THE ECONOMICS OF AGRICULTURAL MECHANIZATION IN SOUTHERN BRAZIL

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
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By

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* * * * *

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Professor Norman Rask, Adviser

The potential and desirability of mechanization as an agricultural development technique is widely debated. While some view it as a production increasing and cost reducing technology and a symbol of an efficient and developed agriculture, others see it as a process of substituting scarce capital for unskilled labor which gives rise to higher levels of unemployment, further income disparity, and an increase in rural-urban migration.

In the midst of this controversy Brazilian officials, through a wide range of price distorting policies and concessions aimed almost exclusively at increasing production, have strongly encouraged mechanization.

The major objective of this study was to determine what effects agricultural mechanization has had on (1) employment, (2) land productivity, (3) labor productivity, and (4) production efficiency under three distinctly different, but characteristic, farm resource situations in Southern Brazil. The path mechanization has taken and the government policies that molded this path were described and literature relating to

the effects of mechanization were reviewed to provide background information.

Tabular, covariance, and regression analyses were used with cross-sectional farm survey data to determine the impact of mechanization. The observations representing each situation were first characterized and compared by categorizing them on the basis of tractor ownership and land unit machine cost. Next, covariance analysis was employed to remove the influence of farm size. And, lastly regression analysis was used to measure the influence of mechanization on employment, productivity and efficiency among both the mechanized and non-mechanized subsamples.

The first of the three farm resource situations was one where increases in farm size via land rental and incremental purchases was the predominant modification associated with mechanization. In the second situation, large tracts of open range land were brought into crop production through the use of mechanization. Neither a change in farm size nor enterprise accompanied mechanization in the third. These situations, while characteristic, represent different factor endowments. Land resources tended to be limited in the first and third situations but relatively elastic in the second where the dependence on hired labor was much greater.

The analysis showed the effects of agricultural mechanization have been quite mixed in Southern Brazil. Mechanization had a very positive impact on land and labor productivity in all but the third situation. Higher land-use intensities were primarily responsible for this increase. Mechanization, resulting in more timely completion of critical tasks,

allowed more land to be cropped and a greater percentage double cropped. Slightly higher yields and larger acreages also contributed.

In the second situation, increases in land-use intensities and yields were sufficient to offset the substitution effects of mechanization for labor and led to levels of employment clearly above those of the non-mechanized farms. Additional machine inputs would have led to higher levels of employment on these mechanized farms as well as on the non-mechanized farms of the first situation. The extra machine inputs would have also returned a sizable profit on these farms and on the non-mechanized farms of the third situation. Likewise, mechanization increased production efficiency in some instances.

Thus, while agricultural mechanization has the potential of being a very positive development technique, the analysis demonstrated that it is location specific and must be used selectively. Positive results can be expected in areas and for activities where substantial increases in land-use intensity will accompany the adoption and use of this technology. Where little or no potential exists for using land more intensively, negative results should be expected. Between these two situations, the results will be mixed.

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CHAPTER I

INTRODUCTION

The potential and desirability of farm mechanization as an agricultural development technique is widely debated. Mechanization is customarily seen as a process of substituting scarce capital for unskilled labor, normally an abundant agricultural resource in low-income countries.[1] To others, however, agricultural mechanization is a symbol of an efficient and developed agriculture. They argue that this modern technology increases productivity, employment, and efficiency.

In addition to seeing the mechanization process as a demonstration of inefficient resource allocation and the cause of the "rural exodus," concerns are raised by critics regarding the lack of necessary skills the operators and machanics must possess and the supporting services and inputs the society must provide. Other issues, somewhat less popular but perhaps just as relevant, relate to the "lumpiness" or indivisibility of tractors and accompanying equipment as inputs, the short-run effects of mechanization on the existing scarcity of foreign exchange, the necessity of having an agrarian structure which allows the fields to be sufficiently large and accessible for mechanization, the social

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[1]While the term "mechanization" embraces every form of farm equipment from the simplest to the most complex, it is used here in the popular and more narrow sense; it refers only to the use of tractors and associated implements in the production and harvesting of agricultural products. The terms "low-income," "less developed," "underdeveloped," and "developing" are used interchangeably in this study.

disparity that is likely to widen between the affluent farmers who have the means of acquiring mechanized equipment and the small farmers who do not, and the back-up of labor in agriculture that might result from scarce capital being invested in agriculture rather than industry.

In the midst of this controversy, mechanization in the agricultural sectors of many low-income countries is proceeding at a rapid pace. Brazil is no exception. The estimated number of tractors being used in this large South American country grew from 8,372 to 63,493 between 1950 and 1960; an increase of 650 percent.[2] By 1970, Brazil's fleet of farm tractors numbered 156,529, and is predicted to increase to 300,000 by 1980.[3]

The government of Brazil, like those in many developing countries, has generally maintained a favorable view toward agricultural mechanization and has used specific policy measures to speed its adoption. This favorable view was expressed by a recent president of Brazil who said, "the acceleration of the rate at which Brazil develops economically is dependent upon the mechanization of its agriculture."[4]

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[2]CIDA (Inter-American Committee for Agricultural Development), Land Tenure Conditions and Socio-Economic Development of the Agricultural Sector--BRAZIL, Pan American Union, OAS (Washington, D.C.: 1966), Table 22.

[3]John H. Sanders, "Mechanization and Employment in Brazilian Agriculture, 1950-1971" (unpublished Ph.D. dissertation, University of Minnesota, 1973), p. 12; Ilo S. Nogueira, "Perspectiva de 70 e Vender 12 mil Tratores," A Granja (Porto Alegre, Brazil: Maio de 1970), p. 54; and Ilo S. Nogueira, "Decada 70--Fronta de 300 mil Tratores vai Elevar A Produtividade," A Granja (Porto Alegre, Brazil: Agosto de 1970), pp. 16-18.

[4]Ministerio do Planejamento e Coordenacao Economica, Brasil, Plano Decenal de Desenvolvimento Economico e Social, Tomo IV, Vol 1 (Marco de 1967), p. 329.

Government attempts to increase the level of agricultural mechanization have resulted in a wide variety of policies and concessions during the past three decades. Prior to and during the early 1940's the importing of tractors and equipment was facilitated through financial guarantees and exchange assistance provided by the government. In the early 1940's the government increased its involvement by providing the Ministry of Agriculture with extra funds for importing these capital inputs directly. During the 1940's and 1950's the public was, at times, strongly subsidizing tractor imports via very favorable exchange rates and financing charges. A much larger and more permanent commitment was made in the late 1950's when the Brazilian government adopted a plan for establishing a local tractor industry.

This infant industry has had mixed success, experiencing both good and bad performance during the 1960's. The government came to its aid in the late 1960's, and again started instituting concessions and policies to increase the level of mechanization in Brazil's agriculture. This aid has also been in a variety of forms and has included increasingly larger quantities of medium-term credit with reduced interest rates and collateral requirements, exemption of certain taxes, personal income tax advantages, and product subsidy and minimum price legislation.

The Problem

Much of the controversy over agricultural mechanization as a development technique may be related to the widely varying resource combinations or situations in which it has been introduced. This would be especially true in reference to varying land-labor factor proportions.

For example, mechanization is characteristically considered to be a labor-replacing technology, and in situations where labor is abundant relative to land, only limited possibilities would exist for improving economic performance through the use of this technology. On the other hand, when land is abundant relative to labor, mechanization may permit a more intensive use of the land resource, and in turn, be expected to improve economic performance. Since the factor proportions or endowments of any given area fall somewhere on a continuum between these two extremes, it is not surprising that mixed results have been experienced.

Within the Brazilian context, it is apparent from the rapid increase in tractor numbers and from the supportive policies which have fueled this increase that officials and farmers alike believe mechanization, and particularly large scale mechanization, can increase their economic performance. Concern about the substitution of this technology for labor or any of the other undesirable aspects that have accompanied mechanization in some other countries seems not to have existed to any degree in Brazil. Consequently, one could hypothesize that the resource endowments in this large country are such that the positive effects of mechanization greatly overshadow its substitution for labor.

Increasingly, however, the areas in Brazil where land is abundant relative to labor are being brought into more intensive uses. It is also apparent that Brazil has not attempted to define mechanization for a specific set of factor conditions and that it has in fact been introduced in some areas where only limited improvements in performance could be expected. Thus, it is appropriate to begin to ask questions and test assumptions about the overall impact of agricultural mechanization in

Brazil. Further, given the variation in factor proportions on farms throughout this large and diverse country, additional insight can be gained on the general role of mechanization as a development technique. Specifically, the questions to be asked are (1) is agricultural mechanization a location specific technology and (2) what are the resource situations where the economic performance of mechanization outweighs its direct substitution for labor?

