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"A RECURSIVE PROGRAMMING MODEL OF AGRICULTURAL DEVELOPMENT WITH FARM SIZE DECOMPOSITION: A CASE STUDY OF SOUTHERN BRAZIL"

by

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OUTLINE

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1. INTRODUCTION

The purpose of this paper is twofold:

1) to develop and describe a dynamic microeconomic model of regional agricultural development that explicitly includes different farm sizes with the help of a recursive programming model that incorporates the principles of decomposition and 2) to report some preliminary results for the wheat regions of the state of Rio Grande do Sul in Southern Brazil from 1960-1969. The resulting framework of analysis is similar to the models of regional agricultural development pioneered by Day (1963), further extended by Heidhues (1966) and recently applied to agriculture in transition in the LDC's by Singh (1971). The model presented here, although following directly the main methodological improvements of its predecessors, goes beyond by relaxing the usual assumptions of homogeneous farm size over which farms in a given region are

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* The major portions of the model building and computer simulations for this study were carried out under the directions of Professor I. J. Singh (Department of Economics and Agricultural Economics, Ohio State University), at the Department of Economics and the Social Systems Research Institute, University of Wisconsin, Madison, during the summer of 1971, under a CIC Exchange Program of Graduate Study in which the author participated. I would like to thank Professor Richard H. Day for providing me with the opportunity to work at the University of Wisconsin with him and his colleagues, especially Professor Gerriet P. Müeller, without whose assistance with the Recursive Decision Systems Processor the computer work for this study could never have been completed in a short summer. I would also like to thank Professors Francis E. Walker, Norman Rask, Dale Adams and Richard L. Meyer for their guidance and continued encouragement. I would like to thank Professor Singh for looking through this draft and its organization.

aggregated to obtain a regional model for analysis. Instead it explicitly treats the farm size issue by considering different farm size aggregates, with different resource availabilities and factor proportions, but facing a similar exogenously given economic environment, and competing for scarce regional resources. With the explicit introduction of farm size differences through the decomposition principle of linear programming, it attempts to arrive at a framework capable of treating dynamically, the differential time paths of development among different farm size groups.

The general focus of the model is the decision making process at the farm operator level in a farm-firm with the resulting interdependence of production consumption and investment decisions.[1/] These decisions are made within the economic, physical and institutional constraints 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 decisions are aggregatable, and in the aggregates represent regional behaviour and production response.[2/] However, unless farm units are also fairly homogeneous 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 one of the purposes of this study to construct an analytical framework that minimizes the possibility of such errors by explicitly treating different farm size with different

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1/ 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 (1971). Also see Day and Singh (1971).

2/ See Day (1963), Day (1969), and Day and Singh (1971).

factor endowments.[3/]

The importance of farm size and its relation to such factors as economies of scale, risk and uncertainty and market response has long been emphasized by many economists (Steindl (1945), Hicks (1948) Heady (1952)). Heady suggests that the difference in farm size is one of 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.[4/]

More recently, with the growing interest in agricultural development in the LDC's, it has been suggested that due to the nature of subsistence production,[5/] the decision making process of a subsistence farm with a few hectares would be significantly different from that of a large farm with several hundred hectares.[6/] Large farms in general have greater access to various economic opportunities through their greater access to knowledge of new technologies, and factor and credit markets due to their greater degree of commercialization

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3/ 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 (1971)), aggregation is somewhat excusable, but where differences in farm size are very large, aggregation errors become serious.

4/ See Heady, (1952, ch. 18)

5/ That is where a large proportion of the farm output is retained for family consumption and a large proportion of the total labor input is family labor. See I. J. Singh (1969), C. Wharton, Jr. (1969) and Nakajima (1965) for a more detailed exposition on the nature of subsistence production and its implications for economic analysis of agricultural production.

6/ For example, in a programming model the lexicographic ordering of utility functions for subsistence farms differ from the commercial large farms. The former may place the highest priority in meeting subsistence consumption level but the latter in maximizing net profit. For the lexicographic ordering of utility functions, see Day and Singh (1971).

and asset structure. These allow them to bring about the reorganization of the farm structure in response to changes in input and output prices and other economic factors in the region. Therefore the farm size and the resulting resource base it provides is a crucial fact upon which production, consumption and investment decisions depend. The explicit incorporation of differences in farm size are fundamental to a proper understanding of the vast hetrogeneity in agricultural development even in a region homogenous with respect to all factors physical, climatic, and economic, exogenous to the farm-firm, where large differences in farm size exist.

The next section presents some of the recent developments in agriculture in Southern Brazil, and a brief regional description which provide an insight into the factors strategic to this development process which we wish to incorporate in our analysis; Section 3 gives the methodology of the R.L.P. model constructed to incorporate these factors; Section 4 gives a very brief description of the data sources; Section 5 reports some preliminary model results for the wheat regions of the state of Rio Grande Do Sul in Southern Brazil from 1960 - 1969; the last section is devoted to a statement on the limitations of the current analysis and items of model extension and improvement to which further research will be directed, in order to overcome some of these limitations.

2. REGIONAL AGRICULTURAL DEVELOPMENT IN SOUTHERN BRAZIL.

The setting for this study are the two adjacent regions called Planalto Medio and Missoes in the state of Rio Grande Do Sul in Southern Brazil. These regions are fairly homogeneous in regard to topography, climate and general agricultural practices. The Planalto Medio (a plateau region) and the Missoes (a lowland region) together comprise about one fourth of the land area of Rio Grande Do Sul, a state that accounts for over 90 percent of the total domestic wheat production in Brazil. Since these regions account for most of the wheat production in Rio Grande Do Sul, we refer to them as "the wheat region of Rio Grande Do Sul" in this study.

2.1 AGRICULTURAL POLICIES AND REGIONAL TRANSFORMATION

In the recent half decade or so, not only has Southern Brazil experienced one of the highest rates of growth in total agricultural output in the world (in excess of 8 percent annually), but the wheat regions of the state of Rio Grande Do Sul have played an important part in this performance.
This performance has been a result of two principal policy instruments 1) price supports for wheat at twice the international price and 2) a subsidized credit program, both designed to increase wheat production. These specific agricultural policies initiated in 1962-63 under a program to increase Brazilian self sufficiency in wheat have brought about a dramatic agricultural transformation of the region whose main features include 1) a shift from the traditional livestock production on extensive natural pastures to intensive cropping of wheat and soybeans and intensive livestock production on improved pasture systems and 2) a consequent increase in mechanized crop farming. This two dimensional transformation -- from extensive livestock to intensive crop farming and from crop farming on non-mechanized to mechanized

farming -- have been accompanied by a substantial increase in the use of modern inputs such as certified seeds, inorganic fertilizers, machine use, credit use and employment. 7/

Engler and Singh in a recent study of the specific impact of these pricing and credit policies have described the changes brought about by these policies as follows:

"The data show that the area under wheat cultivation has increased sevenfold in the eight years since the wheat program was initiated, domestic production has increased over sevenfold since 1964-1965, while per hectare yields have varied from year to year. The total impacts of wheat which have remained in the 2 - 2.5 million metric ton range from 1962-1963 to 1968-1969 have shown a substantial decline in the last two years, while the percentage of total domestic requirements provided by domestic production have increased from an average of about 10% in the 1962-1967 period to our estimated 50% in 1970-1971." 8/ The amount of credit used in the state of Rio Grande do Sul between 1965-1969 increased 238% in real terms.

2.2. THE IMPORTANCE OF FARM SIZE.

In terms of a regional analysis, even though the regions of the Planalto Medio and the Missoes are fairly homogenous, they incorporate a wide distribution of farm sizes as shown in Table 1. As a result of these large differences in farm size, we would expect the resulting differences in resource endowments

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7/ For a detailed description of this transformation process in Southern Brazil see N. Rask (1969) and for a description of the Brazilian program to increase self-sufficiency in wheat and the related policies see Richard Meyer (1971).

8/ See J. J. De C. Engler and I. J. Singh (1971, p.3)

Table 1

Farm Size Distribution In the Planalto Medio
and Missoes Regions of Southern Brazil in 1967

Class by Hectares	Number of Farms	Total Farm Area	% Of Farm Area	Area Exploited
0-10	27,479	146,955	2.56	135,771
10-25	37,575	661,771	11.53	617,384
25-50	15,807	572,528	9.98	541,606
50-100	7,485	528,153	9.20	506,092
100-1000	7,558	2,154,996	37.41	2,112,646
1000-10,000	729	2,581,101	27.56	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
% 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
DELEGACIA REGIONAL DO RIO GRANDE DO SUL--

Also see N. Rask (1971, p. 24-30)

to bring about differences in response to regional economic opportunities as brought about say by the impact of the pricing and credit policies discussed earlier. Among the expected differential responses to these impacts, we could list at least the following:

1) Larger farms operating on a larger scale, and with higher farm incomes, generate 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.[9/]

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

9/ 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.

(3) Farms of different size may choose equipment of different size due to the technical economies of scale inherent in the equipment, or if we consider equipment of the same size we can expect the rates of investments in capacities to differ among different farm size groups in a region.

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

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

These and other factors make it essential that given the large differences in farm size observed in Southern Brazil, we treat different farm size groups explicitly in order to capture the large structural and behavioral differences among farms in a region that lead to differential responses to market and policy changes and to differences in the patterns of production, consumption and investment. A regional model that accounts for differences in farm size would be able to predict important differences with regard to technical change, cropping patterns, employment, resource use and farm specialization in the region.

2.3. ADDITIONAL STRATEGIC DETAILS

In addition to the importance of farm size, there are other strategic details that have to be incorporated in a model of supply response in developing agriculture. These include the details of technology, decision making and market feedback and have been discussed thoroughly by Day (1962), Singh (1969, 1970, 1971) and Day and Singh (1971), and which we wish to incorporate into this analysis. Briefly the technological details include the explicit treatment of mechanical technology, the use of chemical nutrients and the adoption of new power sources, the use of new improved seeds and cultural practices: the details of decision making include the competition of consumption, investment and production decisions for scarce financial resources, and the details of market feedback including adoption and adjustment in response to risk and uncertainty.[10/]

We now turn to developing and describing a methodology that integrates the details of farm size with the other details strategic to the analysis of agricultural development.

10/ For an elaborate discussion of some of the factors considered strategic to the analysis of production response in traditional and commercialized agriculture, see R. H. Day (1962) and I. J. Singh (1970). For their explicit incorporation into a programming framework, see R. H. Day (1963) and I. J. Singh (1971).

3. A RECURSIVE PROGRAMMING MODEL WITH FARM SIZE DECOMPOSITION

3.1 INTRODUCTION

Mathematical programming has been widely used by many economists to analyze the economic behavior of farm-firms at the microeconomic level at any point in time. Further, the firms' decision making process involves dynamic characteristics. Current decisions are functionally related to the decisions made in the past as well as the expectation of future relevant economic variables such as prices of outputs and inputs. That is, a description of actual behavior is "backward looking" because it involves the interaction between present and past outcomes. But the production plans are "forward looking" because decisions made in the present will affect the future and because anticipated future actions will condition present behavior. Thus all decision making is encompassed by time.

