 | 24.42 | 23.57 | 18.98 | 19.07 |
| 1963 | 14.67 | 18.97 | 27.10 | 23.55 | 17.97 | 17.89 |
| 1964 | 13.21 | 19.28 | 29.98 | 23.60 | 16.97 | 17.00 |
| 1965 | 13.27 | 19.61 | 30.68 | 23.59 | 16.06 | 16.04 |
| 1966 | 14.22 | 19.77 | 32.35 | 23.60 | 15.12 | 15.12 |
| 1967 | 16.95 | 19.36 | 34.11 | 23.62 | 14.26 | 14.31 |
| 1968 | 16.23 | 19.00 | 37.28 | 24.10 | 13.44 | 13.41 |
| 1969 | 14.68 | 18.66 | 40.58 | 24.89 | 12.64 | 12.67 |
| 1970 | 15.66 | 18.31 | 43.66 | 25.17 | 11.90 | 11.92 |
| CROPPING PATTERN ON MEDIUM FARMS | | | | | | |
| 1960 | 33.77 | 32.93 | 33.20 | 32.92 | 32.36 | 32.50 |
| 1961 | 33.70 | 32.79 | 31.27 | 32.90 | 32.07 | 32.12 |
| 1962 | 33.66 | 30.98 | 32.32 | 32.89 | 31.73 | 31.78 |
| 1963 | 33.24 | 31.67 | 31.56 | 32.88 | 31.27 | 31.23 |
| 1964 | 32.91 | 31.25 | 30.68 | 32.94 | 30.87 | 30.84 |
| 1965 | 36.39 | 30.76 | 30.73 | 32.93 | 30.39 | 30.42 |
| 1966 | 38.08 | 30.47 | 32.56 | 32.92 | 29.97 | 30.04 |
| 1967 | 37.30 | 30.44 | 34.06 | 32.90 | 29.46 | 29.41 |
| 1968 | 31.78 | 30.42 | 32.74 | 33.50 | 28.97 | 28.91 |
| 1969 | 31.64 | 30.29 | 31.33 | 33.77 | 28.43 | 28.43 |
| 1970 | 27.47 | 30.23 | 30.01 | 34.91 | 27.89 | 27.85 |
| CROPPING PATTERN ON LARGE FARMS | | | | | | |
| 1960 | 46.36 | 48.78 | 44.87 | 43.44 | 46.56 | 46.25 |
| 1961 | 48.30 | 49.39 | 43.84 | 43.50 | 47.93 | 48.19 |
| 1962 | 50.45 | 50.19 | 43.27 | 43.54 | 49.29 | 49.15 |
| 1963 | 52.10 | 49.36 | 41.34 | 43.56 | 50.76 | 50.88 |
| 1964 | 53.89 | 49.47 | 39.34 | 43.46 | 52.16 | 52.16 |
| 1965 | 50.34 | 49.63 | 38.60 | 43.48 | 53.54 | 53.54 |
| 1966 | 47.70 | 49.76 | 35.09 | 43.48 | 54.91 | 54.84 |
| 1967 | 46.15 | 50.20 | 31.84 | 43.48 | 56.28 | 56.28 |
| 1968 | 51.99 | 50.58 | 29.98 | 42.40 | 57.59 | 57.68 |
| 1969 | 53.68 | 51.05 | 28.09 | 41.33 | 58.93 | 58.89 |
| 1970 | 56.88 | 51.46 | 26.33 | 39.92 | 60.21 | 60.23 |

SOURCE: MODEL RESULTS

TABLE 19: CROPPING PATTERN BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | WHEAT | SOYBN | CORN | NAPAS | SUPAS | WIPAS |
|---|---|---|---|---|---|---|
| CROPPING PATTERN ON SMALL FARMS | | | | | | |
| 1960 | 1.42 | 1.42 | 4.15 | 91.74 | 0.95 | 0.32 |
| 1961 | 1.71 | 1.66 | 4.52 | 90.64 | 1.10 | 0.36 |
| 1962 | 2.01 | 1.94 | 4.91 | 89.42 | 1.28 | 0.43 |
| 1963 | 2.48 | 2.26 | 5.31 | 87.98 | 1.48 | 0.49 |
| 1964 | 2.98 | 2.62 | 5.74 | 86.40 | 1.69 | 0.56 |
| 1965 | 3.58 | 3.07 | 5.58 | 85.16 | 1.96 | 0.65 |
| 1966 | 4.27 | 3.55 | 5.97 | 83.23 | 2.23 | 0.74 |
| 1967 | 5.06 | 4.08 | 6.38 | 81.10 | 2.53 | 0.85 |
| 1968 | 5.98 | 4.67 | 6.78 | 78.74 | 2.87 | 0.96 |
| 1969 | 7.10 | 5.38 | 7.25 | 75.91 | 3.27 | 1.09 |
| 1970 | 8.47 | 6.22 | 7.69 | 72.63 | 3.74 | 1.25 |
| CROPPING PATTERN ON MEDIUM FARMS | | | | | | |
| 1960 | 1.71 | 1.81 | 4.46 | 90.63 | 1.04 | 0.35 |
| 1961 | 2.28 | 2.17 | 4.04 | 89.83 | 1.26 | 0.42 |
| 1962 | 3.01 | 2.26 | 4.59 | 88.12 | 1.51 | 0.51 |
| 1963 | 3.97 | 2.66 | 4.36 | 86.60 | 1.81 | 0.60 |
| 1964 | 5.22 | 2.99 | 4.13 | 84.78 | 2.17 | 0.72 |
| 1965 | 6.82 | 3.34 | 3.88 | 82.53 | 2.57 | 0.86 |
| 1966 | 7.89 | 3.78 | 4.15 | 80.11 | 3.05 | 1.02 |
| 1967 | 7.91 | 4.45 | 4.42 | 78.38 | 3.63 | 1.21 |
| 1968 | 8.20 | 5.24 | 4.17 | 76.62 | 4.34 | 1.44 |
| 1969 | 10.74 | 6.14 | 3.93 | 72.31 | 5.16 | 1.72 |
| 1970 | 10.40 | 7.20 | 3.70 | 70.53 | 6.13 | 2.04 |
| CROPPING PATTERN ON LARGE FARMS | | | | | | |
| 1960 | 1.77 | 2.02 | 4.55 | 90.17 | 1.13 | 0.37 |
| 1961 | 2.45 | 2.44 | 4.24 | 88.98 | 1.41 | 0.47 |
| 1962 | 3.36 | 2.73 | 4.58 | 86.99 | 1.75 | 0.58 |
| 1963 | 4.62 | 3.08 | 4.24 | 85.15 | 2.18 | 0.73 |
| 1964 | 6.31 | 3.50 | 3.91 | 82.67 | 2.71 | 0.90 |
| 1965 | 7.00 | 4.01 | 3.62 | 80.89 | 3.36 | 1.12 |
| 1966 | 7.39 | 4.61 | 3.34 | 79.09 | 4.18 | 1.39 |
| 1967 | 7.30 | 5.47 | 3.08 | 77.24 | 5.18 | 1.73 |
| 1968 | 9.98 | 6.48 | 2.84 | 72.15 | 6.41 | 2.14 |
| 1969 | 13.52 | 7.67 | 2.61 | 65.63 | 7.93 | 2.64 |
| 1970 | 15.91 | 9.05 | 2.40 | 59.59 | 9.78 | 3.26 |