While recognizing that Brazil's total land and labor endowment is probably located nearer the "land abundant" end of the continuum than many other less developed countries, mechanization has been introduced in a number of widely different combinations of factor endowments in Brazil. These diverse situations present a unique opportunity to examine the impact of mechanization under different factor proportions and to further the general knowledge about the role of this technology in development.

The Objectives

The major objective of this study is to examine, within the Brazilian context, some of the key economic consequences that are generally associated with agricultural mechanization in developing countries. More specifically, the study is an attempt to determine what effects rapidly induced mechanization has had on (1) employment, (2) labor productivity, (3) land productivity, and (4) production efficiency under three distinctly different farm resource situations in Southern Brazil. A supplemental objective is drawing policy insights for other regions of Brazil and other developing countries.

The Procedure

To look at the impact of agricultural mechanization under different combinations of resources, three techniques are used to analyze farm survey data depicting three characteristic resource situations. The path agricultural mechanization has taken in Brazil, the government policies that have served to mold this path, and literature relating to the effects of mechanization are reviewed to provide the necessary background for this study.

The first of the three farm resource situations is one where increases in farm size is the predominate modification associated with mechanization. The size increases on these farms, where most of the labor is provided by the family, occurs through both land rental and incremental purchases. In the second situation, large tracts of open range land have been brought into crop production through the use of mechanization. Neither a change in farm size nor enterprise has accompanied mechanization in the third situation where the farms are somewhat smaller and are partially irrigated. The land resource tends to be limited in the first and third situations but relatively elastic in the second where the dependence on hired labor is much greater. Both crops and livestock enterprises and the necessary resource combinations are found on many farms in all three situations.

Tabular, covariance, and regression analytical techniques are used to estimate the effects of mechanization on employment, land and labor productivity, and production efficiency. The observations are first characterized and compared by categorizing them on the basis of tractor ownership and land unit machine cost. Covariance analysis is used next

to provide a better estimate of the differences due to mechanization between the non-owners and owners of tractors by isolating the influence of farm size. As a last step, least squares regression analysis is used to measure the extent to which mechanization and other inputs influence the four dependent variables on the two types of sample farms in the different situations. Conclusions and implications are drawn from the results of the analysis.

The cross-sectional survey data used in the analysis were collected in Brazil's two southern-most states through personal interviews.

CHAPTER II

REVIEW OF LITERATURE

While few in-depth research efforts have been conducted to determine what benefits are derived and what costs are incurred in mechanizing agriculture in less developed countries, arguments for and against agricultural mechanization are fairly common. Four main issues frequently included in the controversy are identified and literature pertaining to them reviewed in this section. These issues correspond to the aspirations of many countries to expand agricultural output, reduce rural unemployment, increase farm wages and incomes, and lower food and fiber prices.

The Issues

The four central issues which follow are consistent with the objectives of this study and are presented as postulates. This is followed by an in-depth review of the literature.

1. Mechanization increases total production. Production increases are achieved through higher yields, expanded agricultural area, and increased land-use intensities. Optimum yields, especially from the new high yielding crop varieties, are dependent upon a package of inputs and practices being applied and performed in a precise and timely fashion. Proper seedbed preparation, exact seed and fertilizer placement, and uniform distribution of protective chemicals are included among these.

Expansion on the extensive and intensive margins (increasing agricultural area and land-use intensities) results from extending the capabilities of the human muscle and from gaining greater control over the production environment. With the aid of mechanization, selected production tasks are performed more rapidly, seasonal labor bottlenecks are broken, and in turn, additional land is brought into production and land is used more intensively. Multiple cropping and the production of crops requiring larger quantities of non-land inputs represent more intensive uses of land, and previously unproductive land brought into production might be that which could not be farmed without the aid of mechanization due not only to the time requirements but also to the compactness of the soil, etc.

Mechanization also results in reduced dependence on draft animals, and in so doing lessens the risk of non-performance if unseasonable weather occurs during the critical seeding and harvest periods. Tractors, unlike draft animals, can be used far in excess of eight or nine hours per day. In addition, draft animals consume forage requiring land which could be used to expand crop and livestock enterprises.

2. Mechanization leads to increases in employment. Considerable disagreement surrounds this issue. Mechanization and labor substitute for each other as sources of power, and accordingly, mechanization is generally considered be a labor-saving technology.

When utilized selectively, however, mechanization makes possible a larger total product (as argued above) and the substitution effect (mechanization for labor) may be more than offset by the positive

employment effects of the expanded product. A set of hypothetical isoproduct curves and expansion paths illustrates this point (Figure 1).

In this hypothetical illustration, diminishing substitutability of mechanization for labor as a source of power for a given level of farm output is assumed. Therefore, varying combinations of labor and mechanization will yield equal quantities of output.

The original level of output is O_1 and is being produced with M_1 units of mechanization and L_1 units of labor at A_1.[1] Additional mechanization, however, when used to overcome a limiting constraint, such as labor bottlenecks or compact soil conditions, permits available land to be brought into production or used more intensively which yields a higher level of output (O_2).[2] At this new level of output, M_3 units of mechanization and L_2 units of labor are employed (B_2).

The expansion effect, as measured in additional employment, is the difference between L_1 and L_3 units of labor. A decrease in employment of L_3 minus L_2 units of labor is caused by the substitution of mechanization for labor. The expansion effect being larger than the

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[1]These factor proportions would normally be expected to be determined by the relative prices of the two factors.

[2]Although labor is generally considered to be an abundant resource and may go unemployed or underemployed throughout much of the year in the primary sectors of less developed countries, it often is a limiting constraint on higher levels of output. During the short planting and harvesting periods, labor is often a scarce input. By reducing the amount of labor required per unit of production at these critical times (removing the peaks from the labor input schedule), production can be increased and fuller utilization made of the available labor during the non-critical periods.

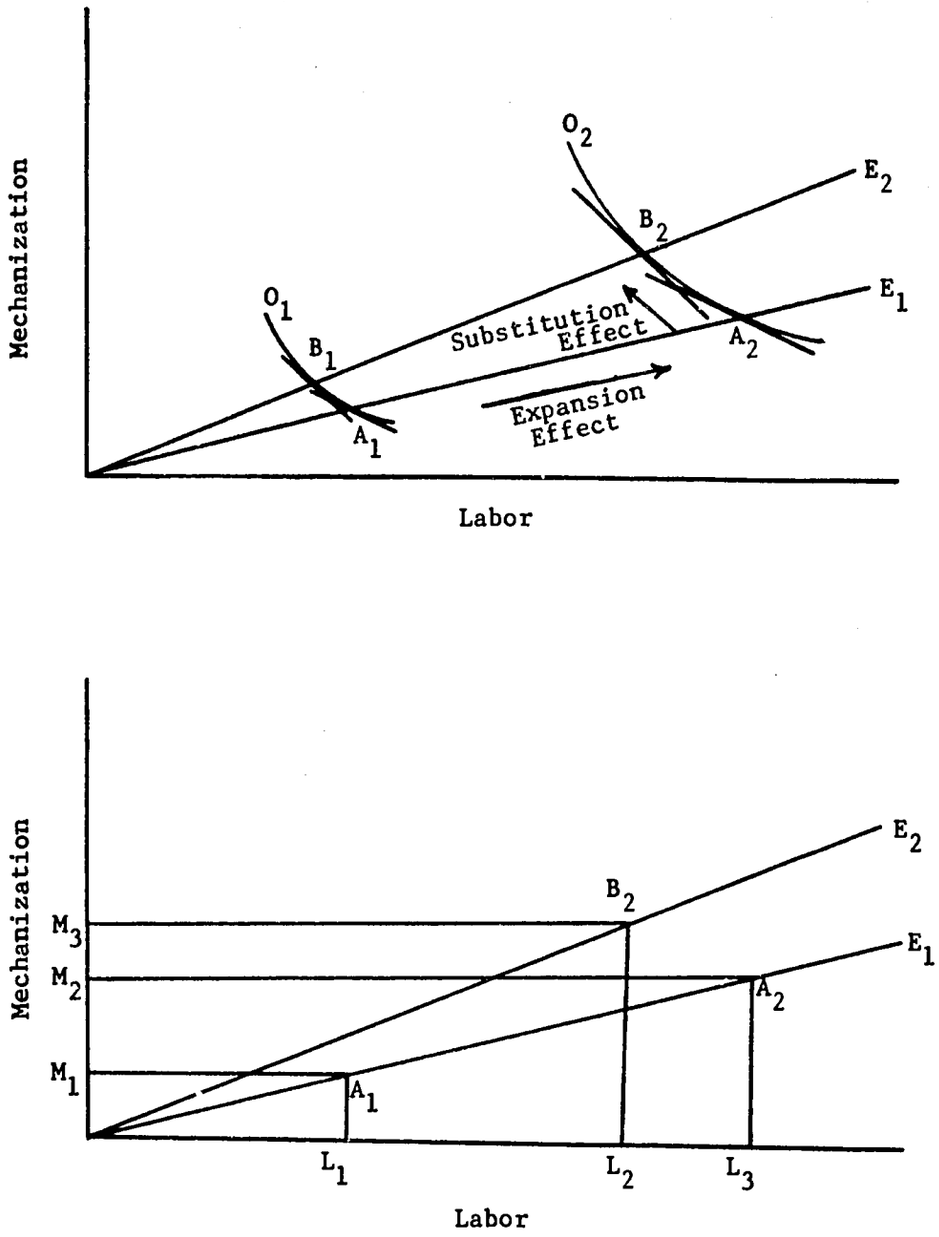

Figure 1.--Changes in Output and the Use of Mechanization and Labor

substitution effect results in an increase in employment of L_2 minus L_1 units of labor.[3]

In addition to the potential positive effects of mechanization on labor within the agricultural sector, it will have a positive influence on employment opportunities in the other sectors of the economy as well. The production, marketing, and servicing of tractors and farm machinery necessitates increased labor inputs in industry and agri-business firms. The increased use of other factors (i.e., soil additives, protective chemicals, improved seed, and fuel and lubricants) that accompany the expanded production will create additional employment opportunities. Likewise, the marketing and processing of a larger product will require added labor.