With regard to the dynamics of agricultural production, Day introduced a new programming approach, called "Recursive Programming." The recursive programming approach is based on explicit hypotheses about a firms' sequential optimizing behavior, subject to behavioral feedback constraints which take account of uncertainty, myopia, limited information and the like. The method deals with the temporal elements of decision making and not with how decisions ought to be made in terms of some optimum or normative decision rules. In this framework Day suggests that a dynamic microeconomic model of agricultural production should be able to explain the following features of farm behavior:[11]

(1) describe farm production and how it changes over time;

11/ Richard H. Day and Theodor Heidhues (1967), and Day (1967).

(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;

(4) illustrate essential features of agricultural development such as changing technology and irreversible changes in resource allocation; to these we might add:

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

The relevance of the programming approach in analyzing these complex simultaneous relationships becomes obvious when we view on-farm decisions as decisions with regard to alternative production, consumption and investment activities carried out within the physical, biological and economic constraints in order to achieve a given objective. The objectives, the activities and the constraints that define them fit readily into a programming framework. We now consider each of these in turn.

3.2 REGIONAL FARM ACTIVITIES

The farm activities for this study are categorized into four basic sets. They are production, investment, purchasing and financial activities and denoted respectively by P, V, C, and F. Denoting all farm activities by A, then $A = P \cup V \cup C \cup F$ with the total number of activities $a = p + v + c + f$ where small letters denote the number of activities corresponding to the capital letter activity sets.[12/] An activity, say activity j, belonging to a given

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12/ I have adopted the set notations used by Day and Singh (1971), and will use it throughout. This is extremely convenient in describing model structure without losing the detailed picture of linear inequality equation systems.

set, say P will be written $j \varepsilon P$. If we wish to refer to an activity without indicating a specific set we write $j \varepsilon A$. An activity level is defined to be the intensity with which a given activity is operated and is denoted by X_j, $j \varepsilon A$. Figure 2 presents a detailed structure of activity sets and their constraints.

Technological change is an important, if not the most important, factor responsible for economic development. Mansfield points out that "about 90 percent of the long-term increase in output per capita in the United States was attributable to technology, increased educational levels, and other factors not directly associated with increase in the quantity of labor and capital".[13/] In view of this important roles of technology in economic growth, the concept of "technology" has been a focal theme for understanding agricultural development (Schultz 1964, Hopper 1965, Hayami and Ruttan 1971) . For example, Schultz suggests that "a technology is embodied in particular factors and, therefore, in order to introduce a new technology it is necessary to employ a set of factors of production that differs from the set formerly employed."[14/] However during period of transition in agriculture, usually multiple technologies, say old and new, exist. Therefore we need to consider explicitly different sets of factors corresponding to existing technological choices. Among many classifications of technology,[15/] this study considers explicitly "mechanical technology", i.e. different power sources so that the

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13/ Mansfield (1969) p. 4.

14/ Schultz (1964) p. 132.

15/ Hayami and Ruttan classifies technology in agriculture development into two categories, mechanical and biological. See Hayami and Ruttan (1971), and I. J. Singh (1970, 1971).

set of production activities, P has two subsets D and T which represent respectively draft animal and tractor power sources. A detailed description of the activity set for farms of a given size is presented in Figure 1.

Figure 1: Activities, Input-Output Coefficients and Constraint Structure for Each Farm Size (Type)

Activities / Constraints	Production		Purchasing	Investment	Financial	RHS
	X_1--X_q	X'_1--X'_q			X_{n-1}, X_n	
Land by type and Season	a_{11}	a'_{11}	a_{13}			B_1 B_2
Labor by type and Season	a_{21}	a'_{21}	a_{23}			
Quasi-fixed capacities	a_{31}	a'_{31}		a_{35}		
Liquidity constraints	a_{41}	a'_{41}	a_{43}	a_{45}	a_{46}	
Outputs	a_{51}	a'_{51}				
Flexibility	a_{61}	a'_{61}				
Adoption	a_{71}	a'_{71}		a_{75}	a_{76}	B_{m-1} B_m
Regional binding constraints			a_{83}		a_{86}	B_{m+i}

The activity set Xj(t) has the following components:

(1) Production activities include crop enterprises (wheat, soybean, corn), improved pasture (summer, winter, and summer and winter pasture) and livestock enterprises involving land preparation, fertilizing, harvesting and selling. Each production activity has two technological choices such as draft animal technology and tractor technology. The former is denoted by X_q and the latter by X'_q.

(2) Purchasing activities include hiring of seasonal labor and buying of fertilizer and other modern inputs.

(3) Investment activities represent the purchase of new quasi-fixed capacities such as tractor, combine and draft animals.

(4) Financial activities include borrowing for modern inputs and machinery, debt repayment, and saving, and cash expenditures for consumption, purchasing and investment activities.

3.3 THE CONSTRAINT STRUCTURE

These activities are carried out subject to a set of physical, financial and behavioral constraints. The constraint structure at the farm level is divided into the six basic sets; a) land and labor by type and season, b) quasi-fixed capacities for various tasks by mechanical and draft animal operations; c) cash availability; d) balance equations of intermediate-final outputs; e) behavioral (learning) constraints; (f) regional binding resource constraint in which regional credit and wage labor are considered. Let us denote these sets in turn by L, K, M, E, D and R. The amount of land and labor available at the beginning of the year is represented by B_i, $i \varepsilon L$ for example. The use of these inputs is constrainted by the amounts available beginning of the year unless investment activities can augment them. Suppose A_{ij} is the amount of ith input requirements for jth activity, then the land-labor constraints can be written as follows:

(1) $$\Sigma_{j \varepsilon P} A_{ij} X_j(t) + \Sigma_{j \varepsilon C} A_{ij} X_j(t) \leq B_i(t), \quad i \varepsilon L$$

where the second term involves use of family labor available plus any hired labor via purchasing activity C.

The quasi-fixed capacities and variable inputs available on the farm constrain production and investment activities formulated in the context of the payback principle:

(2) $\Sigma_{j \varepsilon P} A_{ij} X_{j(t)} + \Sigma_{j \varepsilon V} A_{ij} X_{j(t)} \leq B_{i(t)}, \; i \varepsilon K$

The purchase of variable inputs and investments in additional capacities mechanical or animal, require cash. Financial activities increase working capital through borrowing and decrease it through short term debt repayment. Borrowing is of course limited by institutional banking rules. Financial constraints can then be specified as follows:

(3) $\Sigma_{j \varepsilon C} A_{ij} X_{j(t)} + \Sigma_{j \varepsilon V} A_{ij} X_{j(t)} + \Sigma_{j \varepsilon F} A_{ij} X_{j(t)} \leq B_{i(t)}, \; i \varepsilon F$

Balance equation constraints satisfy the condition that the amounts of intermediate outputs must be equated to the amounts of final output. The hectarage sown for soybean following wheat for example has to be less than or equal to the hectarage sown for wheat. Thus we write the balance equation constraints:

(4) $\Sigma_{j \varepsilon P} A_{ij} X_{j(t)} + \Sigma_{j \varepsilon V} A_{ij} X_{j(t)} \leq B_{i(t)}, \; i \varepsilon E$

The second term involves the requirement that cash available for investment activities must be equal to the cash expenditures on the purchase of investment goods.

Behavioral (learning) constraints are essential part in recursive programming approach in agricultural development, so they deserve more detailed discussion in a separate section.

All the farm activities by different farm size groups compete for <u>regional</u> binding resources i) wage labor and ii) credit which is one of the most important policy instruments. The former adds to family labor hours available through labor hiring activity and the latter auguments cash availability through borrowing activity. These lead us to write the regional resource constraints:

(5) $$\sum^{s}_{j\varepsilon C} A_{ij} X_{j(t)} + \sum^{s}_{j\varepsilon F} A_{ij} X_{j(t)} + \sum^{m}_{j\varepsilon C} A_{ij} X_{j(t)} + \sum^{m}_{j\varepsilon F} A_{ij} X_{j(t)} + \sum^{l}_{j\varepsilon C} A_{ij} X_{j}(t) + \sum^{l}_{j\varepsilon F} A_{ij} X_{j(t)} \leq B_{i(t)}, \; i\varepsilon R$$

where superscripts s, m and l represents small, medium and large farm size groups in the region.

3.4 OPTIMIZING CRITERIA AND DECOMPOSITION

The objective function describes the decision criteria of farm activities. As in any mathematical programming model a farm decision model has to have an optimizing criteria in order to choose among many alternative decision paths. In order to take account of the complex forces which govern the decisions of subsistance farmers Day and Singh (1971) suggest that a lexicographic ordering of goals is most useful. Following their analysis and leaving aside the subsistence consumption goal in the current model, we assume that farmers have three specific goals in a priority order; a) a utility function representing a preference ordering among current cash consumption b) a metric defining the distance of a given choice from a set of safe enough choice and c) net cash returns.16/ These sequential criterias are incorporated in the model by exogenously determing cash consumption expenditures to calculate cash availability, and by using flexibility and adoption constraints to define safe enough choices subject to which net cash returns are maximized.

Southern Brazilian agricultural setting is in many ways different from Asian agricultural structure to which the notion of subsistence agriculture has been applied. The degree of commercialization in Brazilian agriculture is much stronger than Asian counterpart.17/ Considering this fact we follow

16/ See Day and Singh (1971) for a detailed exposition of these goals.

17/ For Asian subsistence agriculture see Singh's (1971) Punjab study and Wharton's (1963) Malayan case study. For Agriculture in Southern Brazil see Rask (1968) and Schuh (1967).

the rule of maximizing short run profit (minimization of short run cost) in specifying our objective functions. We denote the objective functions for a period t by by farm size groups as $Z^{s}_{(t)}$ $Z^{m}_{(t)}$ and $Z^{l}_{(t)}$ where superscripts are defined as before. However the internal consumption of food grains on farm level and the reservation of animal fodders for draft animals are considered through the specification of feedback functions whose discussion follows later. Before considering the objective function in our model we turn to the decomposition principle and its use in our model.

As shown in Figure 2 the decomposition structure in a linear programming model is represented by non-empty matrices along the diagonal, and by null matrices in the off-diagonal zones both bordered at bottom by an array of non-empty matrices representing regional resource availability and competition along with a row of sub-vectors containing the objective functions. Of course each sub-vector in the objective function corresponds to the specific technology matrix A_{ij} of Figure 1. 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 both resources unique to each of the plants and common resources open for competition by each plant. 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. The decomposition principle in mathematical programming, related computer algorithms and empirical applications have been explored by many economists including Dantzig (1963), Baumol and Fabian (1964), Simmonard (1966) and Hiller and Lieberman (1967).

Figure 2
Brief Model Structure of Regional Farm Size Decomposition

						Resource Availability
Regional objective function →	$Z^s(t)$	+	$Z^m(t)$	+	$Z^1(t)$	↓
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		$A^1_{ij}(t)$	$\leq$ $B^1(t)$
Regional linking constraints →	$T^s_{kj}(t)$		$T^m_{kj}(t)$		$T^1_{kj}(t)$	$\leq$ $B^k(t)$

The first row contains the objective functions respectively 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, 1 and r represent the small, medium, large farm types and regional binding constraints. The subscript j denotes the number of activities, i for the number of resource constraints unique to each farm type, and k for the number of regional binding common resource constraints. The B vectors are resource limitations for each farm type and the upper limit of common regional resources.