SOURCE: MODEL RESULTS

TABLE 20: TOTAL LAND USE BY FARM SIZE (IN 1000 HECTARES): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 1058.99976 | 1492.59985 | 1979.99976 |
| 1961 | 1050.49951 | 1477.49976 | 1972.09961 |
| 1962 | 1044.79980 | 1479.19971 | 1983.59961 |
| 1963 | 1043.09961 | 1479.39966 | 1993.19995 |
| 1964 | 1044.29980 | 1485.59985 | 2010.19946 |
| 1965 | 1041.89966 | 1500.89966 | 2021.69971 |
| 1966 | 1049.79956 | 1521.09985 | 2035.19971 |
| 1967 | 1061.59985 | 1529.89990 | 2051.39966 |
| 1968 | 1078.29980 | 1540.39966 | 2070.69922 |
| 1969 | 1090.09961 | 1552.69971 | 2093.69971 |
| 1970 | 1097.19971 | 1567.19946 | 2120.89966 |

SOURCE: MODEL RESULTS

TABLE 21: TOTAL LABOR USE BY FARM SIZE (IN 1000 HOURS): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 47752.3984 | 24342.3008 | 15259.8984 |
| 1961 | 52880.5000 | 23245.8008 | 15075.6992 |
| 1962 | 59099.6016 | 23718.1992 | 15739.3008 |
| 1963 | 66052.8125 | 24184.8984 | 15724.1016 |
| 1964 | 74044.6250 | 24668.6016 | 15844.8984 |
| 1965 | 79873.3750 | 25180.8984 | 15940.1992 |
| 1966 | 90211.1875 | 25665.3008 | 16112.8008 |
| 1967 | 102168.812 | 26178.6016 | 16378.0000 |
| 1968 | 116019.875 | 26702.0000 | 16986.5000 |
| 1969 | 132035.500 | 27236.1992 | 17831.6016 |
| 1970 | 150107.125 | 27780.8984 | 18801.8008 |

SOURCE: MODEL RESULTS

TABLE 22: TOTAL HIRED LABOR BY FARM SIZE (IN 1000 HOURS): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.0 | 1552.30005 | 7219.89844 |
| 1961 | 0.0 | 0.0 | 6874.89844 |
| 1962 | 0.0 | 7.50000 | 7374.50000 |
| 1963 | 0.0 | 0.0 | 7192.00000 |
| 1964 | 0.0 | 0.0 | 7142.19922 |
| 1965 | 0.0 | 0.0 | 7063.39844 |
| 1966 | 0.0 | 0.0 | 7058.39844 |
| 1967 | 0.0 | 0.0 | 7142.60156 |
| 1968 | 0.0 | 0.0 | 7566.39844 |
| 1969 | 0.0 | 0.0 | 8273.10156 |
| 1970 | 0.0 | 0.0 | 9001.10156 |

TABLE 23: TOTAL LABOR HOURS USED AS A PERCENTAGE OF TOTAL FAMILY LABOR HOURS AVAILABLE BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 26.52910 | 106.81123 | 189.79968 |
| 1961 | 28.82713 | 100.00000 | 183.83197 |
| 1962 | 31.55804 | 100.03156 | 188.16109 |
| 1963 | 34.57945 | 100.00000 | 184.29337 |
| 1964 | 38.00320 | 100.00000 | 182.06873 |
| 1965 | 40.19099 | 100.07542 | 179.57143 |
| 1966 | 44.50275 | 100.00000 | 177.95563 |
| 1967 | 49.41339 | 100.00000 | 177.33936 |
| 1968 | 55.01213 | 100.00000 | 180.32178 |
| 1969 | 61.37856 | 100.00000 | 185.58148 |
| 1970 | 68.41116 | 100.00000 | 191.84140 |

TABLE 24: HIRED LABOR HOURS AS A PERCENTAGE OF TOTAL LABOR HOURS USED BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.0 | 6.37696 | 47.31288 |
| 1961 | 0.0 | 0.0 | 45.60251 |
| 1962 | 0.0 | 0.03162 | 46.85403 |
| 1963 | 0.0 | 0.0 | 45.73869 |
| 1964 | 0.0 | 0.0 | 45.07568 |
| 1965 | 0.0 | 0.07545 | 44.31184 |
| 1966 | 0.0 | 0.0 | 43.80617 |
| 1967 | 0.0 | 0.0 | 43.61095 |
| 1968 | 0.0 | 0.0 | 44.54358 |
| 1969 | 0.0 | 0.0 | 46.11533 |
| 1970 | 0.0 | 0.0 | 47.87360 |

SOURCE: MODEL RESULTS

TABLE 25: QUASI-FIXED CAPITAL STOCK (CAPITAL FORMATION IN FARM POWER) BY FARM SIZE (IN 1000 CR$ AT 1970 PRICES): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)*

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 849.1 | 6830.3 | 18166.8 |
| 1961 | 964.8 | 10916.3 | 21769.9 |
| 1962 | 1086.6 | 12768.9 | 44036.8 |
| 1963 | 1224.3 | 17242.6 | 34388.5 |
| 1964 | 1383.8 | 22128.9 | 44036.8 |
| 1965 | 1511.5 | 28730.0 | 49079.5 |
| 1966 | 1716.5 | 33975.6 | 53771.6 |
| 1967 | 1951.5 | 35807.9 | 57598.4 |
| 1968 | 2224.8 | 39368.5 | 75994.6 |
| 1969 | 2542.2 | 52142.1 | 98577.5 |
| 1970 | 2900.8 | 53406.6 | 116869.3 |

TABLE 26: TOTAL VALUE OF LAND IN USE BY FARM SIZE (IN MILLION CR$ AT 1970 PRICES): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)**

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 277.88 | 394.12 | 524.18 |
| 1961 | 278.12 | 391.91 | 525.62 |
| 1962 | 278.78 | 396.16 | 534.62 |
| 1963 | 279.59 | 399.60 | 542.69 |
| 1964 | 282.38 | 405.32 | 554.80 |
| 1965 | 283.67 | 414.55 | 563.37 |
| 1966 | 288.85 | 425.65 | 572.63 |
| 1967 | 295.49 | 432.10 | 582.87 |
| 1968 | 303.97 | 439.13 | 604.18 |
| 1969 | 311.92 | 452.66 | 631.37 |
| 1970 | 319.35 | 461.09 | 658.79 |