3. Mechanization increases labor productivity. Like any type of production increasing technology, mechanization can cause a shift in the production function. This is equivalent to saying the productivities of the resources being used, including labor, increase. In addition to the higher incomes and wage rates that should result from the increased productivity of labor, some of the physical drudgery that accompanies more traditional systems of production should be removed by mechanization. As a consequence, the migration out of agriculture should be slowed.

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[3]A third effect that might be operative but not illustrated in Figure 1 is a change in the production surface resulting from a new technology such as a better tractor or implement. This would be translated into a shift in the iso-product curve, and would be expected to result in an increase in the amount of mechanization employed relative to labor. Again however, the expansion effect of the technology might well be large enough to increase the absolute level of employment.

4. Mechanization results in lower per unit production costs. Since a shift in a production function prompted by mechanization, or any other production expanding technology, represents an increase in the productivities of all the resources being used, the quantities of these inputs needed to produce each unit of output decrease. The decreases, of course, reduce the costs of producing each unit of output and should lead to lower food and fiber prices.

Findings of previous studies are presented next. Some support the above postulates while others tend to refute them. Still others provide a limited amount of insight into when or under what conditions they are likely to hold or be rejected.

The Effect on Production

Although agricultural mechanization is customarily thought of as being a labor-saving technology in the developed countries, it can also be a production increasing technology as argued above.[4] And unless this argument holds, investments in mechanization cannot be justified economically in capital-scarce less developed countries. To facilitate the examination of the issue, the related evidence, where possible, is divided into the various components of the argument, i.e., higher yields, expanded agricultural area, and increased land-use intensity.

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[4]The yield increases that were experienced in U.S. Agriculture between 1920 and 1950 are claimed to have resulted equally from three major factors: the use of better equipment, improved crop varieties, and chemicals. G. W. Giles, "The First Step in Advancing Mechanization," Getting Agriculture Moving: Selected Readings, Vol. II (New York: Agricultural Development Council, 1966), p. 722.

1. Yields. Crop and forage yields (per unit of land) are determined in part by the manner in which the inputs and practices are applied and carried out.[5] Mechanization, it is maintained, enables producers to perform these functions with more precision in a more timely fashion.

To lend support to the premise that mechanization and yields are positively associated, Giles makes an assessment of the yields of major food crops and of the available horsepower for agricultural field production in various countries, regions, and continents. He averages and aggregates the yields on a per hectare basis and totals the human, animal, and tractor horsepower in agriculture per hectare of usable land and land in permanent crops. These values are then plotted to show their relationship and to determine the minimum amount of power needed to optimize per hectare yields (Figure 2). Giles admits to the measurement and heterogenity problems involved in his rather simplistic endeavor, but capitalizes on this to explain the locations of Taiwan and United Arab Republic in the figure. He maintains that these two deviant observations have relatively high yields with respect to their power inputs because a high proportion of their cultivated land is irrigated (reducing the importance of timeliness), because the caloric intake of

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[5]Plowing, for instance, when properly done, brings about important biological and physical modifications which have yield-increasing effects, i.e., incorporates organic materials, facilitates root penetration, permits adequate soil ventilation, and allows more complete water absorption and retention.

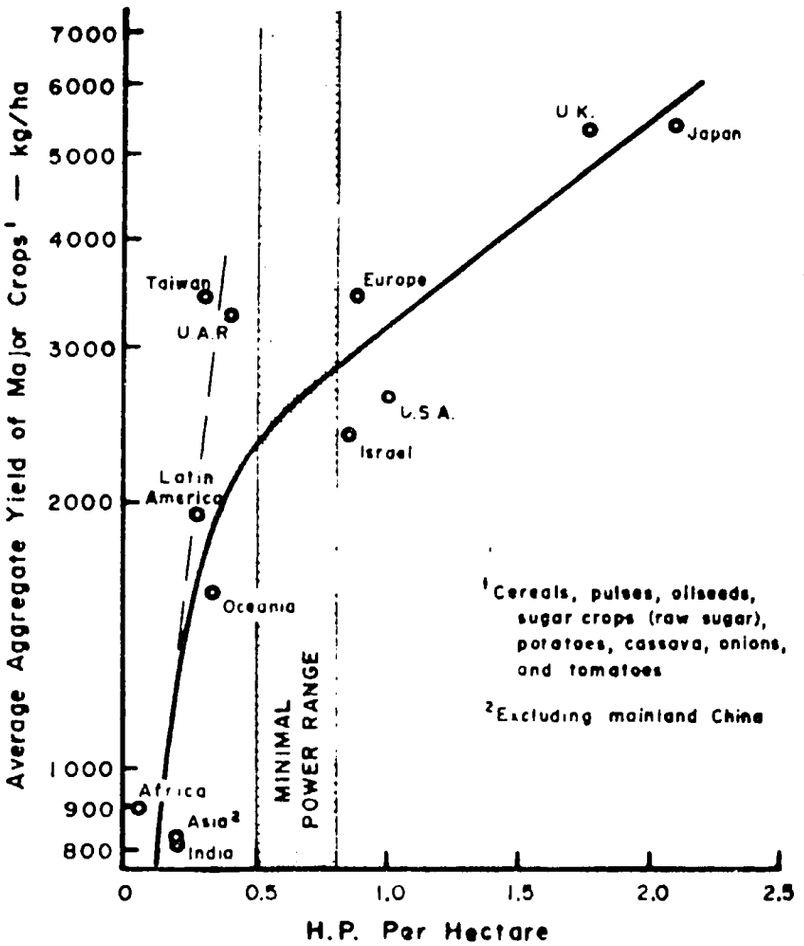

Figure 2.--Relationship Between Yields in Kilograms Per Hectare and Power in Horsepower Per Hectare: Major Food Crops

Source: G. W. Giles, op. cit., p. 180.

their people is relatively large, and because the land quality is relatively high.[6]

A second study relating specifically to the effect of mechanization on yields was conducted in West Pakistan in 1951 through 1954. As reported by Bose and Clark, four different farming systems varying from limited to complete mechanization were compared to a system where only bullock power was employed (traditional farming). Except for the fodder crops, essentially the same cropping pattern was followed under each of the five systems. The yields obtained by producing sugar cane, wheat, grain, and (rabi) oilseeds were consistently higher when produced under each of the mechanized systems. Maize yields were considerably larger for two mechanized systems as compared to the bullock system. The remaining two mechanized systems produced slightly lower maize yields than the bullock system however. Cotton yields for three of the four mechanized systems were lower than those obtained by the traditional means. "Unfortunately, no statistical test was made to determine the significance of these variations, although the percentage increases would seem to be high enough that a statistical significance probably did exist."[7]

While Bose and Clark attribute the increased yields reported above to the "timeliness" of the operations, Lawrence reports the results of two other studies conducted in West Pakistan wherein the "quality"

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[6] G. W. Giles, "Agricultural Power and Equipment," The World Food Problem, a report of the President's Science Advisory Committee, Vol. III (Washington, D.C.: September, 1967), pp. 178-181.