The underlying theory of the decomposition principle is well suited to our regional analysis with farm size decomposition in agricultural development. We might consider each farm size group as branch plant in our previous example, which has initial differential resource endowments but eventually linked together to compete for regional binding scarce resources. These regional resources accessable to "everybody" in the present model include wage labor and credit. An individual farm-firm makes decision within the boundary of its own resource feasibility set (this part is essentially a decentralized decision making process) but further revised within the limitation of the linking regional resources. Thus for example production decisions on a group of homogeneous farms are constrained by on farm resources, but financial resources can be augmented by regional credit agencies. But regional resources of this nature are competed for by all farms in the region, and actual availability to any farm size group will depend upon capital productivity and institutional factors on the supply side. The decomposition principle allows us to take account of this.

3.5 DYNAMIC FEEDBACK AND EXOGENOUS VARIABLES

Once an economic variable is put on a time horizon, a variable becomes a function, at least, of time (period) per se. In line with this proposition are both Ezekiel's Cobweb Theorem (1938) and Nerlovean's version of distributed lag system (1957) formulated in the context of a difference equations. Likewise our data vectors ($Z_{(t)}$, $A_{(t)}$, $B_{(t)}$) on which decisions for a given year t are based, depend themselves on previous decision vectors (i.e. primal and dual solution vector of the system which are denoted by $X^*_{(t-n)}$ and $Y^*_{(t-n)}$ respectively), previous data vectors ($Z_{(t-n)}$, $A_{(t-n)}$, $B_{(t-n)}$) and exogenous variables which are determined outside of the model. The incorporation of such dependence constitutes dynamic feedback and these feedback functions are described below.

3.5.1 EXOGENOUS VARIABLES

One of the most important exogenous data sets used in the model are the sale prices of important crops, especially the support price for wheat. Minimum salary for wage labor is also yearly regulated by law. These policy variables are exogenous to our model hence we treat them as given data. The same is true of other input prices. Of course the price vectors of objective function can be formulated a an myopic expectation framework of an inverse demand function if it is theoretically feasible.[18/]

3.5.2 QUASI-FIXED RESOURCES

Quasi-fixed resources on a farm-firm in the model include land and capacities of draft animals, tractors and combines. We assume 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 as a recursive linkage as follows:

Draft Animal Hours:

Draft animal hours available at t (DAHR(t)) is last year's avalable 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 we write

(6) $$DAHR_{(t)} = (1-\lambda)\ DAHR_{(t-1)} + \delta IVDA^*_{(t-1)}$$

where λ: annual linear depreciation coefficient

δ: conversion coefficient of animal unit to serviceable hours

*: primal solution (exante planning value) of the model

Tractor Hours:

Like draft animal hours, tractor capacity hours available at t ($TRHR_{(t)}$) is:

(7) $$TRHR_{(t)} = (1-\lambda)\ TRHR_{(t-1)} + \delta IVTR^*_{(t-1)}$$

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

18/ See Day (1969).

3.5.3 VARIABLE RESOURCES

Variable resources on a farm-firm include total labor hours, fodder requirements for working draft animals, wage labor hours, working cash availability at the beginning of the year, and limitation of credit availability. We will consider these feedbacks in turn.

Total Labor Hours:

Total labor hours available at t ($TLH_{(t)}$) are equal to family labor hours (FLH) in the previous period plus increments through the regional growth in the farm population (at an annual rate r), plus wage labor hours added by labor hiring activity (HL) in the current period.

(8) $$THL_{(t)} = (1 + r)\ FLH_{(t-1)} + HL*_{(t)}$$

Fodder Requirements for Draft Animals

Working draft animals on the farm must be fed to maintain them as a power source. For simplicity we assume that animals are grazed on an improved pasture system. The hectarage of improved pasture reserved for animal fodder ($SWP_{(t)}$) equals the hectarage reserved last year minus hectarage accounting for animal displacement by depreciation plus hectarage for newly purchased draft animals ($IVDA*_{(t)}$); thus

(9) $$SWP_{(t)} = (1-\lambda)\ SWP_{(t-1)} + \delta\ IVDA*_{(t)}$$

where λ is a depreciation coefficient and δ is a conversion factor of animal units to fodder pasture.

Wage Labor Hours:

Wage labor hours available at current period increases from last year's level by the rate of farm population growth (r) and by a proportion(s) of last year's labor hiring activity ($HL*_{(t-1)}$)

(10) $HLH_{(t)} = (1 + r)\ HLH_{(t)} - \delta\ HL^*_{(t-1)}$

Working Cash Availability

At the beginning of year the amount of cash available on a farm-firm is the value of marketable surplus after internal consumption and living expenditures are met, minus repayment of last year's debt, plus any bank deposits (SAV) made last year and any borrowed (BORR) money in the current period:

(11) $$WCASH_{(t)} = (1-\lambda) \sum_i P_i\ S_{i(t)} - (1 + r_b)\ BORR^*_{(t-1)} + (1 + r_s)\ SAV^*_{(t-1)} + BORR^*_{(t)}$$

where λ: a coefficient accounting for internal consumption of food grains and living expenditure. Of course λ's are different according to farm size

P_i: market price per kilogram of the ith crop

S_i: total kilograms of the ith crop harvested and sold;

r_b: interest rate on working capital borrowed (10%)

r_s: interest rate available on bank deposits (6%)

Regional Credit Availability

Credit availability has an upper limit defined by a proportion (λ) of the value of total regional farm sales last year.

(12) $CRED_{(t)} = \lambda \sum_i P_i\ S_{i(t-1)}$

Another set of important dynamic feedback functions involves flexibility and adoption constraints which is discussed separately in the following section.

3.6 UNCERTAINTY, ADOPTION AND FLEXIBILITY

Flexibility constraints define a limited range in which the year to year changes in hectarage sown for each field crop can take place. These constraints impose a restricted flexibility in the established cropping patterns in an agricultural region in order to take account of farmers' cautious response toward risks and uncertainty with regard to prices of farm outputs and inputs, yield expectations and government policies. 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. The notion of flexibility constraints was suggested first by Henderson (1959) and further extended by Day (1961, 1963).

The coefficients associated with the flexibility constraint for the ith crop hectarage for t+n periods take the general form:19/

(3.6.1) $X_{i(t+1)} \leq g(X_{i(t+1)}, X_{i(t+2)}, ----, X_{i(t+n)}) = \bar{\beta}_i, \ i \in P$

(3.6.2) $-X_{i(t+1)} \leq -h(X_{i(t+1)}, X_{i(t+2)}, ----, X_{i(t+n)}) = \underline{\beta}_i, \ i \in P$

where $1 \leq n$, $X_{i(t+1)}, X_{i(t+2)}, ----, X_{i(t+n)}$, $i \in P$ are the annual hectarages actually sown for the t+n years, and $\bar{\beta}$ and $\underline{\beta}$ are the estimated upper and lower bounds respectively. Following a myopic expectation scheme, the dynamic feedback specifies the following range for the flexibility coefficients:

(13) $(1-\underline{\beta}_i) X^*_{i(t-1)} \leq X_{i(t)} \leq (1+\bar{\beta}_i) X^*_{i(t-1)}, \ i \in D$ where

$X^*_{i(t-1)}$ is of course the ith crop hectare in t-1 obtained from our exante planning values, and recalling that D represents the set of behavioral constraints.

19/ There are several alternative ways of estimating $\bar{\beta}_i$ and $\underline{\beta}_i$ such as point selection method, regression techniques, and desired hectarage principle. See Day (1963).

Adoption constraints place upper limits to the investments in new quaxi-fixed inputs (e.g. tractor) to reflect the fact that farmers are unwilling to 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 in the framework of adoption constraint considering the fact that a new innovation has to go through a time consuming diffusion process. For example, we 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; a) the adoption phase and b) the adjustment phase.[20/] The path of investment in capital goods follows the familiar "S" shaped curve which keeps a track of the minimum rate out of either adoption or adjustment phases. Investments in quasi-fixed inputs grow slowly at first but more rapidly later as diffusion and learning proceeds more rapidly so that the adoption phase is approximated by an exponential equation:

(3.6.3) $K_{(t)} = (1 + \rho)^n K(t - n)$ where $K_{(t)}$ is the number of units of an investment good in use in (t), and ρ is the rate of growth during the adoption phase.

In the second phase investments in capital goods are dominated by an adjustment process based on the hypothesis that capacity is adjusted towards

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20/ These two phases have been analyzed and empirically tested by Day (1962), Tsao (1966), Tabb (1967) and Singh (1971) in studies of investment behavior in various industries using recursive programming technique.

the long run desired capacity in the technique in question. In his Punjab study Singh defines the long run desired capacity for investment in any capital goods in agriculture as "that capacity which will allow all of the task under consideration to be performed by the new operation."[21/] Adopting his definition of "long run desired capacity," and following him we specify the equation of the adjustment phase as follows:

$$(3.6.4) \quad I_{(t)} \leq \alpha(\overline{K}_{(t)} - K_{(t-1)})$$

Where $\overline{K}_{(t)}$ is the current maximum desired capacity, and $K^*_{(t-1)}$ is the capacity utilized last year approaches the current long run desired capacity the investments in capital goods slow down. Substituting $I_{(t)} = K_{(t)} - K_{(t-1)}$ (definition of investment) into the adjustment phase equation, we obtain

$$(3.6.5) \quad K_{(t)} \leq \alpha(\overline{K}_{(t)} - K_{(t-1)}) + K_{(t-1)}$$

where current capacity is constrained by some proportion of the difference between the long run desired capacity and the previous year's available capacity, plus the previous year's capacity itself. Once $K_{(t)}$ is estimated we can immediately solve for unknown α which is called the adjustment coefficient and is associated with that phase. Combining both the adoption and adjustment equation and following the hypothesis that investment in the ith capacity must be less than or equal to the minimum of the two phase equations, we specify

$$(14) \quad K_{i(t)} \leq \min \begin{cases} (1+\rho)^n K_{i(t-n)} \\ \alpha(\overline{K}_{i(t)} - K_{i(t-1)}) + K_{i(t-1)} \end{cases}, \; i \in D$$

Equations (12) and (13) now complete the constraint structure discussed in section 3.3 above.

21/ Singh (1971) p. 217.

3.7 MODEL SUMMARY

The discussions in the previous sections have been focused on the on-farm decision making process. The structural relationships and factor endowments at the farm level are aggregated to the regional level by assigning weights to resource endowments on the basis of farm size groupings in order to approximate regional resource availabilities and other regional aggregates.

Since we have discussed the model components in detail, the complete model can now be succinctly summarized in mathematical notation as follows:[22/]

Let us consider the following decision spaces associated with a mathematical programming problem;

Primal decision space: $X \subset R^n$, $x = (x_1, x_2, \text{---} X_n) \varepsilon X$

Dual decision space: $Y \subset R^m$, $y = (y_1, y_2, \text{---} y_m) \varepsilon Y$

(3.7.1) Decision space: $V = X \times Y \subset R^{n+m}$

where R^{n+m} is $n + m$ dimensional euclidian space.

For a given mathematical programming problem, we have the data space (W) to which three subspaces belong;

objective function space: $W^z \subset R^n$

constraint function space: $W^a \subset R^{\Sigma m_i}$

limitation space: $W^b \subset R^m$

(3.7.2) Of course $W = (W^z, W^a, W^b)$ and $W \subset R^n + R^{\Sigma m_i} + R^m$

Using a discrete time index t and recalling $Z_{(t)}$, $A_{(t)}$, $B_{(t)}$, the direct utility (objective) function at t is defined as follows:

22/ The notation here is based on notes of a seminar given by Professor R. H. Day on "Recursive Decision Systems," in the summer of 1971 at the University of Wisconsin and from Day and Singh, (1971).