SOURCE: MODEL RESULTS

TABLE 27: ESTIMATED TOTAL CAPITAL STOCK (QUASI-FIXED CAPITAL STOCK + VALUE OF LAND IN USE) BY FARM SIZE (IN MILLION CR$ AT 1970 PRICES): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 278.73 | 400.95 | 542.35 |
| 1961 | 279.08 | 402.83 | 547.39 |
| 1962 | 279.86 | 408.93 | 561.84 |
| 1963 | 280.81 | 416.84 | 577.08 |
| 1964 | 283.76 | 427.45 | 598.84 |
| 1965 | 285.18 | 443.28 | 612.45 |
| 1966 | 290.57 | 459.63 | 626.40 |
| 1967 | 297.44 | 467.91 | 641.46 |
| 1968 | 306.19 | 478.50 | 680.17 |
| 1969 | 314.46 | 504.80 | 729.95 |
| 1970 | 322.25 | 514.50 | 775.66 |

*Computation of quasi-fixed capital stock that includes draft animals, combines and tractors is carried out as follows:

Capital Stock(t)=(1-d) X Capital Stock (t-1) + Investment Capital (t)

Where d is a depreciation coefficient.

Small farms' d=20% where capital components are work animals only.

Medium farms' d=12% where capital components are both work animals and tractors and combines, and hence d for medium farms are weighted average of d's for traditional and modern farm powers.

Large farms' d=10% where capital components are only tractors and combines.

**Land in use includes crop lands and improved pasture lands that are evaluated at 400 CR$ per hectare and land left to natural pasture which is evaluated at 250 CR$ per hectare. The per hectare prices of land are weighted averages obtained from the sample farm record data of the three municipios in the wheat region, namely Carazinho, Nao Me Toque and Sao Borja. For the data description, see Norman Rask, "Analysis of Capital Formation and Utilization in Less Developed Countries," Occasional Paper No. 4, Department of Agricultural Economics and Rural Sociology, the Ohio State University December 1969.

TABLE 28: VALUE OF QUASI-FIXED CAPITAL STOCK AS A PERCENTAGE OF THE ESTIMATED VALUE OF TOTAL CAPITAL STOCK: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.30 | 1.70 | 3.34 |
| 1961 | 0.34 | 2.71 | 3.97 |
| 1962 | 0.38 | 3.12 | 4.84 |
| 1963 | 0.43 | 4.14 | 5.96 |
| 1964 | 0.48 | 5.18 | 7.35 |
| 1965 | 0.53 | 6.48 | 8.01 |
| 1966 | 0.59 | 7.39 | 8.58 |
| 1967 | 0.65 | 7.65 | 8.98 |
| 1968 | 0.73 | 8.23 | 11.17 |
| 1969 | 0.81 | 10.33 | 13.50 |
| 1970 | 0.90 | 10.38 | 15.07 |

TABLE 29: TOTAL DRAFT ANIMAL USE BY FARM SIZE (IN 1000 HOURS): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 5798.89844 | 1877.50000 | 0.0 |
| 1961 | 6515.10156 | 1763.69995 | 0.0 |
| 1962 | 7333.89844 | 1787.50000 | 0.0 |
| 1963 | 8271.69922 | 1841.50000 | 0.0 |
| 1964 | 9347.89844 | 1897.60010 | 0.0 |
| 1965 | 10117.6016 | 1940.69995 | 0.0 |
| 1966 | 11505.1016 | 1937.10010 | 0.0 |
| 1967 | 13108.3984 | 1939.19995 | 0.0 |
| 1968 | 14964.3008 | 1988.80005 | 0.0 |
| 1969 | 17115.8008 | 2010.19995 | 0.0 |
| 1970 | 19545.8984 | 2048.19995 | 0.0 |

TABLE 30: TOTAL TRACTOR USE BY FARM SIZE (IN 1000 HOURS): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.0 | 705.80005 | 1194.19995 |
| 1961 | 0.0 | 788.69995 | 1323.80005 |
| 1962 | 0.0 | 921.69995 | 1569.39990 |
| 1963 | 0.0 | 1052.80005 | 1790.30005 |
| 1964 | 0.0 | 1212.00000 | 2101.60010 |
| 1965 | 0.0 | 1426.60010 | 2308.39990 |
| 1966 | 0.0 | 1664.60010 | 2515.39990 |
| 1967 | 0.0 | 1809.60010 | 2723.60010 |
| 1968 | 0.0 | 1950.89990 | 3373.30005 |
| 1969 | 0.0 | 2365.89990 | 4225.10156 |
| 1970 | 0.0 | 2500.80005 | 5020.19922 |

TABLE 31: TOTAL COMBINE USE BY FARM SIZE (IN 1000 HOURS): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.0 | 24.14000 | 71.25000 |
| 1961 | 0.0 | 43.39999 | 91.67999 |
| 1962 | 0.0 | 53.02000 | 114.72000 |
| 1963 | 0.0 | 72.66000 | 145.67999 |
| 1964 | 0.0 | 95.46001 | 187.28999 |
| 1965 | 0.0 | 125.45000 | 211.28000 |
| 1966 | 0.0 | 150.89000 | 231.99001 |
| 1967 | 0.0 | 162.32001 | 249.85001 |
| 1968 | 0.0 | 179.39000 | 373.77002 |
| 1969 | 0.0 | 234.24001 | 421.34009 |
| 1970 | 0.0 | 247.17999 | 503.07007 |

SOURCE: MODEL RESULTS

TABLE 32: TOTAL MECHANICAL POWER USE BY FARM SIZE (IN MILLION BRAKE HORSE POWER HOURS): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.0 | 36.49699 | 63.27249 |
| 1961 | 0.0 | 41.60498 | 70.77393 |
| 1962 | 0.0 | 48.73599 | 84.20593 |
| 1963 | 0.0 | 56.27299 | 96.79893 |
| 1964 | 0.0 | 65.37299 | 114.44443 |
| 1965 | 0.0 | 77.60243 | 125.98387 |
| 1966 | 0.0 | 90.77443 | 137.36943 |
| 1967 | 0.0 | 98.59599 | 149.62250 |
| 1968 | 0.0 | 106.51437 | 184.85349 |
| 1969 | 0.0 | 130.00693 | 232.37205 |
| 1970 | 0.0 | 137.39893 | 276.16333 |