[7] G. L. Bose and E. H. Clark, II, "Some Basic Considerations on Agricultural Mechanization in West Pakistan," The Pakistan Development Review, Vol. IX, No. 3 (Autumn, 1969), pp. 274-275.

aspects of the operations produced much larger increases. The latter two studies were quite similar and were undertaken as an experiment in dryland wheat production during 1968-1969 and 1969-1970 seasons. Four months prior to planting, the soil of the experimental fields was loosened to a depth of approximately 15 inches by chisel plowing. This broke the near-surface hard pan and permitted the limited amount of rainfall to be more readily absorbed and reduced surface evaporation and erosion. With the increased availability of soil moisture, fertilizer was more safely applied and Mexi-Pak wheat was sown. The resulting yields, while showing great variation between individual farmers, averaged from 27 to 29 maunds per acre as contrasted to the 4.9 and 6 maund yields of the neighboring control plots cultivated in the traditional manner. Realizing, however, that Mexi-Pak wheat is less resistant to drought than are desi varieties and that soil moisture is quite crucial to fertilizer application, experimental chisel-plow plantings of the traditional desi varieties were sown with no fertilizer. These yields averaged 16 maunds.[8]

In neighboring India, several sources suggest a positive association between levels of mechanization and yields. Johl constructed Table 1 using 1968-1969 farm management studies conducted by the Department of Economics and Sociology of the Punjab Agricultural University.[9]

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[8] Roger Lawrence, "Some Economic Aspects of Farm Mechanization in Pakistan" (New York: United Nations, August, 1970), pp. 15-17. (Mimeographed.)

[9] S. S. Joh', Mechanization, Labor-Use and Productivity in Indian Agriculture, Economics and Sociology Occasional Paper No. 23, Department of Agricultural Economics and Rural Sociology, The Ohio State University, Columbus, Ohio, 1971, pp. 10-12.

TABLE 1

COMPARISON OF YIELD PER ACRE OF VARIOUS CROPS ON TRACTOR AND BULLOCK OPERATED FARMS IN FEROZEPUR DISTRICT OF PUNJAB, 1968-69

Crop	Yield in Quintals Per Hectare			
	Tube-Well Holdings		Canal Irrigated Holdings	
	Tractor Operated	Bullock Operated	Tractor Operated	Bullock Operated
Wheat Local	13.82	10.62	--	--
Wheat Mexican	24.70	19.81	25.65	22.46
Maize Local	15.62	13.55	--	--
Paddy	28.36	24.17	--	--
American Cotton	--	--	10.15	8.36
Desi Cotton	8.47	6.96	9.25	7.71

Source: Studies in Economics of Farm Management, Ferozepur District of Punjab, Department of Economics and Sociology, Punjab Agricultural University, Ludhiana, 1968-69.

This table shows the yields of six crops under irrigated conditions were 14 to 30 percent higher on tractor operated farms than on farms where bullocks were used. In a case study, B. Singh reports Punjab tractor owners had wheat yields which were 9.7 percent greater than those of the non-mechanized control group.[10] Another study showed upland rice yields in Raipur were increased by as much as 40 percent through more efficient seedbed preparation.[11] And the Department of Agriculture, as well as farmers in the State of Gujarat, claim higher yields from better plowing.[12]

Ninety-three percent of the farmers using tractors from the Ministry of Agriculture's tractor hire service in the northern part of Nigeria's Western State reported yield increases. They estimated that on an average their yields were 54 percent larger on the mechanically tilled land. In this region, where little use was customarily made of draft animals and where the optimal planting season is relatively short, these yield increases were attributed to the timeliness the tractor afforded.[13] As a result of the transition from oxen, all of the seven sierra farmers included in a study of Peruvian potato producers claimed

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[10] B. Singh, "Economics of Tractor Cultivation--A Case Study," Indian Journal of Agricultural Economics, Vol. XXIII, No. 1 (Bombay, January/March, 1968), pp. 83-88.

[11] L. P. Schertz, "Food, Man and Machines," War on Hunger (Washington, D.C.: U.S. Agency for International Development, January, 1969), p. 14.

[12] E. M. Schebeck, "Mechanization in Gujarat" (Washington, D.C.: Economics Department, World Bank, January 31, 1969), p. 8. (Mimeographed draft.)

[13] M. J. Purvis, A Study of the Economics of Tractor Use in Oys Division of the Western State, CSNRD-17, Michigan State University, East Lansing, September, 1968, p. 36.

improved yields. The larger yields were attributed to the more complete discing and harrowing and deeper furrowing. Two of the farmers estimated the increases to be 20 percent.[14] The production of crops grown by commercial farmers using tractors and other non-traditional inputs increased fivefold in Colombia between 1948-50 and 1967, while the production of all major crops increased little more than 50 percent. The yield increases in the crops grown by commercial farmers averaged approximately 70 percent and were considerably larger than the increases in those produced under traditional methods. Most of the rise in production resulted from an expansion in area.[15]

In two regions of the State of Sao Paulo, Brazil, comparisons were made between two systems of peanut production in 1964-65. The two systems within each region employed basically the same input quantities and techniques with the exception of the power source. Tractors were used in the one system while only draft animals were used in the other. In the first region where no fertilizer was used, the yields of the mechanized system were 23 and 77 percent greater than the yields of the non-mechanized system during the wet and dry seasons respectively. Applying approximately equal quantities of soil nutrients, the yield of the mechanized system was 22 percent larger than that of the

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[14] R. M. Lidman, "The Tractor Factor: Agricultural Mechanization in Peru," Public and International Affairs, No. 1 (Princeton, N.J.: Princeton University, 1968), p. 20.

[15] L. J. Atkinson, Changes in Agricultural Production and Technology in Colombia, Foreign Agricultural Economic Report No. 52, EDS/USDA (Washington, D.C.: June, 1969), pp. 6-14.

non-mechanized system in the second region during the wet season. No comparisons are reported for the dry season in the latter region.[16]

A comparison of Brazilian wheat yields by source of power for recent years is presented in Table 2. The yields, it is observed, in Brazil and in the States of Rio Grande do Sul and Parana were larger for the mechanized producers than for the non-mechanized (animal and manual) producers during six of the eight seasons. However, Santa Catarina's mechanized producers consistently had lower yields than the non-mechanized producers of that state. Little or nothing can be said about the yields obtained by those producers relying on draft animals versus those using only hand tools.

In spite of the general implication of the information thus far presented and of the view held by many farmers alike, it is not clear that mechanization in and of itself has any yield-increasing effects. Rice yields in Rio Grande do Sul, for instance, showed little increase (13 percent) between the 1950-54 five-year period and the 1968-69 season. Yet during this same time span, the tractor/rice acreage and the tractor horsepower/rice acreage ratios increased approximately three and three-and-one-half fold respectively.[17] Yields reported on "highly mechanized" Japanese farms for 1960 were no higher than those of the "hoe" cultivated farms. And International Rice Research Institute data

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[16] O. J. Thomazini Ettori and M. H. Falcao, "Aspectos Economicos da Producao de Amendoim em Sao Paulo," Agricultura em Sao Paulo (March and April, 1965), p. 23.

[17] Instituto Rio Grandense do Arroz, Anuario Estatistico do Arroz-Safra 1968/69 (Porto Alegre, Brazil: 1970), pp. 59 and 92.

TABLE 2

WHEAT YIELDS AMONG MECHANIZED AND NON-MECHANIZED PRODUCERS, BRAZIL, RIO GRANDE DO SUL, SANTA CATARINA AND PARANA[a] 1962/1963 THROUGH 1969/1970 (KILOGRAMS PER HECTARE)

Crop Year	Brazil			Rio Grande do Sul			Parana			Santa Catarina		
	Mechanized	Non-Mechanized		Mechanized	Non-Mechanized		Mechanized	Non-Mechanized		Mechanized	Non-Mechanized	
1962/1963	1,310	1,034		1,330	1,061		1,046	936		634	926	
1963/1964	368	409		364	378		574	519		312	511	
1964/1965	841	812		839	801		928	782		828	871	
1965/1966	728	716		730	725		687	736		468	666	
		Animal	Manual		Animal	Manual		Animal	Manual		Animal	Manual
1966/1967	890	804	817	885	783	787	1,084	1,053	617	567	797	951
1967/1968	705	743	818	690	680	793	1,043	1,048	1,042	599	704	818
1968/1969	927	857	854	911	853	844	1,138	918	943	657	819	748
1969/1970	1,076	862	754	1,084	897	905	1,024	825	592	692	765	765

[a]In 1969, approximately 80 percent of Brazil's 3.3 million hectares of wheat were accounted for by Rio Grande do Sul, 15 percent by Parana, and 5 percent by Santa Catarina (see Table 7).

Source: Anuario Estatistico do Trigo-Safra 69/70, CCLEF, Ministerio da Agricultura, Porto Alegre, Brazil, 1971, pp. 1/4, 2/5, 3/5, 4/5.

show "no consistent or significant difference in yields" on those farms employing tractors and on those using animal power.[18]

Much of the apparent contradiction contained in the above appears to stem from variation in the "non power-related" factors which have yield-influencing properties. In several instances little or no attempt was made to neutralize or isolate the effect of soil quality, protective chemicals, soil additives, seed varieties, climatic conditions, etc. By general implication, the summation of the positive and negative effects of all the factors are ascribed to the power variable. In examining technological change in Rio Grande do Sul, Knight notes that while the changes have been quite substantial in wheat, rice and soybean culture during recent years, the yields of these crops have showed little change. He attributes this lack of response to "declining soil fertility, the extension of cultivation to more marginal lands, and in the case of wheat, the development of new strains of rust."[19] The yield increases experienced in the crops produced by farmers using non-traditional inputs in Colombia have only been moderate in size. Here too, any positive effects forthcoming from mechanization and other non-traditional inputs were partially negated by the lower quality lands that were rapidly brought into production.[20]

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[18] R.D.A. Shaw, "The Employment Implications of the Green Revolution" (paper prepared for the Overseas Development Council, Washington, D.C., 6/1970), p. 4/6.