(3.7.3) $\Pi = \xi(X_{(t)}, Z_{(t)}) \varepsilon R^n$

The constraint function takes the form;

(3.7.4) $\psi(X_{(t)}, A_{(t)}) \leqq B_{(t)}$

with non-negativity assumption of decision variables

$X_{(t)} \geqq 0$

The feasibility operator Γ, associated with constraint function and limitation space, defines

(3.7.5) $\Gamma(A_{(t)}, B_{(t)}) = \{X_{(t)} \mid \psi(X_{(t)}, A_{(t)}) \leqq B_{(t)}, X_{(t)} \geqq 0\}$

The "indirect utility function" following Day (1971), and Day and Kennedy. (1970) is defined from (3.7.3) and (3.7.5);

(3.7.6) $\Pi(Z_{(t)}, A_{(t)}, B_{(t)}) = \underset{X_{(t)}}{\text{Max}}\{\xi(X_{(t)}, Z_{(t)}) \mid X_{(t)} \varepsilon \Gamma(A_{(t)}, B_{(t)})\}$

Denoting the primal decision operator Φ_x the optimal feasibility set is expressed;

(3.7.7) $\Phi_x(Z_{(t)}, A_{(t)} B_{(t)}) = \Gamma(A_{(t)}, B_{(t)}) \cap \{X_{(t)} \mid$
$\xi(X_{(t)}, Z_{(t)}) \geqq \Pi(Z_{(t)}, A_{(t)}, B_{(t)})\}$ 23/

Equation (3.7.3) usually provides a non-unique solution but operationally we use the computer alogrithmic code to obtain an exante optimal feasible solution.

To equation (3.7.7) we add the feedback operator ω to complete the ith order recursive linear programming model.

(3.7.8) $W_{(t)} = \omega(X^*_{(t-i)}, Y^*_{(t-i)}, E_{x(t)})$

where $Ex_{(t)}$ is the set of exogenous variables at t. Euqation (3.7.8) describes how decisions once acted on, or once scheduled for the future,

23/ The dual statement corresponding to the primal formulation in (4.7.7) is useful to obtain $Y^*_{(t-i)}$. For a topological treatment of recursive decision system and related theory, especially existence problems, see Day and Kennedy (1970).

interact with the decision maker's environment to produce new information upon which succeeding plans can be based.

The model for this study is formulated for the initial year 1960 in the context of (3.7.6) and the model structures for succeeding years are generated in sequence by equation (3.7.8) to obtain the primal optimal solution sets for the entire period (1960-1969) year by year using the "Recursive Decision System Processor" developed by G. Müeller,[24/] and available at the Social Systems Research Institute at the University of Wisconsin, Madison.

4. DATA SOURCES

Detailed data on various economic variables such as resource use, credit and cash flows, family labor employment and the availability of on-farm resources and patterns of land use, were obtained from a random sample of some 430 crop and livestock farms in the wheat regions of Rio Grande do Sul. The physical input-output coefficients for various crop outputs sown under different technologies were obtained partly from the sample data and partly supplemented by information obtained from local agronomists and agricultural engineers.[25/] The input coefficients for land preparation by draft animals were obtained from physical data on agricultural tasks provided by Singh et. al.[26/] The resulting data for the input-output structure are fairly reliable.

24/ See Müeller (1971).

25/ The input-output coefficient for tractor technologies, i.e. the tractor capacity requirements per hectare of crop output are same as those used by Engler. These were obtained from a field survey conducted by Richard Meyer and John Stitzlein as a part of the Capital Formation Project. See Engler (1971).

26/ Singh classifies all agricultural operations task by task and provides different input-output coefficients for different sizes of tractors and for draft animals. See Singh et. al (1968).

Less reliable perhaps are the data on available regional resources of land by categories, labor, and quasi-fixed capacities, since these were obtained from the 1960 Brazilian census, while other data were obtained from the annual volumnes of the "Conjuntura Economica," "Anuario Estatistico do Brazil," "Trigo-Estudo Do Custo De Producao" and other available literatures.

The vectors of output and input prices are partly from the series of "Anuario Estatistico do Brasil" and partly estimated on the basis of price indices published by the "Instituto de Economia Agricola" in the state of Sao Paulo, a state adjacent to Rio Grande do Sul.

Farm sizes for this study were grouped as follows:[27/]

Small sized farms (SMALL FARM): 0-50 ha.

Medium sized farms (MEDIUM FARM): 51-300 ha.

Large sized farms (LARGE FARM): above 300 ha.

In constructing the matrix of input-output coefficients for various farm sizes, the following assumptions were made:

1) The different farm size groups have identical input-output relationships, that is each farm type uses the same amount of inputs to produce one unit of output for a given technological choice; except for the tasks of land preparation and harvesting, where it is assumed that large farms have certain economies of scale with respect to machine operations.
2) Different farm size groups faced with a similar regional economic environment, that is they all face identical input and output prices.
3) Different farm size groups have different on-farm resource endowments and hence different factor endowments.
4) All farms compete for regional credit and wage labor resources.

27/ A similar grouping has been used in other studies in the Capital Formation Project for which the sample data was collected.

5. PRELIMINARY RESULTS: WHEAT REGION, RIO GRANDE DO SUL (1960-1969)

The tables in the appendix present in detail, the results of the model which pertain to important features of agricultural transformation in the region. They include regional dynamic paths with regard to cropping patterns, resource use, factor productivities, factor proportions, investment patterns and credit use by farm size.[28/] We discuss these briefly below.

5.1 REGIONAL LAND USE BY FARM SIZE AND TECHNOLOGY

Various aspects of land use and cropping patterns for the region by farm size and technology are presented in Tables 2 to 7. The most important transition in the region, a shift from extensive livestock enterprises to intensive crop farming, especially wheat is clearly evident in Tables 2 through 7. Wheat production on small farms increased approximately 10 times during 1960-1969, but crop production is confined to traditional draft animal technologies. Medium farms also increased their wheat production substantially, but whereas production with draft animal technologies increased 1.4 times, production with tractor technologies increased sixfold in the period. Large farms have increased wheat production 5.6 times totally under mechanized technologies. Along with the increases in wheat production, soybeans as a complementary crop to wheat have also increased at slow but steady rate among the three farm size groups.[29/]

28/ The tables of the model results are grouped into five categories: a) land use pattern by farm size, b) input-output relationship by farm size, gross annual new investments in power sources and their relationships with land and labor use, d) some factor relationships and cash expenditures, and e) credit use and other factor relationships.

29/ In these regards the model captures the general features of transformation in the region. See Norman Rask (1969).

Specifically soybeans following wheat have increased about 3.5 times on small farms and 1.3 times on medium farms, employing draft animals. In the case of the medium sized farms employing tractor technology soybeans production after wheat increased fourfold. Large farms employing labor saving tractor technology experienced an increase of 2.7 times. Corn production declined slightly for all three farm size groups. The small farms employed draft animals while the medium and large farms used tractors to produce corn.

Of course in the transition from livestock to intensive crop farming the increases in crop production are offset by a substantial decline in natural pasture which accounted for approximately 90% of total exploited areas of each farm size in 1960 (Tables 5 and 7). In 1969 the areas devoted to natural pasture were reduced by 20%, 9% and 18.5% for small, medium and large farms respectively (Table 7). However, it is important to note that summer/winter improved pastures expanded at a more rapid rate than either wheat or soybeans, although the area sown to improved pastures is much less than the area sown to wheat.[30/] The rates of adoption of improved pasture activities are positively correlated with farm size and time. This indeed conforms with our hypothesis that large farms respond more quickly than smaller farms to changes in the exogeneous environment. Further it might suggest that the new pasture and livestock practices could be highly competitive with wheat. A more favorable pricing policy for beef would reinforce a shift from extensive to intensive livestock enterprises in the region.

30/ Recall that we have livestock enterprises under four alternative pasture systems namely a) natural pasture, b) summer pasture, c) winter pasture, and d) summer and winter pastures. Systems b), c) and d) require that the land be tilled, seeded and fertilizer and protective chemicals be applied.

As for technological choices in improved pastures, small farms adopted draft animals whereas the medium and large farms employed tractors, suggesting that only part of the impetus towards mechanization in the region is provided by the transition to crop farming, with the other part coming from the mechanization of the land preparation tasks required by improved pasture systems.

5.2 REGIONAL RESOURCE USE, INVESTMENT PATTERNS, AND FACTOR PRODUCTIVITIES

Even though each farm size group was endowed with at least a certain amount of serviceable hours of both draft animals and tractors in 1960, small farms employed only draft animals, medium farms adopted both animals and tractors and large farms used only tractors. This outcome is essentially the result of differential factor endowments for each farm size group. The most critical factors accounting for this are 1) family labor availability which is assumed to have zero cost, and 2) cash constraints facing the farm operator, which are in turn related to the purchasing prices of draft animals and tractors. Larger farms have a relative scarcity of the former factor and relatively larger endowments of the latter one due to larger cash revenues, so that mechanization is relatively more profitable for them.

The use of draft animals increased 2.9 and 1.3 times respectively on small and medium farms during 1960-1969 (Table 15). Tractor usage increased 2.4 times on medium farms and three times on large farms between 1960 and 1969 (Table 16). Of course, the intensification in the use of power per hectare has been accompanied by the growth in annual investments in power sources (Tables 13 and 14). The gross investment in draft animals increased 3.6 times on small farms and two times on medium farms during 1961-1969. The gross investment in tractors on medium and large farms grew 1.4 and 2.6 times over the same period.

Summing up the investment patterns in power sources in the region, relatively labor abundant small farms invested exclusively in the labor intensive sources (draft animals) whereas relatively labor scarce large farms invested soly in capital intensive sources (tractors). Medium farms, maintaining a position between small farms and large farms in terms of labor availability followed a mixed investment pattern by purchasing both draft animals and tractors. However, the farms in this size group invested more heavily in mechanical power sources than in draft animals.

The use of both labor and capital grew over time at a differential rate for each farm size group (Tables 25 and 22). This feature is likely to continue until the transition phase is over in the region.

Examining regional labor usage, we see that the family labor available on small farms was underutilized while family labor was almost fully utilized on medium farms. Family labor is not sufficient to meet labor requirements on large farms which have to resort to hiring wage labor (Tables 23 and 24). It should be emphasized, however, that over time there is an increase in the labor use per hectare as a result of a shift to crop farming in the region. With increased double cropping this has meant a substantial increase in regional farm employment, with labor usage growing 143%, 116% and 104% on small, medium and large farms respectively, between 1960 and 1969. As expected, the labor use per hectare is inversely correlated with farm size.