TABLE 33: GROSS NEW INVESTMENTS IN DRAFT ANIMALS BY FARM SIZE (IN 1000): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.12000 | 0.0 | 0.0 |
| 1961 | 0.78000 | 0.0 | 0.0 |
| 1962 | 0.86000 | 0.12300 | 0.0 |
| 1963 | 0.97000 | 0.16700 | 0.0 |
| 1964 | 1.10500 | 0.17100 | 0.0 |
| 1965 | 1.06300 | 0.17000 | 0.0 |
| 1966 | 1.38600 | 0.15200 | 0.0 |
| 1967 | 1.58000 | 0.15900 | 0.0 |
| 1968 | 1.81300 | 0.17700 | 0.0 |
| 1969 | 2.08300 | 0.16900 | 0.0 |
| 1970 | 2.36900 | 0.17700 | 0.0 |

TABLE 34: GROSS NEW INVESTMENTS IN TRACTORS BY FARM SIZE(IN 1000): WHEAT REGION IN THE STATE OF RIO GRAND DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.0 | 0.07800 | 0.17200 |
| 1961 | 0.0 | 0.06900 | 0.10700 |
| 1962 | 0.0 | 0.09900 | 0.17800 |
| 1963 | 0.0 | 0.10200 | 0.17100 |
| 1964 | 0.0 | 0.12200 | 0.22800 |
| 1965 | 0.0 | 0.15600 | 0.18600 |
| 1966 | 0.0 | 0.17400 | 0.20000 |
| 1967 | 0.0 | 0.13800 | 0.21000 |
| 1968 | 0.0 | 0.14700 | 0.44000 |
| 1969 | 0.0 | 0.29000 | 0.55100 |
| 1970 | 0.0 | 0.15700 | 0.55400 |

TABLE 35: TOTAL OUTLAYS ON INVESTMENT GOODS BY FARM SIZE(IN 1000 CR$ AT 1970 PRICES): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 43.92000 | 4987.19531 | 14872.7930 |
| 1961 | 285.47998 | 4905.59375 | 5416.79687 |
| 1962 | 314.75977 | 3162.61768 | 7677.19922 |
| 1963 | 335.01978 | 6005.91797 | 9890.39453 |
| 1964 | 404.42969 | 6955.38281 | 13097.1953 |
| 1965 | 389.05786 | 9256.61719 | 9446.39453 |
| 1966 | 507.27588 | 8693.22656 | 9599.99609 |
| 1967 | 578.27979 | 5909.39062 | 9203.99219 |
| 1968 | 663.55786 | 7857.57812 | 24155.9922 |
| 1969 | 762.37793 | 17497.8477 | 30182.3984 |
| 1970 | 867.05396 | 7521.57422 | 28149.5977 |

SOURCE: MODEL RESULTS

TABLE 36: TOTAL OUTLAYS ON ALL INPUTS BY FARM SIZE (IN 1000 CRS AT 1970 PRICES): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 34405.4258 | 72081.9375 | 150526.312 |
| 1961 | 35723.2969 | 60518.8984 | 141719.375 |
| 1962 | 36997.0273 | 62812.6953 | 154775.937 |
| 1963 | 38761.9336 | 69483.8125 | 162096.125 |
| 1964 | 40754.7031 | 75345.8125 | 174229.375 |
| 1965 | 42240.1328 | 84305.5625 | 175365.250 |
| 1966 | 45031.7031 | 90377.2500 | 180433.687 |
| 1967 | 48253.3359 | 90894.1875 | 185123.125 |
| 1968 | 52099.1484 | 96532.2500 | 221639.062 |
| 1969 | 56405.0977 | 118072.312 | 256904.187 |
| 1970 | 61155.5508 | 111102.062 | 282264.062 |

TABLE 37: TOTAL OUTLAYS ON VARIABLE INPUTS BY FARM SIZE (IN 1000 CRS AT 1970 PRICES): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 34361.5039 | 67094.6875 | 135653.500 |
| 1961 | 35437.8164 | 55613.3047 | 136302.562 |
| 1962 | 36682.2656 | 59650.0742 | 147148.687 |
| 1963 | 38406.9102 | 63477.8945 | 152205.687 |
| 1964 | 40330.2734 | 68390.3750 | 161142.125 |
| 1965 | 41851.0742 | 75048.9375 | 165918.812 |
| 1966 | 44524.4258 | 81684.0000 | 170833.687 |
| 1967 | 47675.0547 | 84984.7500 | 175919.125 |
| 1968 | 51435.5898 | 88674.6250 | 197483.062 |
| 1969 | 55642.7187 | 100574.437 | 226721.750 |
| 1970 | 60288.4961 | 103580.437 | 256114.437 |

TABLE 38: TOTAL OUTLAYS ON NUTRIENTS BY FARM SIZE (IN 1000 CRS AT 1970 PRICES): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 6257.99609 | 9729.29297 | 13322.3945 |
| 1961 | 7005.59375 | 10300.4922 | 14710.4922 |
| 1962 | 7820.39453 | 12303.8867 | 17562.2891 |
| 1963 | 8872.49219 | 13878.8867 | 20101.1992 |
| 1964 | 10019.0898 | 15852.8906 | 23820.2891 |
| 1965 | 10787.6914 | 18515.6914 | 25596.8945 |
| 1966 | 12255.5898 | 21205.7891 | 26932.8945 |
| 1967 | 13950.2891 | 22343.9922 | 27890.0859 |
| 1968 | 15932.6953 | 23417.0898 | 35212.7930 |
| 1969 | 18236.3906 | 28341.5937 | 45032.3945 |
| 1970 | 20838.2891 | 28837.1953 | 53115.2930 |

TABLE 39: TOTAL DEMAND FOR DEBT BY FARM SIZE (IN MILLION CRS AT 1970 PRICES): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.0 | 0.0 | 0.0 |
| 1961 | 0.0 | 0.0 | 0.0 |
| 1962 | 0.0 | 0.0 | 0.0 |
| 1963 | 2.61728 | 0.0 | 10.04012 |
| 1964 | 12.68031 | 18.91904 | 46.10347 |
| 1965 | 13.14167 | 34.31859 | 34.18555 |
| 1966 | 17.86287 | 51.84103 | 61.97263 |
| 1967 | 6.29317 | 34.69774 | 33.55768 |
| 1968 | 0.0 | 26.25003 | 60.85378 |
| 1969 | 3.33251 | 69.49225 | 139.72505 |
| 1970 | 7.87930 | 77.77730 | 192.53612 |

SOURCE: MODEL RESULTS

TABLE 40: TOTAL OUTPUT BY FARM SIZE (IN 1000 CR$ AT 1970 PRICES): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 96344.5000 | 141893.625 | 191914.250 |
| 1961 | 98943.8125 | 146176.000 | 200503.125 |
| 1962 | 101917.250 | 153419.250 | 213496.812 |
| 1963 | 105164.000 | 162253.687 | 228371.875 |
| 1964 | 110939.812 | 173141.687 | 248889.375 |
| 1965 | 115450.437 | 187693.000 | 261549.000 |
| 1966 | 122272.187 | 201333.000 | 273373.500 |
| 1967 | 130327.750 | 208523.812 | 284423.187 |
| 1968 | 140032.250 | 217744.375 | 322433.500 |
| 1969 | 150839.375 | 243152.687 | 372008.062 |
| 1970 | 162829.375 | 251526.625 | 413104.875 |