[19] P. T. Knight, Agricultural Modernization in Rio Grande do Sul, Brazil, USAID/Brazil (Rio de Janeiro, May, 1969), pp. I-27, I-28.

[20] L. J. Atkinson, op. cit., p. 14.

The second element which possibly explains away part of the inconsistency observed above is the differences in relative yield potentials. Lawrence suggests that this is best documented by field trials undertaken in Afghanistan where wheat was produced under a variety of fertility and water conditions using traditional, improved native, and tractor tillage. In these trials, the largest yield increases were consistently obtained when water availability and natural soil fertility were low. The conclusion of the trials was that where the relative yield would normally be high, tractor tillage would probably result in little yield benefits, but where the normal yield would be medium to low, the benefit of this tillage method might well be enormous.[21]

2. Area and land-use intensity. Mechanization extends man's capabilities, and in turn impowers him to produce more by using his land more intensively and/or by bringing more land into production. ". . . man, at his best, is capable of exerting only about one-eighth of a horsepower and then over only limited periods of time."[22] He is able to cultivate two or two-and-a-half acres by hand. Using draft animals, the same man might manage ten to twenty acres, and by using a tractor, many times more assuming the intensity of cultivation remains more or less constant.[23] For Latin America, an FAO study suggested that on the

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[21] R. Lawrence, op. cit., pp. 17-18.

[22] J. W. Berth, "Pre-Conditions for Agricultural Mechanization," The Influence of Mechanization of Agriculture Upon the Social and Economic Progress of the Developing Countries, Proceedings of the Royal Commonwealth Society Agricultural Conference (London, July 5, 1965), p. 22.

[23] Idem. and M. Monteiro and P. Minoga, "A Mecanizacao na Agricultura Brasileira," Revista Brasileira de Economia, Vol. 23, No. 4 (Rio de Janeiro, October/December, 1969), p. 73.

average a man with a team of oxen could plow 0.35 hectares or harrow 0.98 hectares in an eight-hour day, but he could perform these operations on 2.26 and 5.70 hectares respectively with a 30-horsepower tractor.[24] While these figures are tenuous and subject to wide variation, they are suggestive of the potential increases in output per man through increases in area and/or intensity.

Land-use intensities are increased when more non-land inputs are employed per unit of land. Mechanization has a positive influence on land-use intensities when it reduces the loss of production-land-time between two crops and when it leads to the production of crops requiring more non-land inputs. Mechanization can likewise lead to an extension of the land input. Among a group of progressive farms in the Punjab, Johl reports an increase of 11 percent in area cultivated and 14 percent in intensity of cropping accompanying an 82 percent increase in tractor use and a 183 percent decrease in bullock use between 1966-1967 and 1969-1970.[25] Officials of the Department of Agriculture in India's Gujarat State attribute increases in cropping intensities of 10 to 20 percent to mechanization.[26] B. Singh, to the contrary, found little difference between the cropping intensities of tractor owners and the non-tractor users in his case study. This, however, may have been due to the much larger holdings of the tractor owners.[27]

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[24] El Uso de la Maquinaria Agricola en Colombia, Consejo Economico y Social, CEPAL/FAO/UN (Rome, August 24, 1967), pp. 7-8.

[25] S. S. Johl, op. cit., p. 8.

[26] E. M. Schebeck, op. cit., p. 9.

[27] B. Singh, op. cit., pp. 84-85.

As reported earlier, yield increases in Colombia and Rio Grande do Sul, Brazil, have been overshadowed by the expansion in area. A similar situation exists in Nigeria's Western State. "Because of the availability of tractors they (the farmers) were able to nearly double their acreage under cash crops." ". . . under the traditional agricultural system the bottleneck on production is labor supplies during the planting season. That season is relatively short if good yields are to be obtained."[28]

While not relating specifically to changes in yield, area, or land-use, several studies employing 1965 farm level data from Southern Brazil associate mechanization with total production. Crop expenditures have generally been very important in explaining the variation in output in these studies, and Rask reports a very high degree of correlation (.87) between this independent variable and mechanization (for those farmers employing tractors). However, gross farm output per unit of land among the crop farms was lowest for the mechanized farms, even though they had crop expenditures per hectare of cultivated and artificial pasture land three times larger than either of the two types of non-mechanized crop farms. The contradiction probably arises from the very large size difference (a difference of more than ninefold), and in turn the negative relation between size and intensity of use. One-half of the land in the mechanized farms was cultivated or devoted to improved pasture versus

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[28] M. J. Purvis, op. cit., p. 36.

approximately 70 percent in the other types of crop farms.[29] Another study showed "equipment investment per hectare" to be the most important of four variables associated with variations in "production per hectare." But while the coefficient was small, it was negative (-.065). This, like the above, is at least partially due to the inverse relation between size and intensity and in turn, productivity.[30]

When the mechanized crop farms were compared with non-mechanized farms of the same size, the results were quite different however. Gross farm output and net farm income on the mechanized farms were six and four times larger, respectively, than on the non-mechanized farms. The non-mechanized farms were range-type livestock farms from an adjacent region, and in addition to being nearly identical in size, these mechanized and non-mechanized farms had very similar capital bases.[31]

Many of the farmers included in the 1965 survey were reinterviewed four years later. Steitieh divided the reinterviewed farmers into three groups on tractor ownership and tractor rental. He found that those who owned tractors had increased their production per hectare by the largest amount between the two periods and that their 1969 per hectare production was 27 percent greater than those who rented tractor services and

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[29] N. Rask, Analysis of Capital Formation and Utilization in Less Developed Countries, Economics and Sociology Occasional Paper No. 4, Department of Agricultural Economics and Rural Sociology, The Ohio State University, Columbus, Ohio, 1969, pp. 5, 49-71, 106-114.

[30] N. A. Barranda, "Analysis of Factors Associated with Variations in Land and Labor Productivity in Southern Brazil" (unpublished M.S. thesis, The Ohio State University, 1970), p. 69.

[31] B. P. Rao, "The Economics of Agricultural Credit-Use in Southern Brazil" (unpublished Ph.D. dissertation, The Ohio State University, 1970), pp. 79-86.

15 percent greater than those who did not own or rent a tractor. And although production was lowest for those farms where tractor services were rented, these services had a very significant effect on increasing crop production. ". . . this study showed that by increasing the investment in mechanized equipment more farms were able to pursue intensive cropping practices on larger areas" and "at the same time, more machinery services were made available to non-mechanized farms" which allowed them to increase their production.[32]

The Effect on Labor

Capital, in the form of agricultural mechanization, is customarily considered as being a factor substitute for labor and in turn partially responsible for the so-called rural exodus problem.[33] Yet in a dynamic situation where production increases, there is no reason to believe that increased quantities of both labor and mechanization cannot be productively employed simultaneously. Myrdal claims, in fact, agriculture is often labor extensive in underdeveloped countries and any type of production increasing technological reform expands the opportunity to utilize more labor.[34] Technological reforms give rise to shifting production

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[32] A. M. Steitieh, "Input Productivity and Productivity Change of the Crop Enterprise in Southern Brazil" (unpublished Ph.D. dissertation, The Ohio State University, 1971), pp. 22, 92, 96.

[33] S. S. Johl, op. cit., p. 5, claims that while most arguments against mechanization assume human labor and machines supply the same motive-power, in actuality they are quite different and cannot be aggregated as one homogeneous input.

[34] G. Myrdal, Asian Drama: An Inquiry Into the Poverty of Nations (New York: Pantheon, 1968), pp. 1,294-99; and G. Myrdal, "Toward Survival," War on Hunger (Washington, D.C.: U.S. Agency for International Development, 1970), pp. 1 and 17.

functions (increases in the productivity of resources already in use) and to the productive absorption of greater quantities of inputs. It is this which distinguishes modern from traditional agriculture.[35] Thus, mechanization, when used to bring more land into production, to increase land-use intensity, and/or to increase yields, enables agriculture to absorb more inputs productively including labor.