Indices of average productivity for capital, labor and land are presented in Tables 8, 9, and 12. Capital productivity, measured by the ratio of gross revenue/total annual cash outlays[31/] was down approximately 50% for the three farm size groups during the 1960-1969 period. This trend is expected to continue as the region approaches capital satiation

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31/ All cash outlays and cash sales are valued at constant 1960 prices. The price deflator used to eliminate inflationary trends is the Index of wholesale Agricultural Prices in the Sao Paulo region of Rio Grande do Sul. Source: Conjuctura Economica, Vol. 17, No. 9, 1970, p. 91.

with capital outlays growing faster than output. The capital productivity on small farms is 110% higher than medium farms which is in turn about 115% higher than on large farms (Table 8). Average labor productivity defined by the ratio of gross revenues/total labor hours employed, remained more or less constant through 1960-1969 (Table 9). The productivity on large farms is roughly three times higher than on medium farms which is in turn 1.6 times higher than on small farms. The differences in labor productivity are even greater if we measure 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. Average land productivity defined by the ratio of gross revenues/land utilized, was slightly higher on small farms than on either medium or large farms (Table 12). It grew 116% over the 1960-1969 period on small farms, remained at a rather constant level on medium farms with little fluctuation, and showed little increase on large farms.

Whereas capital productivity has declined steadily, at different rates for different farm size groups, average labor and land productivities have remained almost constant. This suggests that although there has been increased capitalization in the region, speciallly in the mechanical technology spectrum, there have been little or no breakthroughs in the yield technology spectrum which mainly increases land and labor productivities.

The differences in factor productivities among farm sizes also bears out the importance of factor endowments with productivities being higher where factors are relatively scarce.

5.3 FACTOR PROPORTIONS AND THE DYNAMICS OF TRANSFORMATION

One of the basic features of the model formulation are the differences in factor endowments among farms of different sizes. These differences in factor endowments are accentuated through time and result in the differences in the dynamic path of regional resource use, resulting in widely different factor proportions as expected.

The dynamics of regional transformation has involved a twofold transaction -- from extensive livestock to intensive crop farming and improved livestock. Both of these transitions have required increased use of "all factors" through time as conversion to intensive farming usually does. As long as this conversion continues we can expect increasing employment opportunities and an increasing demand for capital in the region, although these increases would be differentially distributed among farms of different sizes.

The differences in factor proportions due to differences in farm size are most evident in the land/labor ratios (Tables 19 and 25) and in the machine use/land and machine use/labor ratios (Tables 16 and 18) and draft animal/land and draft animal/labor ratios (Tables 15 and 17). Increasing mechanization on medium and large farms has increased machine use but due to increases in intensive cropping labor demand and hence labor use per hectare have increased over time.

Differences in capital and labor endowments were crucial to the choice of technologies with small farms employing labor intensive and capital saving technologies, and large farms using capital intensive and labor saving technologies, while medium farms have a comparable position between these two. The differential time path of resource significantly related to differences in initial factor proportions.

5.4 REGIONAL CAPITAL UTILIZATION AND CREDIT

Total annual capital expenditures per hectare increased more than two times on small and large farms whereas they expanded a little less than twofold on medium farms during the 1960-1969 decade (Table 28). This sizeable growth in real capital expenditures in the region has been mainly financed by a liberal credit policy which has made credit available up to 60 percent of total gross revenues on each farm and that too at negative real interest rates. This institutional credit policy has favored an increasing capitalization and dependence on credit on large farms relative to smaller farms, and has been a key mechanism in the regional transformation process.

This process is evident in the fact that average credit use per hectare has increased by 490%, 230% and 160% respectively on large, medium and small farms(Table 30). The dependence on external funding of farm capital utilization has increased over time (Table 31) with an increasing rate of dependence on large farms (the ratio of external to internal funding increased 15 fold), and a somewhat smaller increased dependence on medium farms (ratio increased less than twofold). The ratio of external to internal funding actually declined some 45% on small farms.

These results indicate that not only has the liberal credit policy increased credit use in the region over time, but that this credit has been more accessible to larger farmers whose dependence on credit has increased substantially. Thus, credit policies have helped to further widen the gap in initial factor endowments, providing increasing proportions of it to farms where it is relatively abundant and relatively less productive. These policies to the extent that they are continued will lead to further increasing rate of capitalization in the region further accelerating a process of transition already under way. And to the extent that credit continues to go to larger farmers, it will continue to be inefficiently allocated, further perpetuating differences in factor proportions and productivities rather than reducing them. All evidence points to the crucial role credit policies have played in the regional transformation in Southern Brazil.

6. FURTHER RESEARCH

Although the model captures in detail the fundamental features of agricultural transformation in the region, it can still be improved in many aspects. The following items are suggestions for the further research.

6.1 MODEL IMPROVEMENTS

One of the basic concerns in the process of model building was computer limitation of the "Recursive Decision System Processor" available at the University of Wisconsin, Madison.[32/] Efforts have been made to keep the size of the matrix as small as possible so that it is manageable, using this program. If the computer processor is able to handle bigger size problems, the current model structure can be expanded immediately in the following ways:

a) Detailed Breakdowns of Technology

This includes a more detailed breakdown of both the mechanical and biochemical technologies. The former allows us to investigate the investment patterns of different farm size groups on different size of machines, say 25 h.p. and 50 h.p. tractors. The latter will enable us to analyze, for example, differential levels of fertilizer applications on different farm size groups by incorporating linearly segmented fertilizer response functions for each crop.[33/]

32/ The "Recursive Decision System Processor" can handle a R.L.P. problem with a 120 X 100 matrix. A new processor with expanded capabilities is under development by G. Mueller at the University of Wisconsin, Madison. Any L.P. problem is manageable with the "MPS 360" at the Ohio State University, but that is extremely time consuming for R.L.P. problems since the feedback has to be estimated separately, and thus the n periods problem decomposes into single period runs.

33/ This has been done by Singh (1971).

b) Seasonal Classification of Labor and Land Availabilities

By considering labor and land availabilities on a monthly basis, we can analyze the sharp seasonal pattern of labor use including labor hiring activities by each month and several crop rotations. Currently only two periods are considered as constraining production in the cropping year; the land preparation and harvesting periods.

Other improvements include the following items:

c) Parametric Analysis of Key Policy Variables

This is the next step in the agenda for this study. The parametric analysis will essentially focus on wheat pricing and credit availability. Parametric programming on these can be attempted in both comparative dynamics and comparative statics sense, which are quite different from each other. Comparative dynamic parametrics on credit availability and borrowing rates have already been computed and will be analyzed.

d) Future Projections

Once the model is carefully evaluated to prove "goodness of fit" in producing a quantitative history of "what has already happened" in the region, we are in a position to extend the analysis by projecting the future. Indeed it is desirable to examine policy variables in the projection framework because changes in farm policies are concerned about the future time period. By doing so we are able to simulate various economic performance variables under alternative policy options, in which many policy makers are interested.

e) Interfarm Resource Transfers

Theoretically this is probably the most important issue, specially the inclusion of a land market and a renting mechanism for land and other quasi-fixed capacities in the model. The resource transfers within a given farm size do not significantly effect the regional aggregates. However, land transactions between farm size groups have very important economic implications in any dynamic regional analysis. Because it may involve a deterioration of small farms or a diverging structural duality between small and large farms, this aspect should be incorporated.

In addition to these items for model improvement, other theoretical extensions may deal with stochastic and/or non-linear treatments of some of the components in the model.

6.2 DATA IMPROVEMENT

Further breakdowns of both mechanical and biochemical technologies require new sets of data in this regard. Data on machine operations by task are also desirable if we are to incorporate a detailed classification of mechanical technology.

Actual hectarage by crop and farm size are neccessary for model evaluation and testing. Accuracy of resource availability, specially data on quasi-fixed capacities by farm size are crucial for this study and are not currently available. More reliable data on labor availability are also very important and this should be considered in relation with non-farm linkages. Thus urban out migration and/or rural immigration should be examined to obtain accurate data on labor availability. The supply functions of non-farm inputs such as tractors, combines, fertilizer, protective chemicals and certified seeds must be considered so that non-farm linkages of the model are enhanced.

6.3 MODEL EVALUATION AND TESTING

The necessity for effective model evaluation and testing is mentioned briefly in subsection 6.1. It is a natural step to evaluate the model's performance in terms of its ability to predict what has already happened in order to have confidence in use of the model for policy. Theil has developed various information concepts which have proved to be useful in model evaluation. Day and Singh recently applied the information concepts to evaluate their Punjab model.[34] This model should also be evaluated and tested not only to improve our understanding of the past but also to examine its "goodness of fit" and ability to project future regional trends.

34/ See Day and Singh (1971).

APPENDIX

PART I: LAND USE PATTERN BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1969)

Column Names Used in the Tables of the Part I

Name	Activity Description
1.	Production by Draft Animal Technology
2.	Production by Tractor Technology
WHEAT.	Hectarage sown for Wheat = WHEAT 1 + WHEAT 2
SOYBW.	Hectarage sown for Soybean following Wheat
SOYBI.	Hectarage sown for Soybean independent of Wheat
CORN	Hectarage sown for Corn = CORN 1 + CORN 2
NATPAS	Hectarage used for Natural Pasture = NAPAS
SUPAS.	Hectarage sown for Summer Pasture* = SUPAS 1 + SUPAS 2
WIPAS.	Hectarage sown for Winter Pasture* = WIPAS 1 + WIPAS 2
SOYBN.	Hectarage sown for Total Soybeans = SOYBI 1 + SOYBW 2 + SOYBI 1 + SOYBI 2

Remarks - * Both Summer Pasture and Winter Pasture are improved pasture systems which require the tasks of land preparation, seeding and fertilizing.