TABLE 41: AVERAGE NET LAND PRODUCTIVITY PER HECTARE BY FARM SIZE (IN CONSTANT 1970 CR$/HA): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 58.48827 | 46.77187 | 20.90300 |
| 1961 | 60.18138 | 57.97432 | 29.80769 |
| 1962 | 62.13651 | 61.25372 | 29.60318 |
| 1963 | 64.61708 | 62.70778 | 33.25092 |
| 1964 | 67.20776 | 65.82921 | 37.14058 |
| 1965 | 70.26611 | 68.88364 | 42.62935 |
| 1966 | 73.57635 | 72.94441 | 45.66618 |
| 1967 | 77.31197 | 76.88713 | 48.40599 |
| 1968 | 81.54787 | 78.68874 | 48.67651 |
| 1969 | 86.62900 | 80.55670 | 54.97630 |
| 1970 | 92.66664 | 89.60222 | 63.10567 |

TABLE 42: AVERAGE NET LABOR PRODUCTIVITY PER HOUR BY FARM SIZE (IN CONSTANT 1970 CR$/HR): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 1.29709 | 2.86792 | 2.71220 |
| 1961 | 1.19553 | 3.68484 | 3.89924 |
| 1962 | 1.09849 | 3.82013 | 3.73084 |
| 1963 | 1.02043 | 3.83586 | 4.21491 |
| 1964 | 0.94788 | 3.96439 | 4.71193 |
| 1965 | 0.91658 | 4.10579 | 5.40669 |
| 1966 | 0.85622 | 4.32318 | 5.76807 |
| 1967 | 0.80332 | 4.49335 | 6.06301 |
| 1968 | 0.75791 | 4.53944 | 5.93380 |
| 1969 | 0.71522 | 4.59243 | 6.45505 |
| 1970 | 0.67734 | 5.05472 | 7.11851 |

TABLE 43: AVERAGE NET PRODUCTIVITY OF ANNUAL TOTAL CASH OUTLAYS BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 1.80027 | 0.96850 | 0.27495 |
| 1961 | 1.76973 | 1.41538 | 0.41479 |
| 1962 | 1.75474 | 1.44249 | 0.37939 |
| 1963 | 1.73887 | 1.33513 | 0.40887 |
| 1964 | 1.72213 | 1.29796 | 0.42852 |
| 1965 | 1.73319 | 1.22634 | 0.49145 |
| 1966 | 1.71525 | 1.22770 | 0.51509 |
| 1967 | 1.70090 | 1.29414 | 0.53640 |
| 1968 | 1.68780 | 1.25566 | 0.45477 |
| 1969 | 1.67421 | 1.05935 | 0.44804 |
| 1970 | 1.66254 | 1.26392 | 0.47417 |

SOURCE: MODEL RESULTS

TABLE 44: AVERAGE NET PRODUCTIVITY OF TOTAL CAPITAL STOCK (IN CR$ AT 1970 PRICES) BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.222 | 0.168 | 0.063 |
| 1961 | 0.227 | 0.202 | 0.090 |
| 1962 | 0.232 | 0.208 | 0.084 |
| 1963 | 0.240 | 0.205 | 0.089 |
| 1964 | 0.247 | 0.206 | 0.093 |
| 1965 | 0.257 | 0.204 | 0.106 |
| 1966 | 0.267 | 0.208 | 0.111 |
| 1967 | 0.276 | 0.216 | 0.115 |
| 1968 | 0.287 | 0.215 | 0.099 |
| 1969 | 0.300 | 0.201 | 0.098 |
| 1970 | 0.316 | 0.224 | 0.106 |

TABLE 45: YEARLY CHANGE IN TOTAL CAPITAL STOCK AND GROSS OUTPUT (IN MILLION CR$ AT 1970 PRICES) BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | | MEDIUM FARM | | LARGE FARM | |
|---|---|---|---|---|---|---|
| | $\Delta K$ | $\Delta Y$ | $\Delta K$ | $\Delta Y$ | $\Delta K$ | $\Delta Y$ |
| 1961 | 0.35 | 2.599 | 1.88 | 4.282 | 5.04 | 8.589 |
| 1962 | 0.78 | 2.973 | 6.10 | 7.243 | 14.45 | 12.994 |
| 1963 | 0.95 | 4.246 | 15.24 | 8.834 | 15.24 | 14.875 |
| 1964 | 2.95 | 4.775 | 21.76 | 10.888 | 21.76 | 20.518 |
| 1965 | 1.42 | 4.511 | 15.83 | 14.551 | 13.61 | 12.660 |
| 1966 | 5.39 | 6.822 | 16.35 | 13.640 | 13.95 | 11.825 |
| 1967 | 6.87 | 8.056 | 8.28 | 7.191 | 15.06 | 11.050 |
| 1968 | 8.75 | 9.705 | 10.59 | 9.221 | 53.77 | 38.010 |
| 1969 | 8.27 | 10.807 | 26.30 | 25.408 | 49.78 | 49.575 |
| 1970 | 7.79 | 11.990 | 9.70 | 8.374 | 45.71 | 44.097 |

Where $\Delta K$ is a yearly change in value of total capital stock (value of quasi-fixed capital stock and land in use) and $\Delta Y$ is a yearly change in value of gross output.

TABLE 46: INCREMENTAL CAPITAL-OUTPUT RATIOS (ICOR AT CONSTANT 1970 PRICES) BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1961 | .135 | 0.439 | 0.586 |
| 1962 | .262 | 0.842 | 1.112 |
| 1963 | .224 | 1.725 | 1.025 |
| 1964 | .618 | 1.998 | 1.061 |
| 1965 | .315 | 1.088 | 1.075 |
| 1966 | .790 | 1.199 | 1.179 |
| 1967 | .853 | 1.151 | 1.362 |
| 1968 | .902 | 1.148 | 1.415 |
| 1969 | 0.765 | 1.035 | 1.004 |
| 1970 | 0.649 | 1.158 | 1.037 |

$$\text{Where: ICOR} = \frac{\{\text{Total Capital Stock}(t) - \text{Total Capital Stock}(t-1)\}}{\{\text{Gross Output}(t) - \text{Gross Output}(t-1)\}}$$