This is not to say, however, that there have not been misguided attempts, both large and small, to mechanize agriculture in underdeveloped countries. Too often the emphasis has been on saving labor rather than on increasing production. Subsidized big tractor mechanization policies are believed to be one of the major causes of unemployment in African agriculture.[36] In a study of mechanized farmers in the Punjab, Bose and Clark reported remarkably consistent responses "that the labor force per acre had been reduced about 50 percent from the pre-mechanization period." They also reported on a much earlier study (1953) wherein the permanent labor force on 60 mechanized farms decreased from 2,000 to 340.[37] Findings based on a survey conducted in India's Mysore State to assess the impact of mechanization on labor revealed a 17 percent decrease in employment between the purchase year (1950-1964) and mid-1965 on 39 farms. Year of purchase, or length of ownership, had no effect on the decrease. Only three of the farmers

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[35] J. W. Mellor, The Economics of Agricultural Development (Ithaca, N.Y.: Cornell University Press, 1966), p. 288.

[36] C. Eicher, et al., Employment Generation in African Agriculture, Research Report No. 9, Institute of International Agriculture, Michigan State University, East Lansing, July, 1970, p. 21.

[37] B. R. Bose and E. H. Clark, II, op. cit., p. 289.

increased the amount of area they cultivated and none reportedly changed his cropping pattern.[38]

While there is little or nothing to indicate whether total production changed as mechanization was introduced and as employment was reduced in the above, a study employing data covering more than a decade in three regions of Afganistan shows increases in irrigated area, output, marketable surplus, and net farm income accompanied by a 7 percent decrease in farm labor force on large farms through the use of tractors. (The researcher, however, believed "off-farm employment was no doubt increased by more than that."[39])

Several studies report no significant changes in on-farm employment resulting from the adoption of mechanization. In a case study of 40 West Pakistan farms (47 tractors and 4,421 acres) it was found that while some farmers decreased their labor forces with the acquisition of a tractor others employed additional labor, and the total on all the farms remained unchanged. Whether employment increased or decreased on each individual farm appeared to be a function of how intensively the land was used prior to and after mechanization took place.[40] Researchers "could not find any signs that the substitution of tractors for bullocks resulted in a displacement of farm labor" on 15 mechanized

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[38] K. K. Barkar, "A Note on the Impact of Mechanization on Farm Labor," Indian Agriculturist, Vol. X, No. 2 (Calcutta, July, 1966), pp. 152-54.

[39] R. G. Ridker, "Agricultural Mechanization in South Asia," Development Digest, Vol. IX, No. 1 (January, 1971), p. 109.

[40] T. Bergmann, "Problems of Mechanization in Indian Agriculture," Indian Journal of Agricultural Economics, Vol. VIII, No. 4 (Bombay, October/December, 1963), pp. 22-23.

farms in India's Gujarat State.[41] In Colombia, "the increase in tractors has been associated more with the expansion in acreage cultivated . . . than with the substitution for oxen and hand cultivation."[42]

On the positive side, evidence is ample to verify that both mechanization and farm employment can increase simultaneously. In Nigeria's Western State, the total amount of labor used per farm increased as farmers selectively employed mechanization to break the labor bottleneck during the planting season. (Mechanization allowed them to nearly double their cropped acreage.)[43] Johl presents rather complete information for a sample of progressive farms in the Punjab wherein total tractor and labor utilization increased 82 and 58 percent respectively between 1966/1967 and 1969/1970. The increases in both employment and mechanization, while spurred by higher yielding varieties and assured high prices, were made possible by the vertical and horizontal expansion in cultivated land on these farms.[44] Likewise, Taiwan, Japan, and Egypt simultaneously have capital investments in machinery and have employment levels in agriculture per unit of area substantially above the levels generally prevailing in developing countries.[45]

There is no reason to believe that the level of mechanization and employment are necessarily related inversely in Southern Brazil's

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[41] E. M. Schebeck, op. cit., p. 10.

[42] L. J. Atkinson, op. cit., p. 19.

[43] M. J. Purvis, op. cit., pp. 36-38.

[44] S. S. Johl, op. cit., pp. 6-8.

[45] L. P. Schertz, op. cit., p. 15.

agriculture. The study wherein mechanized crop farms were compared with non-mechanized range livestock farms of the same size and capital base showed the mechanized farms utilizing 50 percent more labor annually than the non-mechanized farms.[46] Mechanized peanut production in Sao Paulo was found to generally absorb more labor per unit of land than the non-mechanized technique. In two instances the mechanized system utilized 14 and 41 percent more, while in the third instance, it utilized 3 percent less.[47] And although the number of tractors increased 696 percent in Southern Brazil between 1950 and 1960, the crop area and number of people employed in agriculture increased 51 and 46 percent during this same ten-year period.[48]

While several researchers suggest agricultural mechanization has had a healthy influence on employment in the non-farm sectors, few have attempted or been able to quantify the dimensions of the influences.[49]

In a labor surplus economy, technologies should be employed which not only reduce unemployment and underemployment but also expand the productivity of labor. Agricultural mechanization, by extending the capacity of the human muscle, enables each person to produce more. This

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[46] B. P. Rao, op. cit., p. 81.

[47] O. J. Thomazini Ettori and M. J. Falcao, op. cit., p. 23.

[48] R. Araiyo Sias, "Fundamentos de Uma Politica de Desenvolvemento Agricola," Anais da V Reunias da Sociedade Brasileira de Economistas Rurais, Vol. I, No. 1 (Rio de Janeiro, 1968), p. 55.

[49] See S. S. Johl, op. cit., pp. 22-23; and R. L. Meyer and D. Larson, "Brazil's Program for Increasing Wheat Production," Research Notes in Agricultural Capital Formation and Technological Change, No. 7, Department of Agricultural Economics and Rural Sociology, The Ohio State University, Columbus, Ohio, May, 1971.

in turn should tend to counter the movement out of agriculture arising from the inability to generate sufficient earnings.

Labor productivity is generally envisioned as total output divided by the labor input, but may also be defined as the output attributable to labor, i.e., output = f (labor, capital, land). Any time mechanization or other technology prompts an increase in production which is larger than the increase in the labor input, labor's productivity, as generally envisioned, is expanded. This does not suggest, however, that the change in production is totally or even partially attributable to labor or that the technology is profitable.

Mechanization with few exceptions has influenced total production positively through higher yields, expanded agricultural area, and/or increased land-use intensities, and the production increases have generally been relatively larger than the increases in labor inputs. In Southern Brazil, studies show total production per man to be considerably higher on the mechanized than on non-mechanized farms and also show the variation in output to be explainable to a high level by the variation in machinery and equipment investment.[50] Yet the productivity of labor, as expressed by its marginal value product, is not so evident. Data from 1965 indicate the addition of one man would reduce annual production by approximately U.S. $492 on mechanized crop farms. The marginal value product of a hectare of land was approximately U.S. $13 and the returns to operating expenses and working assets were 1.04 and .19

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[50] B. P. Rao, op. cit., pp. 81, 84; A. M. Steitieh, op. cit., p. 22; N. A. Barranda, op. cit., pp. 49, 59.

respectively for those same farms.[51] A later study employing some of the same observations showed the annual product of an additional unit of labor to be a positive U.S. $1,196.[52] The marginal value products of labor among this latter group of farmers in 1969 were estimated at U.S. $1,366 for those engaging in custom machine rental activities and U.S. $670 for those employing their equipment only on their own farms. The estimated marginal products of labor for those farmers not owning but renting some machinery and for those neither owning nor renting machinery were U.S. $149 and $99 annually in 1969, when the minimum salary was approximately $390.[53]

The Effect on Cost of Production

Agricultural mechanization, it is maintained, promotes capital formation and development by providing savings through reduced production costs. Several studies relate to the cost of production premise.

To the extent custom hire charges approximate the costs incurred, the cost of plowing in Iran was reported to be one-third less for tractors than for oxen.[54] In another study the cost of tractor plowing with a mould board plow, tractor plowing with a disk-harrow, and bullock plowing with a traditional plow in the Punjab were compared. The first

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[51] B. P. Rao, op. cit., p. 108.

[52] The MVP of labor in the latter study was calculated using an elasticity coefficient which was significant at the .05 level, whereas the elasticity coefficient employed in the previous study was not significant at the .10 level but only at the .20 level.

[53] A. M. Steitieh, op. cit., pp. 49, 50, 52, 55, 56, 58, 85.