TABLE 2 : REGIONAL LAND USE BY FARM SIZE AND TECHNOLOGY: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	WHEAT1	WHEAT2	SOYBW1	SOYBW2	SOYBI1	SOYBI2	CORN1	CORN2	NATPAS	SJPAS1	SJPAS2	WIPAS1	WIPAS2
LAND USE ON SMALL FARMS (IN 1000 HA)--MODEL SOLUTION													
1960	20.00	0.0	20.00	0.0	0.0	0.0	66.00	0.0	940.00	16.61	0.0	5.54	0.0
1961	26.00	0.0	23.18	0.0	0.0	0.0	64.02	0.0	936.47	16.88	0.0	5.63	0.0
1962	33.80	0.0	26.87	0.0	0.0	0.0	62.10	0.0	929.57	17.65	0.0	5.88	0.0
1963	43.94	0.0	31.14	0.0	0.0	0.0	60.24	0.0	919.65	18.88	0.0	6.29	0.0
1964	57.12	0.0	36.08	0.0	0.0	0.0	58.42	0.0	906.00	20.58	0.0	9.86	0.0
1965	74.26	0.0	41.83	0.0	0.0	0.0	56.68	0.0	887.70	22.77	0.0	7.59	0.0
1966	96.54	0.0	48.47	0.0	0.0	0.0	61.21	0.0	857.27	25.49	0.0	8.50	0.0
1967	125.50	0.0	56.18	0.0	0.0	0.0	62.19	0.0	822.98	28.75	0.0	9.58	0.0
1968	163.15	0.0	65.12	0.0	0.0	0.0	60.32	0.0	790.06	26.60	0.0	8.87	0.0
1969	212.10	0.0	75.47	0.0	0.0	0.0	58.51	0.0	758.46	14.95	0.0	4.98	0.0
LAND USE ON MEDIUM FARMS (IN 1000 HA)--MODEL SOLUTION													
1960	17.25	12.25	17.25	12.75	0.0	0.0	0.0	66.00	1352.77	7.88	9.54	0.0	5.80
1961	18.23	12.53	18.23	12.53	0.0	0.0	0.0	62.70	1351.66	6.61	13.55	0.0	6.72
1962	20.84	20.68	19.17	16.61	0.0	0.0	0.0	59.56	1339.44	0.0	23.59	0.0	7.87
1963	21.42	18.03	20.07	18.03	0.0	0.0	0.0	56.59	1338.84	0.0	27.84	0.0	9.29
1964	20.95	21.01	20.95	21.01	0.0	0.0	0.0	53.76	1332.25	3.00	30.01	0.0	11.00
1965	22.50	19.39	21.88	19.39	0.0	0.0	0.0	51.07	1326.63	0.0	39.31	0.0	13.10
1966	22.93	26.94	22.70	25.30	0.0	0.0	0.0	48.52	1311.05	0.0	46.92	0.0	15.64
1967	23.18	44.14	23.18	32.63	0.0	0.0	0.0	49.20	1280.68	0.0	56.10	0.0	18.64
1968	23.38	67.50	23.38	41.53	0.0	0.0	0.0	46.74	1244.84	0.0	67.15	0.0	0.81
1969	23.92	62.43	23.92	51.58	0.0	0.0	0.0	44.40	1234.00	0.0	80.44	0.0	25.92
LAND USE ON LARGE FARMS (IN 1000 HA)--MODEL SOLUTION													
1960	0.0	40.00	0.0	40.00	0.0	0.0	0.0	90.00	1789.04	0.0	23.17	0.0	7.78
1961	0.0	39.42	0.0	39.42	0.0	0.0	0.0	83.70	1788.75	0.0	28.56	0.0	9.57
1962	0.0	46.00	0.0	46.00	0.0	0.0	0.0	77.84	1778.94	0.0	35.38	0.0	11.83
1963	0.0	42.59	0.0	42.59	0.0	0.0	0.0	72.39	1776.16	0.0	43.97	0.0	14.69
1964	0.0	49.70	0.0	49.70	0.0	0.0	0.0	67.32	1759.95	0.0	54.04	0.0	18.27
1965	0.0	58.00	0.0	58.00	0.0	0.0	0.0	62.61	1738.15	0.0	68.27	0.0	22.77
1966	0.0	81.49	0.0	67.69	0.0	0.0	0.0	58.23	1696.65	0.0	85.21	0.0	28.42
1967	0.0	114.09	0.0	79.00	0.0	0.0	0.0	54.15	1640.00	0.0	106.40	0.0	35.48
1968	0.0	159.73	0.0	92.19	0.0	0.0	0.0	50.36	1562.67	0.0	132.92	0.0	44.32
1969	0.0	223.62	0.0	107.58	0.0	0.0	0.0	46.84	1458.09	0.0	166.08	0.0	55.37

Source: Model Results

TABLE 3 : 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 (1960-1969)

YEAR	WHEAT1	WHEAT2*	SOYBW1	SOYBW2	SOYBI1	SOYBI2	CORN1	CORN2	NATPAS	SJPAS1	SUPAS2	WIPAS1	WIPAS2
LAND USE ON SMALL FARMS AS A PERCENTAGE OF REGIONAL LAND USE													
1960	53.7	0.0	53.7	0.0	*****	*****	100.0	0.0	23.0	67.8	0.0	100.0	0.0
1961	58.8	0.0	56.0	0.0	*****	*****	100.0	0.0	23.0	71.9	0.0	100.0	0.0
1962	61.9	0.0	58.4	0.0	*****	*****	100.0	0.0	23.0	100.0	0.0	100.0	0.0
1963	67.2	0.0	60.8	0.0	*****	*****	100.0	0.0	22.8	100.0	0.0	100.0	0.0
1964	73.2	0.0	63.3	0.0	*****	*****	100.0	0.0	22.7	87.3	0.0	100.0	0.0
1965	76.7	0.0	65.7	0.0	*****	*****	100.0	0.0	22.5	100.0	0.0	100.0	0.0
1966	80.8	0.0	68.1	0.0	*****	*****	100.0	0.0	22.2	100.0	0.0	100.0	0.0
1967	84.4	0.0	70.8	0.0	*****	*****	100.0	0.0	22.0	100.0	0.0	100.0	0.0
1968	87.5	0.0	73.6	0.0	*****	*****	100.0	0.0	22.0	100.0	0.0	100.0	0.0
1969	89.9	0.0	75.9	0.0	*****	*****	100.0	0.0	22.0	100.0	0.0	100.0	0.0
LAND USE ON MEDIUM FARMS AS A PERCENTAGE OF REGIONAL LAND USE													
1960	46.3	23.4	46.3	24.2	*****	*****	0.0	42.3	33.1	32.2	29.2	0.0	42.7
1961	41.2	24.1	44.0	24.1	*****	*****	0.0	42.8	33.2	28.1	32.2	0.0	41.3
1962	38.1	31.0	41.6	26.5	*****	*****	0.0	43.3	33.1	0.0	40.0	0.0	39.9
1963	32.8	29.7	39.2	29.7	*****	*****	0.0	43.9	33.2	0.0	38.8	0.0	38.7
1964	26.8	29.7	36.7	29.7	*****	*****	0.0	44.4	33.3	12.7	35.7	0.0	37.6
1965	23.3	25.1	34.3	25.1	*****	*****	0.0	44.9	33.6	0.0	36.5	0.0	36.5
1966	19.2	24.8	31.9	27.2	*****	*****	0.0	45.5	33.9	0.0	35.5	0.0	35.5
1967	15.6	27.9	29.2	29.2	*****	*****	0.0	47.6	34.2	0.0	34.5	0.0	34.4
1968	12.5	29.7	26.4	31.1	*****	*****	0.0	48.1	34.6	0.0	33.6	0.0	1.8
1969	10.1	21.8	24.1	32.4	*****	*****	0.0	48.7	35.8	0.0	32.6	0.0	31.9
LAND USE ON LARGE FARMS AS A PERCENTAGE OF REGIONAL LAND USE													
1960	0.0	76.6	0.0	75.8	*****	*****	0.0	57.7	43.8	0.0	70.8	0.0	57.3
1961	0.0	75.9	0.0	75.9	*****	*****	0.0	57.2	43.9	0.0	67.8	0.0	58.7
1962	0.0	69.0	0.0	73.5	*****	*****	0.0	56.7	43.9	0.0	60.0	0.0	60.1
1963	0.0	70.3	0.0	70.3	*****	*****	0.0	56.1	44.0	0.0	61.2	0.0	61.3
1964	0.0	70.3	0.0	70.3	*****	*****	0.0	55.6	44.0	0.0	64.3	0.0	62.4
1965	0.0	74.9	0.0	74.9	*****	*****	0.0	55.1	44.0	0.0	63.5	0.0	63.5
1966	0.0	75.2	0.0	72.8	*****	*****	0.0	54.5	43.9	0.0	64.5	0.0	64.5
1967	0.0	72.1	0.0	70.8	*****	*****	0.0	52.4	43.8	0.0	65.5	0.0	65.6
1968	0.0	70.3	0.0	68.9	*****	*****	0.0	51.9	43.4	0.0	66.4	0.0	98.2
1969	0.0	78.2	0.0	67.6	*****	*****	0.0	51.3	42.3	0.0	67.4	0.0	68.1

Note: ***** denotes zero activity levels.

Source: Model Results

TABLE 4 : CROPPING PATTERNS BY FARM SIZE AND BY TECHNOLOGY: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

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	1.87	0.0	1.87	0.0	0.0	0.0	6.08	0.0	88.00	1.56	0.0	0.52	0.0
1961	2.42	0.0	2.16	0.0	0.0	0.0	5.97	0.0	87.34	1.57	0.0	0.53	0.0
1962	3.14	0.0	2.50	0.0	0.0	0.0	5.77	0.0	86.40	1.64	0.0	0.55	0.0
1963	4.07	0.0	2.88	0.0	0.0	0.0	5.58	0.0	85.14	1.75	0.0	0.58	0.0
1964	5.25	0.0	3.32	0.0	0.0	0.0	5.37	0.0	83.27	1.89	0.0	0.91	0.0
1965	6.81	0.0	3.83	0.0	0.0	0.0	5.20	0.0	81.38	2.09	0.0	0.70	0.0
1966	8.80	0.0	4.42	0.0	0.0	0.0	5.58	0.0	78.11	2.32	0.0	0.77	0.0
1967	11.36	0.0	5.08	0.0	0.0	0.0	5.63	0.0	74.47	2.60	0.0	0.87	0.0
1968	14.64	0.0	5.84	0.0	0.0	0.0	5.41	0.0	70.91	2.39	0.0	0.80	0.0
1969	18.86	0.0	6.71	0.0	0.0	0.0	5.20	0.0	67.45	1.33	0.0	0.44	0.0
CROPPING PATTERN ON MEDIUM FARMS AS A PERCENTAGE OF TOTAL LAND USE ON MEDIUM FARMS													
1960	1.15	0.82	1.15	0.85	0.0	0.0	0.0	4.40	90.10	0.52	0.64	0.0	0.39
1961	1.21	0.83	1.21	0.83	0.0	0.0	0.0	4.17	89.95	0.44	0.90	0.0	0.45
1962	1.38	1.37	1.27	1.10	0.0	0.0	0.0	3.95	88.84	0.0	1.56	0.0	0.52
1963	1.42	1.19	1.33	1.19	0.0	0.0	0.0	3.75	88.66	0.0	1.84	0.0	0.62
1964	1.38	1.39	1.38	1.39	0.0	0.0	0.0	3.55	88.00	0.20	1.98	0.0	0.73
1965	1.49	1.28	1.45	1.28	0.0	0.0	0.0	3.37	87.67	0.0	2.60	0.0	0.87
1966	1.51	1.77	1.49	1.66	0.0	0.0	0.0	3.19	86.25	0.0	3.09	0.0	1.03
1967	1.52	2.89	1.52	2.14	0.0	0.0	0.0	3.22	83.83	0.0	3.67	0.0	1.22
1968	1.54	4.45	1.54	2.74	0.0	0.0	0.0	3.08	82.15	0.0	4.43	0.0	0.05
1969	1.55	4.04	1.55	3.34	0.0	0.0	0.0	2.87	79.79	0.0	5.20	0.0	1.68
CROPPING PATTERN ON LARGE FARMS AS A PERCENTAGE OF TOTAL LAND USE OF LARGE FARMS													
1960	0.0	2.01	0.0	2.01	0.0	0.0	0.0	4.52	89.90	0.0	1.16	0.0	0.39
1961	0.0	1.98	0.0	1.98	0.0	0.0	0.0	4.21	89.91	0.0	1.44	0.0	0.48
1962	0.0	2.30	0.0	2.30	0.0	0.0	0.0	3.90	89.13	0.0	1.77	0.0	0.59
1963	0.0	2.14	0.0	2.14	0.0	0.0	0.0	3.63	89.15	0.0	2.21	0.0	0.74
1964	0.0	2.49	0.0	2.49	0.0	0.0	0.0	3.37	88.04	0.0	2.70	0.0	0.91
1965	0.0	2.89	0.0	2.89	0.0	0.0	0.0	3.12	86.57	0.0	3.40	0.0	1.13
1966	0.0	4.04	0.0	3.35	0.0	0.0	0.0	2.89	84.09	0.0	4.22	0.0	1.41
1967	0.0	5.62	0.0	3.89	0.0	0.0	0.0	2.67	80.82	0.0	5.24	0.0	1.75
1968	0.0	7.82	0.0	4.51	0.0	0.0	0.0	2.47	76.52	0.0	6.51	0.0	2.17
1969	0.0	10.87	0.0	5.23	0.0	0.0	0.0	2.28	70.86	0.0	8.07	0.0	2.69