TABLE 47: AVERAGE NET PRODUCTIVITY OF WORKING CAPITAL BY FARM SIZE (IN CR$): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 1.80257 | 1.04049 | 0.30510 |
| 1961 | 1.78398 | 1.54023 | 0.43127 |
| 1962 | 1.76980 | 1.51897 | 0.39906 |
| 1963 | 1.75495 | 1.46145 | 0.43544 |
| 1964 | 1.73939 | 1.42997 | 0.46332 |
| 1965 | 1.74930 | 1.37760 | 0.51943 |
| 1966 | 1.73479 | 1.35835 | 0.54404 |
| 1967 | 1.72154 | 1.38413 | 0.56446 |
| 1968 | 1.70958 | 1.36693 | 0.51040 |
| 1969 | 1.69715 | 1.24366 | 0.50769 |
| 1970 | 1.68645 | 1.33571 | 0.52670 |

SOURCE: MODEL RESULTS

TABLE 48: AVERAGE LABOR HOURS PER HECTARE BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 45.09198 | 16.30865 | 7.70702 |
| 1961 | 50.33842 | 15.73320 | 7.64449 |
| 1962 | 56.56548 | 16.03447 | 7.93472 |
| 1963 | 63.32358 | 16.34778 | 7.88887 |
| 1964 | 70.90359 | 16.60513 | 7.88725 |
| 1965 | 76.66129 | 16.77719 | 7.88455 |
| 1966 | 85.93181 | 16.87285 | 7.91706 |
| 1967 | 96.24040 | 17.11131 | 7.98382 |
| 1968 | 107.59518 | 17.33446 | 8.20327 |
| 1969 | 121.12241 | 17.54118 | 8.51679 |
| 1970 | 136.80930 | 17.72646 | 8.86501 |

TABLE 49: AVERAGE DRAFT ANIMAL HOURS EMPLOYED PER HECTARE BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 5.47583 | 1.25787 | 0.0 |
| 1961 | 6.20191 | 1.19371 | 0.0 |
| 1962 | 7.01943 | 1.20842 | 0.0 |
| 1963 | 7.92992 | 1.24476 | 0.0 |
| 1964 | 8.95135 | 1.27735 | 0.0 |
| 1965 | 9.71072 | 1.29302 | 0.0 |
| 1966 | 10.95933 | 1.27020 | 0.0 |
| 1967 | 12.34778 | 1.26753 | 0.0 |
| 1968 | 13.87768 | 1.29109 | 0.0 |
| 1969 | 15.70113 | 1.29465 | 0.0 |
| 1970 | 17.81435 | 1.30692 | 0.0 |

TABLE 50: AVERAGE TRACTOR HOURS EMPLOYED PER HECTARE BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.0 | 0.47287 | 0.60313 |
| 1961 | 0.0 | 0.53381 | 0.67126 |
| 1962 | 0.0 | 0.62311 | 0.79119 |
| 1963 | 0.0 | 0.71164 | 0.89820 |
| 1964 | 0.0 | 0.81583 | 1.04547 |
| 1965 | 0.0 | 0.95050 | 1.14181 |
| 1966 | 0.0 | 1.09434 | 1.23595 |
| 1967 | 0.0 | 1.18282 | 1.32768 |
| 1968 | 0.0 | 1.26649 | 1.62906 |
| 1969 | 0.0 | 1.52373 | 2.01801 |
| 1970 | 0.0 | 1.59571 | 2.36701 |

TABLE 51: TOTAL ANNUAL CAPITAL EXPENDITURES (IN CONSTANT 1970 CR$) PER HECTARE BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 32.48860 | 48.29286 | 76.02339 |
| 1961 | 34.00600 | 40.96034 | 71.96217 |
| 1962 | 35.41063 | 42.46396 | 79.02780 |
| 1963 | 37.16032 | 46.96756 | 81.32455 |
| 1964 | 39.02586 | 50.71742 | 86.67267 |
| 1965 | 40.54146 | 56.17001 | 86.74149 |
| 1966 | 42.89552 | 59.41571 | 89.65649 |
| 1967 | 45.45340 | 59.41185 | 90.24236 |
| 1968 | 48.31601 | 62.66701 | 107.03584 |
| 1969 | 51.74306 | 76.04323 | 122.70345 |
| 1970 | 55.73784 | 70.89209 | 133.08694 |

SOURCE: MODEL RESULTS

TABLE 52: GROSS NEW INVESTMENT CAPITAL (IN CONSTANT 1970 CR$) PER HECTARE BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.04147 | 3.34128 | 7.51151 |
| 1961 | 0.27176 | 3.32020 | 2.74672 |
| 1962 | 0.30126 | 2.13806 | 3.84513 |
| 1963 | 0.34035 | 4.05970 | 4.96207 |
| 1964 | 0.38727 | 4.68187 | 6.51040 |
| 1965 | 0.37341 | 6.16738 | 4.67250 |
| 1966 | 0.48321 | 5.71509 | 4.71698 |
| 1967 | 0.54472 | 3.86260 | 4.48669 |
| 1968 | 0.61537 | 5.10100 | 11.66562 |
| 1969 | 0.69937 | 11.26931 | 14.41582 |
| 1970 | 0.79024 | 4.79937 | 13.27248 |

TABLE 53: AVERAGE WORKING CAPITAL USE (IN CONSTANT 1970 CR$) PER HECTARE BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 32.44713 | 44.95155 | 68.51187 |
| 1961 | 33.73425 | 37.64014 | 69.11545 |
| 1962 | 35.10936 | 40.32590 | 74.18265 |
| 1963 | 36.81998 | 42.90787 | 76.38247 |
| 1964 | 38.63858 | 46.03552 | 80.16225 |
| 1965 | 40.16805 | 50.00262 | 02.06897 |
| 1966 | 42.41231 | 53.70061 | 83.93951 |
| 1967 | 44.90868 | 55.54921 | 85.75565 |
| 1968 | 47.70064 | 57.56598 | 95.37022 |
| 1969 | 51.04370 | 64.77391 | 108.28761 |
| 1970 | 54.94760 | 66.09268 | 119.81445 |

TABLE 54: TOTAL OUTLAYS ON NUTRIENTS PER HECTARE BY FARM SIZE (IN CONSTANT 1970 CR$/HA): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL(1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 5.90935 | 6.51835 | 6.72848 |
| 1961 | 6.66882 | 6.97157 | 7.45930 |
| 1962 | 7.48506 | 8.31793 | 8.85375 |
| 1963 | 8.50589 | 9.38143 | 10.08489 |
| 1964 | 9.59407 | 10.67104 | 11.84971 |
| 1965 | 10.35387 | 12.33639 | 12.66108 |
| 1966 | 11.67422 | 13.94109 | 13.25811 |
| 1967 | 13.14082 | 14.60487 | 13.59564 |
| 1968 | 14.77576 | 15.20196 | 17.00526 |
| 1969 | 16.72910 | 15.25310 | 21.50851 |
| 1970 | 18.99223 | 18.40045 | 25.04375 |