[54] O. Nervick and E. Haghjos, "Mechanization in Underdeveloped Countries," Journal of Farm Economics, Vol. XLIII, No. 3 (August, 1961), p. 665.

and third methods were almost identical in cost per acre. The cost, however, was reduced two-thirds by employing the disk-harrow method; a method that is nearly equivalent to traditional bullock plowing where the soil is loosened to a depth of 3 or 4 inches.[55] Lawrence found "a consistent downward trend in both market and opportunity costs of a unit of production as one moves from techniques involving less mechanization to techniques involving more mechanization" in West Pakistan.[56] In addition to obtaining higher yields, extending their acreage, and employing more labor, farmers in Nigeria's Western State were able to decrease their costs per unit of production by mechanizing some of their operations.[57] Likewise, Peruvian potato farmers obtained production costs estimated to be one-third lower per hectare by mechanizing.[58]

Excluding land and assigning a cost to labor approximately 50 percent above the minimum wage, the per unit production costs of producing peanuts employing the mechanized technique in Sao Paulo was lower in two of the three instances where comparisons with the non-mechanized technique could be made. Had a "rent" charge been included, the mechanized technique would have yielded lower per unit production costs than the non-mechanized technique in each instance since yields were significantly higher for the mechanized farmers.[59] Rio Grande do Sul's Rice Institute

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[55] S. N. Mathur and K. William Kapp, "The Transition from Bullock to a Tractor Economy in India: Some Indirect Effects and Benefits," Weltwirtschafthiches Archiv, Vol. 87, No. 2 (Hamburg, 1961), p. 341.

[56] R. Lawrence, op. cit., pp. 12-13.

[57] M. J. Purvis, op. cit., p. 36.

[58] R. M. Lidman, op. cit., pp. 21, 23, 25.

[59] O. J. Thomazini Ettori and M. J. Falcao, op. cit., p. 23.

(IRGA) estimated the cost of plowing rice land by oxen and mould board plow to be 13 percent more than plowing by tractor.[60] And the Federation of Southern Brazil's Wheat Cooperatives (FECOTRIGO) estimated it would cost Cr$24.75 and Cr$34.11 to produce 60 kilograms of wheat employing mechanized and non-mechanized techniques respectively.[61,62]

For Northeast Brazil, however, a study based on rental rates suggests that while labor hired to work with only a hoe is generally the most expensive, the employment of animal powered implements costs less per hectare than a mechanized system.[63] B. Singh, in his case study, also reports those farmers employing bullocks had slightly lower production costs per acre and per unit of wheat than the mechanized farmers.[64,65] And at a conference held in Japan in 1967, where a number of

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[60] Instituto Rio Grandense do Arroz, "Estudo Sobre Custo de Producao do Arroz--Safra 1970/1971" (Porto Alegre, January 15, 1971), pp. 9, 38-41. (Mimeographed.)

[61] Federacao das Cooperativas Friticolas do Sul Ltda., Trigo; Estudo do Custo de Producao--Safra de 1970 (Porto Alegre, July, 1970).

[62] The 10-year/20,000-hour tractor life used by FECOTRIGO is undoubtedly much greater than normally experienced, and if reduced, would push the mechanization cost up. Even the 10-year/10,000-hour life employed by IRGA is probably seldom experienced.

[63] K. D. Frederick, "Agricultural Development in the Brazilian Northeast: Technological Alternatives and Probable Development Patterns" (California Institute of Technology, January, 1970), pp. III-42, 48. (Draft.)

[64] B. Singh, op. cit., p. 86.

[65] But since the mechanized farmers had higher yields, their net imcomes were slightly larger than the incomes of the non-mechanized farmers.

studies pertaining to Asia were summarized, the bullock, in some cases, was reported as being the cheapest source of power.[66,67]

Normally, however, it appears that the production costs incurred by the farmer are lower when mechanization is employed. Yet quite often, governments subsidize agricultural mechanization, and the farmers' financial costs considered above may be only a portion of the total production costs actually incurred by society. The subsidies may be in the form of negative interest rates, state supported training centers for tractor drivers, tax exemptions, favorable import exchange rates, supported product prices, etc.

Unfortunately, very little effort has been expended in examining the overall economic costs (and benefits) of mechanization. Bose and Clark using benefit-cost analysis and, in instances, rather tenuous assumptions, conclude that while mechanization in West Pakistan at current prices is profitable for the farmer it is unprofitable for the economy when the effects of the subsidies are removed. They also concluded that the indirect costs were larger than the indirect benefits.[68] On the contrary, however, the projections of a study carried out in Ethiopia indicate the country would enjoy an internal rate of return approaching 20 percent from its investment in a mechanization scheme.[69]

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[66]The bullock's "position has been eroded by the more exacting requirements of an increasingly intensive agriculture, and increased labor and feed costs."

[67]D.G. Dalrymple, Technological Change in Agriculture, Foreign Agriculture Service -USDA (Washington, 1969), p. 59

[68]S. R. Bose and E. H. Clark, II, op. cit.; and R. G. Ridker, op. cit., p. 110.

[69]C. Eicher, et al., op. cit., pp. 23-24.

And while this appraisal was severely criticized for its "undocumented speculation," an adequate appraisal "calls for an anticipation and evaluation of a whole series of potential catalytic effects"; effects which might lead to a variety of socio-cultural changes.[70]

In summary, the evidence presented in this section is far from conclusive. The literature suggests in some instances agricultural mechanization is compatible with the goals of decreased production costs, increased labor utilization and productivity, and increased output (via expanded area, higher yields, and more intensive land use). In other instances, however, mechanization apparently is not compatible with these goals. This suggests that agricultural mechanization is location specific, and if it is to be employed, must be done so selectively.

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[70] S. N. Mathur and K. W. Kapp, op. cit., p. 335.

CHAPTER III

MECHANIZATION IN BRAZIL: A BRIEF REVIEW

The purpose of this chapter is to present a descriptive review of agricultural mechanization in Brazil. Presented first is a summary of the estimated number of tractors imported from abroad, the number produced in Brazil, the approximate number in use, and their gec raphical distribution. This is followed by a discussion of some of the factors thought to have influenced the level (numbers) and distribution of mechanization in Brazil.

Tractor Numbers

Tractors are not new to Brazil. Indeed, 1,706 were being used on Brazilian farms in 1920. During the three decades that followed, however, the number grew to only 8,372. The expansion then quickened, and in 1960 and 1970 respectively, there were 63,493 and 156,529 agricultural tractors in use (Table 3).

The majority of these 156,529 tractors were produced by Brazil's own industry which came into production in December, 1960. Yet some of these tractors were imported as were many thousands during the previous half century. The number imported annually, while showing a great amount of fluctuation from one year to the next, generally moved upward until 1951 when 11,000 were imported. At this point, the number fell drastically but then bounded to a peak of 14,000 in 1954. Again the

TABLE 3

NUMBERS OF TRACTORS USED IN AGRICULTURE AND THEIR GEOGRAPHICAL DISTRIBUTION, FOR SELECTED YEARS, BRAZIL, 1920-1970

Year	Brazil	South Central Brazil[a]	Sao Paulo	Rio Grande do Sul
1920	1,706[b]			817[b]
1940	3,380[c]	3,103[d]	1,410[b]	
1950	8,372[c]	7,860[d]	3,819[c]	2,245[c]
1955	45,000[e]			
1960	63,493[c]	60,238[d]	28,101[c]	16,675[c]
1965	73,298[f]			
1970[g]	156,529[b]		65,731[b]	38,317[b]

[a]This region approximates the area south of the 18th parallel.

[b]These figures represent census estimates and were taken from: H. M. Clements, The Mechanization of Agriculture in Brazil, A Sociological Study of Minas Gerais (Gainesville, Fla.: University of Florida Press, 1969), p. 63; and J. H. Sanders, "Mechanization and Employment in Brazilian Agriculture, 1950-1971" (unpublished Ph.D. dissertation, University of Minnesota, 1973), p. 40.

[c]1940, 1950, and 1960 agricultural census estimates.

[d]These estimates were based on the agriculture censuses and were taken from "Motomecanizacao da Agricultura no Brasil," Estudos APEC: A Economia Brasilerra e Suas Perspectivas VI, APEC Editora S.A. July, 1967, Rio de Janeiro, Table VIII.

[e]This is an FAO estimate as reported in "72 Mil Tractors--Meta Para a Agricultura," Desenvolvimento e Conjuntura (Rio de Janeiro, January, 1958).

[f]This estimate is based on an estimate from "Motomecanizacao da Agricultura no Brasil," op. cit., Table XXIII, of 64,323 conventional four-wheel tractors. To the latter figure was added 8,975 two-wheel tractors and small "micro tractors." The number of these two types of tractors was derived using an eight-year life.

[g]The 1970 census estimates seem quite high. The Brazilian tractor industry's organization estimated there were approximately 90,000 conventional four-wheel agricultural tractors in operation in May of 1970. Adding 19,000 two-wheel and small "micro tractors" we came up with only about 70 percent of the census figure. Other estimates reveal similar discrepencies. Additionally, the total number of all kinds and sizes of tractors produced and imported from January 1, 1961, through December 31, 1970, was approximately 123,000. Assuming all of these were purchased for agricultural uses and all were still operational at the time of the census, more than half of the tractors that were in use in 1960 would still have to have been in use in 1970.

number decreased, held relatively steady at less than half the peak figure and then in 1960 rose to approximate the 1951 peak. The number quickly fell as Brazil's own tractor industry came into production (Figure 3).