Source: Model Results

TABLE 5: REGIONAL LAND USE BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	WHEAT	SOYBN	CORN	NAPAS	SUPAS	WIPAS
LAND USE BY CROP ON SMALL FARMS (IN 1000 HA)						
1960	20.00	20.00	66.00	940.00	16.61	5.54
1961	26.00	23.18	64.02	936.47	16.88	5.63
1962	33.80	26.87	62.10	929.57	17.65	5.88
1963	43.94	31.14	60.24	919.65	18.88	6.29
1964	57.12	36.08	58.42	906.00	20.58	9.86
1965	74.26	41.83	56.68	887.70	22.77	7.59
1966	96.54	48.47	61.21	857.27	25.49	8.50
1967	125.50	56.18	62.19	822.98	28.75	9.58
1968	163.15	65.12	60.32	790.06	26.60	8.87
1969	212.10	75.47	58.51	758.46	14.95	4.98
LAND USE BY CROP ON MEDIUM FARMS (IN 1000 HA)						
1960	29.50	30.00	66.00	1352.77	17.42	5.80
1961	30.76	30.76	62.70	1351.66	20.16	6.72
1962	41.52	35.78	59.56	1339.44	23.59	7.87
1963	39.45	38.10	56.59	1338.84	27.84	9.29
1964	41.96	41.96	53.76	1332.25	33.01	11.00
1965	41.89	41.27	51.07	1326.63	39.31	13.10
1966	49.87	48.00	48.52	1311.05	46.92	15.64
1967	67.32	55.81	49.20	1280.68	56.10	18.64
1968	90.88	64.91	46.74	1244.84	67.15	0.81
1969	86.35	75.50	44.40	1234.00	80.44	25.92
LAND USE BY CROP ON LARGE FARMS (IN 1000 HA)						
1960	40.00	40.00	90.00	1789.04	23.17	7.78
1961	39.42	39.42	83.70	1788.75	28.56	9.57
1962	46.00	46.00	77.84	1778.94	35.38	11.83
1963	42.59	42.59	72.39	1776.16	43.97	14.69
1964	49.70	49.70	67.32	1759.95	54.04	18.27
1965	58.00	58.00	62.61	1738.15	68.27	22.77
1966	81.49	67.69	58.23	1696.65	85.21	28.42
1967	114.09	79.00	54.15	1640.00	106.40	35.48
1968	159.73	92.19	50.36	1562.67	132.92	44.32
1969	223.62	107.58	46.84	1458.09	166.08	55.37

Source: Model Results

TABLE 6: LAND USE BY FARM SIZE AS A PERCENTAGE OF REGIONAL LAND USE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	WHEAT	SOYBN	CORN	NAPAS	SUPAS	WIPAS
CROPPING PATTERN ON SMALL FARMS						
1960	22.35	22.22	29.73	23.03	29.04	28.97
1961	27.03	24.83	30.42	22.97	25.73	25.68
1962	27.86	24.73	31.13	22.96	23.04	22.99
1963	34.88	27.85	31.84	22.79	20.82	20.78
1964	38.39	28.24	32.55	22.66	19.12	25.20
1965	42.64	29.65	33.27	22.46	17.47	17.46
1966	42.36	29.53	36.44	22.18	16.17	16.17
1967	40.89	29.42	37.57	21.98	15.03	15.04
1968	39.43	29.30	38.32	21.96	11.74	16.43
1969	40.63	29.19	39.07	21.98	5.72	5.77
CROPPING PATTERN ON MEDIUM FARMS						
1960	32.96	33.33	29.73	33.14	30.45	30.33
1961	31.98	32.95	29.80	33.15	30.73	30.66
1962	34.22	32.93	29.85	33.09	30.79	30.77
1963	31.31	34.07	29.91	33.18	30.70	30.69
1964	28.20	32.85	29.95	33.32	30.67	28.11
1965	24.05	29.25	29.98	33.56	30.16	30.14
1966	21.88	29.24	28.89	33.92	29.77	29.76
1967	21.93	29.22	29.72	34.21	29.33	29.26
1968	21.96	29.21	29.69	34.60	29.62	1.49
1969	16.54	29.20	29.65	35.76	30.76	30.05
CROPPING PATTERN ON LARGE FARMS						
1960	44.69	44.44	40.54	43.83	40.51	40.69
1961	40.99	42.22	39.78	43.88	43.54	43.66
1962	37.92	42.34	39.02	43.95	46.18	46.25
1963	33.81	38.08	38.26	44.02	48.48	48.53
1964	33.41	38.91	37.50	44.02	50.21	46.69
1965	33.30	41.11	36.75	43.98	52.37	52.39
1966	35.76	41.23	34.67	43.90	54.06	54.07
1967	37.17	41.36	32.71	43.81	55.63	55.70
1968	38.60	41.49	31.99	43.44	58.64	82.08
1969	42.83	41.61	31.28	42.26	63.52	64.18

Source: Model Results

TABLE 7: CROPPING PATTERN BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	WHEAT	SOYBN	CORN	NAPAS	SUPAS	WIPAS
CROPPING PATTERN ON SMALL FARMS						
1960	1.87	1.87	6.18	88.00	1.56	0.52
1961	2.42	2.16	5.97	87.34	1.57	0.53
1962	3.14	2.50	5.77	86.40	1.64	0.55
1963	4.07	2.88	5.58	85.14	1.75	0.58
1964	5.25	3.32	5.37	83.27	1.89	0.91
1965	6.81	3.83	5.20	81.38	2.09	0.70
1966	8.80	4.42	5.58	78.11	2.32	0.77
1967	11.36	5.08	5.63	74.47	2.60	0.87
1968	14.64	5.84	5.41	70.91	2.39	0.80
1969	18.86	6.71	5.20	67.45	1.33	0.44
CROPPING PATTERN ON MEDIUM FARMS						
1960	1.96	2.00	4.40	90.10	1.16	0.39
1961	2.05	2.05	4.17	89.95	1.34	0.45
1962	2.75	2.37	3.95	88.84	1.56	0.52
1963	2.61	2.52	3.75	88.66	1.84	0.62
1964	2.77	2.77	3.55	88.00	2.18	0.73
1965	2.77	2.73	3.37	87.67	2.60	0.87
1966	3.28	3.16	3.19	86.25	3.09	1.03
1967	4.41	3.65	3.22	83.83	3.67	1.22
1968	6.00	4.28	3.08	82.15	4.43	0.05
1969	5.58	4.88	2.87	79.79	5.20	1.68
CROPPING PATTERN ON LARGE FARMS						
1960	2.01	2.01	4.52	89.90	1.16	0.39
1961	1.98	1.98	4.21	89.91	1.44	0.48
1962	2.30	2.30	3.90	89.13	1.77	0.59
1963	2.14	2.14	3.63	89.15	2.21	0.74
1964	2.49	2.49	3.37	88.04	2.70	0.91
1965	2.89	2.89	3.12	86.57	3.40	1.13
1966	4.04	3.35	2.89	94.09	4.22	1.41
1967	5.62	3.89	2.67	80.82	5.24	1.75
1968	7.82	4.51	2.47	76.52	6.51	2.17
1969	10.87	5.23	2.28	70.86	8.07	2.69

Source: Model Results

PART II: INPUT-OUTPUT RELATIONSHIP BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1969)

Definitions Used for the Tables in Part II

Average Productivity of Annual Total Cash Outlays
= Gross Revenue/Total Cash Expenditures on Variable Inputs and on Investments in Power Sources

Average Productivity of Labor
= Gross Revenue/Total Labor Hours Employed

Average Productivity of Working Capital
= Gross Revenue/Cash Outlays on Variable Inputs

Average Productivity of New Investment Capital
= Gross Revenue/Cash Outlays on Investments in Power Sources

Cr$ = Brazilian Currency Unit

TABLE 8: AVERAGE PRODUCTIVITY OF ANNUAL TOTAL CASH OUTLAYS BY FARM SIZE WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	5.93093	4.81937	3.77928
1961	4.61820	4.97713	4.51165
1962	4.26669	4.57948	4.40871
1963	4.02299	4.09897	3.93207
1964	4.24109	4.14084	3.81620
1965	3.27232	3.35803	2.85419
1966	3.25226	2.96886	2.56713
1967	3.62769	3.01587	2.61069
1968	3.19635	2.49203	2.15485
1969	2.91888	2.46087	1.81749

Source: Model Results

TABLE 9: AVERAGE PRODUCTIVITY OF LABOR PER HOUR BY FARM SIZE (in constant 1960 Cr$/Hr) WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.10608	0.29333	0.73844
1961	0.11106	0.30082	0.78474
1962	0.12051	0.32565	0.86938
1963	0.12629	0.34329	0.94360
1964	0.10968	0.28970	0.81761
1965	0.10396	0.26406	0.77771
1966	0.10621	0.27628	0.84584
1967	0.10051	0.26905	0.83941
1968	0.09320	0.23950	0.76350
1969	0.08626	0.21455	0.74270

Source: Model Results

TABLE 10: AVERAGE PRODUCTIVITY OF WORKING CAPITAL BY FARM SIZE (In Cr$): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	5.93771	5.66215	5.03663
1961	4.65499	5.13008	4.60748
1962	4.29719	5.04759	4.80485
1963	4.05423	4.17018	3.99107
1964	4.27645	4.35519	4.11826
1965	3.30380	3.43250	3.10347
1966	3.28927	3.23209	2.88616
1967	3.68069	3.48518	3.05550
1968	3.24354	2.91845	2.56649
1969	2.96398	2.63287	2.18753

Source: Model Results

TABLE 11: AVERAGE PRODUCTIVITY OF NEW INVESTMENT CAPITAL BY FARM SIZE (In Cr$) WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	5190.73828	32.40109	15.13882
1961	584.38086	166.93637	216.90379
1962	601.21802	49.38072	53.47415
1963	522.08569	240.05200	265.97974
1964	512.95166	84.13383	52.03029
1965	343.34082	154.79085	35.53410
1966	289.03442	36.45328	23.22354
1967	251.95648	22.39648	17.93338
1968	219.71281	17.05585	13.43521
1969	191.85898	37.66898	10.74418

Source: Model Results

TABLE 12: AVERAGE REVENUE PER CROPPED HECTARE BY FARM SIZE (in constant 1960 Cr$/Ha): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	5.63709	5.66155	5.69519
1961	5.93969	5.91718	5.94954
1962	6.55102	6.51212	6.51758
1963	7.10337	6.99127	7.02313
1964	6.29392	6.00261	6.03059
1965	6.23416	5.58329	5.77345
1966	7.03606	5.93157	6.28270
1967	7.17882	5.86243	6.32999
1968	6.75084	5.36648	5.89803
1969	6.54040	4.80454	5.93769

Source: Model Results

PART III: GROSS ANNUAL NEW INVESTMENTS IN POWER SOURCES AND THEIR RELATIONSHIPS WITH LAND AND LABOR USE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