TABLE 55: TOTAL OUTLAYS ON NUTRIENTS AS A PERCENTAGE OF TOTAL WORKING CAPITAL BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL(1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 18.21222 | 14.50084 | 9.82090 |
| 1961 | 19.76868 | 18.52162 | 10.79252 |
| 1962 | 21.31927 | 20.62677 | 11.93506 |
| 1963 | 23.10129 | 21.86412 | 13.20650 |
| 1964 | 24.83028 | 23.17999 | 14.78716 |
| 1965 | 25.77637 | 24.67148 | 15.42736 |
| 1966 | 27.52553 | 25.96075 | 15.79483 |
| 1967 | 29.26118 | 26.29176 | 15.85392 |
| 1968 | 30.97600 | 26.40787 | 17.83078 |
| 1969 | 32.77408 | 28.17970 | 19.86240 |
| 1970 | 34.56429 | 27.84038 | 20.90211 |

SOURCE: MODEL RESULTS

TABLE 56: RATIOS OF DRAFT ANIMAL/LABOR HOURS EMPLOYED BY FARM SIZE WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.12144 | 0.07713 | 0.0 |
| 1961 | 0.12320 | 0.07587 | 0.0 |
| 1962 | 0.12409 | 0.07536 | 0.0 |
| 1963 | 0.12523 | 0.07614 | 0.0 |
| 1964 | 0.12625 | 0.07692 | 0.0 |
| 1965 | 0.12667 | 0.07707 | 0.0 |
| 1966 | 0.12754 | 0.07528 | 0.0 |
| 1967 | 0.12830 | 0.07408 | 0.0 |
| 1968 | 0.12898 | 0.07448 | 0.0 |
| 1969 | 0.12963 | 0.07381 | 0.0 |
| 1970 | 0.13021 | 0.07373 | 0.0 |

TABLE 57: RATIOS OF TRACTOR/LABOR HOURS EMPLOYED BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.0 | 0.02899 | 0.07826 |
| 1961 | 0.0 | 0.03393 | 0.08781 |
| 1962 | 0.0 | 0.03886 | 0.09971 |
| 1963 | 0.0 | 0.04353 | 0.11386 |
| 1964 | 0.0 | 0.04913 | 0.13264 |
| 1965 | 0.0 | 0.05665 | 0.14482 |
| 1966 | 0.0 | 0.06486 | 0.15611 |
| 1967 | 0.0 | 0.06913 | 0.16630 |
| 1968 | 0.0 | 0.07306 | 0.19859 |
| 1969 | 0.0 | 0.08687 | 0.23694 |
| 1970 | 0.0 | 0.09002 | 0.26701 |

TABLE 58: AVERAGE ANNUAL TOTAL CAPITAL EXPENDITURES (IN CONSTANT 1970 CR$) PER LABOR HOUR BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.72050 | 2.96118 | 9.86417 |
| 1961 | 0.67555 | 2.60343 | 9.40052 |
| 1962 | 0.62601 | 2.64829 | 9.83372 |
| 1963 | 0.58683 | 2.87302 | 10.30877 |
| 1964 | 0.55041 | 3.05432 | 10.99593 |
| 1965 | 0.52884 | 3.34800 | 11.00145 |
| 1966 | 0.49918 | 3.52138 | 11.19816 |
| 1967 | 0.47229 | 3.47208 | 11.30316 |
| 1968 | 0.44905 | 3.61517 | 13.04795 |
| 1969 | 0.42720 | 4.33512 | 14.40724 |
| 1970 | 0.40741 | 3.99922 | 15.01261 |

TABLE 59: AVERAGE ANNUAL WORKING CAPITAL (IN CONSTANT 1970 CR$) PER LABOR HOUR BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.71958 | 2.75630 | 8.88954 |
| 1961 | 0.67015 | 2.39240 | 9.04121 |
| 1962 | 0.62069 | 2.51495 | 9.34912 |
| 1963 | 0.58146 | 2.62469 | 9.67977 |
| 1964 | 0.54495 | 2.77236 | 10.16997 |
| 1965 | 0.52397 | 2.98039 | 10.40883 |
| 1966 | 0.49356 | 3.18266 | 10.60236 |
| 1967 | 0.46663 | 3.24634 | 10.74118 |
| 1968 | 0.44333 | 3.32090 | 11.62588 |
| 1969 | 0.42142 | 3.69267 | 12.71460 |
| 1970 | 0.40164 | 3.72848 | 13.51343 |

SOURCE: MODEL RESULTS

TABLE 60: BORROWING/INTERNAL CAPITAL FINANCING RATIOS BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.0 | 0.0 | 0.0 |
| 1961 | 0.0 | 0.0 | 0.0 |
| 1962 | 0.0 | 0.0 | 0.0 |
| 1963 | 0.04235 | 0.0 | 0.05833 |
| 1964 | 0.30862 | 0.21851 | 0.37868 |
| 1965 | 0.25552 | 0.30965 | 0.34728 |
| 1966 | 0.32877 | 0.46814 | 0.37517 |
| 1967 | 0.11486 | 0.33083 | 0.19954 |
| 1968 | 0.0 | 0.23077 | 0.32879 |
| 1969 | 0.05329 | 0.67354 | 0.92940 |
| 1970 | 0.14793 | 1.25709 | 2.29388 |

TABLE 61: TOTAL CREDIT USE AS A PERCENTAGE OF TOTAL CASH OUTLAYS BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.0 | 0.0 | 0.0 |
| 1961 | 0.0 | 0.0 | 0.0 |
| 1962 | 0.0 | 0.0 | 0.0 |
| 1963 | 4.06292 | 0.0 | 5.51116 |
| 1964 | 23.58351 | 17.93250 | 27.46693 |
| 1965 | 20.35156 | 23.64398 | 25.77629 |
| 1966 | 24.74261 | 31.88666 | 27.28156 |
| 1967 | 10.30285 | 24.85899 | 16.63445 |
| 1968 | 0.0 | 18.75037 | 24.74339 |
| 1969 | 5.05933 | 40.24658 | 48.17041 |
| 1970 | 12.88688 | 55.69518 | 69.64063 |

TABLE 62: AVERAGE CREDIT USE/LABOR HOUR RATIOS BY FARM SIZE(IN CONSTANT 1970 CR$/HR): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.0 | 0.0 | 0.0 |
| 1961 | 0.0 | 0.0 | 0.0 |
| 1962 | 0.0 | 0.0 | 0.0 |
| 1963 | 0.03962 | 0.0 | 0.63852 |
| 1964 | 0.17125 | 0.76693 | 2.90967 |
| 1965 | 0.16453 | 1.36288 | 3.39930 |
| 1966 | 0.19801 | 2.01989 | 3.84617 |
| 1967 | 0.06160 | 1.32542 | 2.04895 |
| 1968 | 0.0 | 0.98307 | 3.58248 |
| 1969 | 0.02524 | 2.55147 | 7.83581 |
| 1970 | 0.05249 | 2.79967 | 10.24030 |