Remarks: Power sources include draft animals and tractors

TABLE 13: GROSS NEW INVESTMENTS IN DRAFT ANIMALS BY FARM SIZE (in 1000's): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.08600	0.04200	0.0
1961	0.86000	0.24000	0.0
1962	0.95000	0.24000	0.0
1963	1.09600	0.24900	0.0
1964	1.28100	0.25400	0.0
1965	1.52000	0.26000	0.0
1966	2.00000	0.26500	0.0
1967	2.32000	0.26000	0.0
1968	2.64700	0.26900	0.0
1969	3.09800	0.28000	0.0

Source: Model Results

TABLE 14 : GROSS NEW INVESTMENTS IN TRACTORS BY FARM SIZE (in 1000's): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.0	0.08300	0.19600
1961	0.0	0.06100	0.06600
1962	0.0	0.09600	0.10200
1963	0.0	0.03600	0.05700
1964	0.0	0.06000	0.12800
1965	0.0	0.06000	0.15200
1966	0.0	0.10800	0.22700
1967	0.0	0.16500	0.28900
1968	0.0	0.19200	0.37500
1969	0.0	0.12000	0.49100

Note: The size of Tractor considered is 50 H.P.
Source: Model Results

TABLE 15 : AVERAGE DRAFT ANIMAL HOURS EMPLOYED PER HECTARE BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.74490	0.16181	0.0
1961	0.78588	0.16810	0.0
1962	0.84500	0.17318	0.0
1963	0.92391	0.17917	0.0
1964	1.02444	0.18462	0.0
1965	1.16091	0.19085	0.0
1966	1.37285	0.19521	0.0
1967	1.60344	0.19728	0.0
1968	1.86327	0.20312	0.0
1969	2.15713	0.20377	0.0

Source: Model Results

TABLE 16 : AVERAGE TRACTOR HOURS EMPLOYED PER HECTARE BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.0	0.47686	0.62381
1961	0.0	0.48243	0.62373
1962	0.0	0.56822	0.66844
1963	0.0	0.57163	0.67093
1964	0.0	0.59785	0.73619
1965	0.0	0.62604	0.82455
1966	0.0	0.71050	0.97861
1967	0.0	0.86650	1.18278
1968	0.0	1.06094	1.45425
1969	0.0	1.11497	1.81336

Source: Model Results

TABLE 17 : RATIOS OF DRAFT ANIMAL/LABOR HOURS EMPLOYED BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.01402	0.00838	0.0
1961	0.01469	0.00855	0.0
1962	0.01554	0.00866	0.0
1963	0.01642	0.00880	0.0
1964	0.01785	0.00891	0.0
1965	0.01936	0.00903	0.0
1966	0.02072	0.00909	0.0
1967	0.02252	0.00905	0.0
1968	0.02572	0.00907	0.0
1969	0.02845	0.00910	0.0

Source: Model Results

TABLE 18 : RATIOS OF TRACTOR/LABOR HOURS EMPLOYED BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.0	0.02471	0.08088
1961	0.0	0.02453	0.08227
1962	0.0	0.02842	0.08916
1963	0.0	0.02807	0.09014
1964	0.0	0.02885	0.09899
1965	0.0	0.02961	0.11107
1966	0.0	0.03309	0.13175
1967	0.0	0.03977	0.15685
1968	0.0	0.04735	0.18825
1969	0.0	0.04979	0.22682

Source: Model Results

PART IV: SOME FACTOR RELATIONSHIPS AND CASH EXPENDITURES: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1969)

Definitions Used in the Tables of Part IV

Gross New Investment Capital
= Cash Outlays on Purchasing Power Sources

Annual Working Capital = Cash Outlays on Variable Inputs

Total Annual Capital = Gross New Investment Capital + Annual Working Capital Expenditures

TABLE 19: AVERAGE HECTARES OF LAND CROPPED PER LABOR HOUR BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.01882	0.05181	0.12966
1961	0.01870	0.05084	0.13190
1962	0.01840	0.05001	0.13339
1963	0.01778	0.04910	0.13436
1964	0.01743	0.04826	0.13446
1965	0.01668	0.04730	0.13470
1966	0.01509	0.04658	0.13463
1967	0.01400	0.04589	0.13261
1968	0.01381	0.04463	0.12945
1969	0.01319	0.04466	0.12508

Source: Model Results

TABLE 20: AVERAGE GROSS NEW INVESTMENT CAPITAL (in constant 1960 Cr$) PER LABOR HOUR BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.00002	0.00905	0.04878
1961	0.00019	0.00180	0.00362
1962	0.00020	0.00659	0.01626
1963	0.00024	0.00143	0.00355
1964	0.00021	0.00344	0.01571
1965	0.00030	0.00171	0.02189
1966	0.00037	0.00758	0.03642
1967	0.00040	0.01201	0.04681
1968	0.00042	0.01404	0.05683
1969	0.00045	0.00570	0.06913

Source: Model Results

TABLE 21: AVERAGE ANNUAL WORKING CAPITAL (in constant 1960 Cr$) PER LABOR HOUR BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL, SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.01786	0.05181	0.14661
1961	0.02386	0.05864	0.17032
1962	0.02804	0.06452	0.18094
1963	0.03115	0.08232	0.23643
1964	0.02565	0.06652	0.19853
1965	0.03147	0.07693	0.25059
1966	0.03229	0.08548	0.29307
1967	0.02731	0.07720	0.27472
1968	0.02873	0.08206	0.29749
1969	0.02910	0.08149	0.33951

Source: Model Results

TABLE 22: AVERAGE ANNUAL TOTAL CAPITAL EXPENDITURES (in constant 1960 Cr$) PER LABOR HOUR BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.01789	0.06086	0.19539
1961	0.02405	0.06044	0.17394
1962	0.02825	0.07111	0.19720
1963	0.03139	0.08375	0.23998
1964	0.02586	0.06996	0.21425
1965	0.03177	0.07864	0.27248
1966	0.03266	0.09306	0.32949
1967	0.02770	0.08921	0.32153
1968	0.02916	0.09610	0.35432
1969	0.02955	0.08719	0.40864

Source: Model Results

TABLE 23: 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 (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.0	0.0	32.1
1961	0.0	0.0	23.1
1962	0.0	0.0	20.9
1963	0.0	0.0	18.8
1964	0.0	0.0	17.1
1965	0.0	0.0	15.7
1966	0.0	0.0	14.5
1967	0.0	0.0	14.6
1968	0.0	0.0	15.5
1969	0.0	0.0	17.3

Source: Model Results

TABLE 24: 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 (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	52.3	100.0	134.8
1961	51.7	100.0	130.0
1962	51.8	99.5	126.4
1963	52.8	99.3	122.8
1964	54.1	100.0	120.6
1965	54.5	100.0	118.6
1966	59.4	99.4	116.9
1967	63.3	100.0	117.0
1968	63.5	100.0	118.4
1969	65.7	100.0	120.9

Source: Model Results

TABLE 25: AVERAGE LABOR HOURS PER CROPPED HECTARE BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	53.14142	19.30083	7.71250
1961	53.48105	19.67021	7.58156
1962	54.35899	19.99709	7.49683
1963	56.25014	20.36526	7.44292
1964	57.38316	20.71997	7.43704
1965	59.96877	21.14375	7.42365
1966	66.24785	21.46921	7.42775
1967	71.42740	21.78957	7.54100
1968	72.43286	22.40746	7.72494
1969	75.81918	22.39336	7.99478

Source: Model Results

TABLE 26: AVERAGE ANNUAL WORKING CAPITAL USE (in constant 1960 Cr$) PER CROPPED HECTARE BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.94937	0.99989	1.13075
1961	1.27598	1.15343	1.29128
1962	1.52449	1.29014	1.35646
1963	1.75221	1.67649	1.75971
1964	1.47176	1.37827	1.47649
1965	1.88697	1.62660	1.86032
1966	2.13910	1.83521	2.17683
1967	1.95040	1.68211	2.07167
1968	2.08132	1.83881	2.29809
1969	2.20663	1.82483	2.71433

Source: Model Results

TABLE 27: GROSS NEW INVESTMENT CAPITAL (in constant 1960 Cr$) PER CROPPED HECTARE BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUI SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.00109	0.17473	0.37620
1961	0.01016	0.03545	0.02743
1962	0.01090	0.13188	0.12188
1963	0.01361	0.02912	0.02640
1964	0.01227	0.07135	0.11687
1965	0.01816	0.03607	0.16248
1966	0.02434	0.16272	0.27053
1967	0.02849	0.26176	0.35297
1968	0.03073	0.31464	0.43900
1969	0.03409	0.12755	0.55264

Source: Model Results

TABLE 28: TOTAL ANNUAL CAPITAL EXPENDITURES (in constant 1960 Cr$) PER HECTARE BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO S SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.95046	1.17463	1.50695
1961	1.28615	1.18837	1.31871
1962	1.53539	1.42202	1.47834
1963	1.76582	1.70562	1.78611
1964	1.48403	1.44961	1.59336
1965	1.90512	1.66267	2.02279
1966	2.16344	1.99793	2.44736
1967	1.97889	1.94387	2.42464
1968	2.11204	2.15346	2.73709
1969	2.24072	1.95238	3.26698

Source: Model Results

PART V: CREDIT USE AND OTHER FACTOR RELATIONSHIPS

TABLE 29: AVERAGE CREDIT USE/LABOR HOUR RATIOS BY FARM SIZE (in constant 1960 Cr$/Hr): WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.00631	0.02594	0.09336
1961	0.0	0.00121	0.04223
1962	0.0	0.0	0.03428
1963	0.0	0.00543	0.05029
1964	0.00464	0.01541	0.07899
1965	0.00555	0.01004	0.10479
1966	0.00735	0.01934	0.17842
1967	0.00390	0.02349	0.22335
1968	0.00360	0.03838	0.29954
1969	0.00686	0.05073	0.43741

Source: Model Results

TABLE 30: AVERAGE CREDIT USE PER HECTARE BY FARM SIZE (in constant 1960 Cr$/Ha) WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.33537	0.50063	0.72001
1961	0.0	0.02384	0.32019
1962	0.0	0.0	0.25702
1963	0.0	0.11064	0.37428
1964	0.26654	0.31936	0.58747
1965	0.33266	0.21233	0.77790
1966	0.48691	0.41518	1.32524
1967	0.27858	0.51187	1.68432
1968	0.26070	0.85989	2.31396
1969	0.52022	1.13592	3.49700

Source: Model Results

TABLE 31: BORROWING/INTERNAL CAPITAL FINANCING RATIOS BY FARM SIZE: WHEAT REGION IN THE STATE OF RIO GRANDE DO SUL SOUTHERN BRAZIL (1960-1969)

YEAR	SMALL FARM	MEDIUM FARM	LARGE FARM
1960	0.54525	0.74278	0.91495
1961	0.0	0.02046	0.32067
1962	0.0	0.0	0.21045
1963	0.0	0.06936	0.26510
1964	0.21893	0.28256	0.58403
1965	0.21156	0.14640	0.62488
1966	0.29043	0.26232	1.18100
1967	0.16384	0.35745	2.27509
1968	0.14082	0.66474	5.46858
1969	0.30237	1.39127	15.20260

Source: Model Results

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