TABLE 63: AVERAGE CREDIT USE PER HECTARE BY FARM SIZE (IN CONSTANT 1970 CR$/HR): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.0 | 0.0 | 0.0 |
| 1961 | 0.0 | 0.0 | 0.0 |
| 1962 | 0.0 | 0.0 | 0.0 |
| 1963 | 2.50914 | 0.0 | 5.03719 |
| 1964 | 12.14240 | 12.73495 | 22.93477 |
| 1965 | 12.61318 | 22.86534 | 26.80197 |
| 1966 | 17.01550 | 34.08128 | 30.45039 |
| 1967 | 5.92801 | 22.67973 | 16.35843 |
| 1968 | 0.0 | 17.04105 | 29.38800 |
| 1969 | 3.05707 | 44.75575 | 66.73596 |
| 1970 | 7.18128 | 49.62820 | 90.78040 |

SOURCE: MODEL RESULTS

TABLE 64: AVERAGE GROSS FARM INCOME (IN 1000 CR$ AT 1970 PRICES) WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 1.60251 | 16.88405 | 58.08542 |
| 1961 | 1.57745 | 16.67152 | 58.16742 |
| 1962 | 1.55742 | 16.77263 | 59.35413 |
| 1963 | 1.55447 | 17.00060 | 61.24211 |
| 1964 | 1.55749 | 17.38893 | 63.58951 |
| 1965 | 1.55355 | 18.06824 | 64.04236 |
| 1966 | 1.57707 | 18.57657 | 64.15712 |
| 1967 | 1.61167 | 18.51241 | 63.03705 |
| 1968 | 1.65933 | 18.45760 | 69.51994 |
| 1969 | 1.71319 | 19.75566 | 76.89293 |
| 1970 | 1.77262 | 19.58929 | 82.41331 |

TABLE 65: AVERAGE NET FARM INCOME (IN 1000 CR$ AT 1970 PRICES) WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 1.03024 | 8.30696 | 12.52662 |
| 1961 | 1.00792 | 9.76928 | 17.05359 |
| 1962 | 0.99206 | 9.90560 | 16.32495 |
| 1963 | 0.98691 | 9.72023 | 17.77306 |
| 1964 | 0.98533 | 9.82182 | 19.07510 |
| 1965 | 0.98515 | 9.95258 | 21.10277 |
| 1966 | 0.99625 | 10.23766 | 21.81174 |
| 1967 | 1.01495 | 10.44297 | 22.00798 |
| 1968 | 1.04197 | 10.27483 | 21.73230 |
| 1969 | 1.07256 | 10.16253 | 23.79161 |
| 1970 | 1.10686 | 10.93649 | 26.50838 |

TABLE 66: AVERAGE GROSS RETURNS TO AVAILABLE FAMILY LABOR PER HOUR BY FARM SIZE (IN 1000 CR$ AT 1970 PRICES): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.53525 | 6.22614 | 23.86992 |
| 1961 | 0.53891 | 6.28822 | 24.44861 |
| 1962 | 0.54422 | 6.47038 | 25.52263 |
| 1963 | 0.55578 | 6.70880 | 26.76556 |
| 1964 | 0.56940 | 7.01862 | 28.59843 |
| 1965 | 0.58093 | 7.45929 | 29.46367 |
| 1966 | 0.60319 | 7.84450 | 30.19200 |
| 1967 | 0.63032 | 7.96537 | 30.79639 |
| 1968 | 0.66398 | 8.15449 | 34.22751 |
| 1969 | 0.70120 | 8.92749 | 38.66666 |
| 1970 | 0.74210 | 9.05387 | 42.40213 |

TABLE 67: AVERAGE NET RETURNS TO AVAILABLE FAMILY LABOR PER HOUR BY FARM SIZE (IN 1000 CR$ AT 1970 PRICES): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| YEAR | SMALL FARM | MEDIUM FARM | LARGE FARM |
|---|---|---|---|
| 1960 | 0.34411 | 3.06326 | 5.14775 |
| 1961 | 0.34434 | 3.68481 | 7.16788 |
| 1962 | 0.34666 | 3.82129 | 7.01983 |
| 1963 | 0.35286 | 3.83581 | 7.76763 |
| 1964 | 0.36022 | 3.96434 | 8.57875 |
| 1965 | 0.36838 | 4.10882 | 9.70866 |
| 1966 | 0.38104 | 4.32315 | 10.26449 |
| 1967 | 0.39695 | 4.49332 | 10.75188 |
| 1968 | 0.41695 | 4.53937 | 10.69970 |
| 1969 | 0.43899 | 4.59240 | 11.96394 |
| 1970 | 0.46338 | 5.05468 | 13.63871 |

SOURCE: MODEL RESULTS

TABLE 68: AVERAGE NET FARM INCOME BY FARM SIZE AS A PROPORTION OF SMALL FARMS' AVERAGE NET FARM INCOME: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| Year | Small Farm | Medium Farm | Large Farm |
|---|---|---|---|
| 1960 | 1.0 | 8.06 | 12.16 |
| 1961 | 1.0 | 9.69 | 16.92 |
| 1962 | 1.0 | 9.98 | 16.46 |
| 1963 | 1.0 | 9.84 | 18.01 |
| 1964 | 1.0 | 9.96 | 19.36 |
| 1965 | 1.0 | 10.10 | 21.41 |
| 1966 | 1.0 | 10.28 | 21.89 |
| 1967 | 1.0 | 10.29 | 21.68 |
| 1968 | 1.0 | 9.86 | 20.86 |
| 1969 | 1.0 | 9.48 | 22.18 |
| 1970 | 1.0 | 9.88 | 23.95 |

Source: Model results.

TABLE 69: AVERAGE NET RETURNS TO AVAILABLE FAMILY LABOR PER HOUR BY FARM SIZE AS A PROPORTION OF SMALL FARMS' AVERAGE NET RETURN TO AVAILABLE FAMILY LABOR PER HOUR: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1970)

| Year | Small Farm | Medium Farm | Large Farm |
|---|---|---|---|
| 1960 | 1.0 | 8.90 | 14.96 |
| 1961 | 1.0 | 10.70 | 20.82 |
| 1962 | 1.0 | 11.09 | 20.25 |
| 1963 | 1.0 | 10.87 | 22.02 |
| 1964 | 1.0 | 11.01 | 23.82 |
| 1965 | 1.0 | 11.16 | 26.36 |
| 1966 | 1.0 | 11.35 | 26.94 |
| 1967 | 1.0 | 11.32 | 27.10 |
| 1968 | 1.0 | 10.89 | 25.66 |
| 1969 | 1.0 | 10.46 | 27.25 |
| 1970 | 1.0 | 10.91 | 29.43 |

Source: Model results.

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