Production of the conventional four-wheel farm tractor by the Brazilian industry rose rapidly to 11,537 in 1964, fell to a low of 6,223 three years later, and then increased to 14,049 in 1970. This upswing continued, and the industry produced 22,122 and 29,142 of these tractors in 1971 and 1972 respectively (Figure 3 and Appendix Table 30).

The distribution of Brazil's agricultural tractors, like the rate of expansion, has been very uneven. Sao Paulo and Rio Grande do Sul have traditionally accounted for the majority of the country's tractors (Table 3). Their distribution within these and the other south-central states has been strongly influenced by government policies and concessions aimed at increasing the production of specific agricultural commodities and assisting the infant tractor industry. Factor and product price relationships have been severely distorted at times by these policies and concessions. At one time for instance, most of the tractors in Rio Grande do Sul were owned by rice farmers. In the late 1960's and early 1970's the producers of this crop were purchasing only 10 percent of the tractors sold in this southern-most state, and wheat farmers were purchasing a much larger proportion.[1]

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[1]"A Lavoura de Arroz Nao Compra Trator," Correio do Povo (Porto Alegre, April 16, 1971).

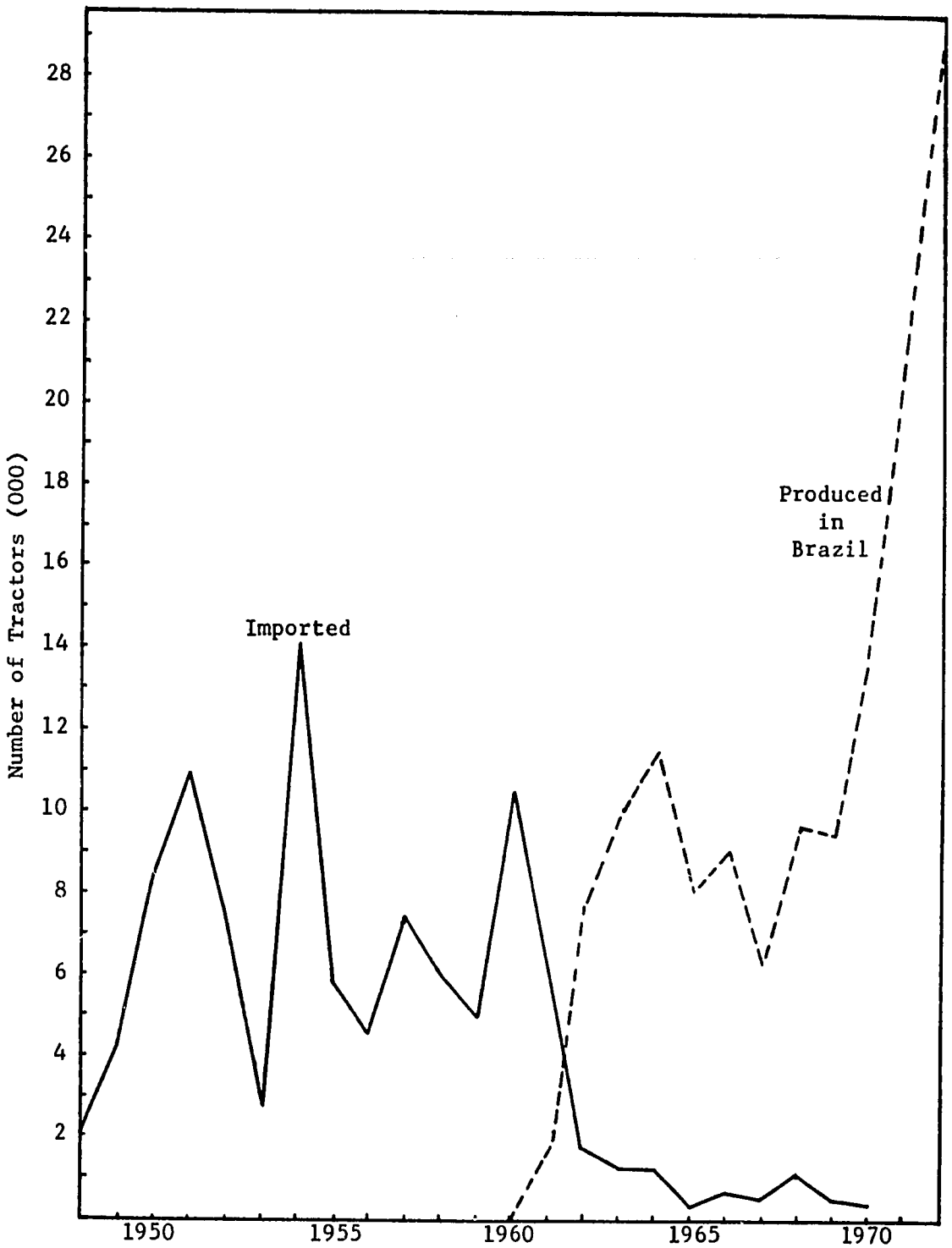

Figure 3.--Number of Tractors Imported and Produced Domestically, Brazil, 1948-1972 (see data in Appendix Tables 30 and 31). (Domestic production includes only conventional four-wheel tractors.)

Influencing Factors

1. Labor. The availability of labor is generally expected to influence the demand for mechanization since these two inputs are characteristically considered to be factor substitutes. In Southern Brazil, however, it appears that the adoption and use of tractors and mechanized equipment have been both stimulated and forestalled by labor. Stimulation, it is maintained, has come from a shortage of general farm labor, while a lack of labor capable of operating and maintaining these relatively large capital inputs efficiently and effectively has tended to discourage mechanization. Minimum wage legislation and a small amount of rural unrest and agitation among farm workers has probably tended to encourage mechanization in some instances.[2]

Prima facie, the fact that Brazil's rural labor force includes nearly one-half of the workers in the country, accounts for less than one-quarter of the gross national product, is underemployed much of the year (25 percent worked less than nine months in 1969), and is migrating to urban centers in search of better employment hardly suggests a general shortage of farm labor exists.[3] However, in Southern Brazil, unemployment and underemployment are undoubtedly lower than in other regions of the country and many examples can be cited where planting and harvesting have been delayed due to labor shortages.

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[2]"Campanha de Agitacao Rural no RGS Esta Causando Desemprego," Correio do Povo (Porto Alegre, October 18, 1970).

[3]"Governo Estimula a Producao Rural e Aumenta Produtividade com Technologia," Correio do Povo (Porto Alegre, November 21, 1970); and K. C. Abercrombie, "Agricultural Mechanization and Employment in Latin America," International Labor Review, CVI (July, 1972), p. 14.

The large number of severely damaged and prematurely scrapped tractors and implements is evidence of the existing shortage of trained and experienced personnel. "This shortage is one of the largest barriers confronting mechanized agriculture in Brazil."[4] Too often the life of these costly inputs is shortened as a result of inadequate operation, deficient maintenance, or improper repairs. While the situation is hopefully being imporved, the average life of a tractor on a Brazilian farm in 1964 was estimated to be 4,000 hours; one-half the number determinted to be economically necessary.[5]

Some efforts have been made to do something about the short supply of skilled labor. The scope and success of these, however, have generally been modest at best. While 1,000 tractor operators could have been trained annually in short courses offered at eight different centers in the late 1960's, only about one-half of the openings were filled.[6] Beyond these short courses, a limited amount of educational assistance was provided by some of the tractor companies.[7]

Thus, while the extent to which the level and distribution of mechanization have been influenced by the supply and characteristics of agricultural labor is not readily apparent, it would be injudicious

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[4]Newton Martins, Professor of Agricultural Engineering, Universidade Federal de Rio Grande do Sul, private consersation, April, 1970.

[5]"Mais Financimento Para Deslanchar," Coopercotia (Sao Paulo, March, 1964), pp. 18-22.

[6]N. Martins, "Mecanizacao Agricola," A Granja (Porto Alegre, April, 1969), pp. 35-37.

[7]"Notas Sobre a Massey-Ferguson do Brasil S. A.," Massey-Ferguson do Brasil (Sao Paulo, June 15, 1970). (Mimeographed.)

to ignore the existence of the various relationships between these two inputs.

2. Prices. The price of an input is normally thought to be an important factor influencing a farmer's decision to buy that input. Both the nominal and relative prices of tractors are examined here.

The average price of medium-size tractors (36-45 horsepower rating) from 1935 to 1970 appear in the first column of Table 4. Since persistent inflation renders an examination of these prices difficult, they are converted to U.S. currency (second column). Suggested retail prices for similar tractors produced and sold in the United States appear in the third column.

In Table 5 indices are used to facilitate a comparison of tractor prices relative to other agricultural product and input prices. Fertilizer prices appear to have increased the least during the period while labor, as measured by legislated minimum wage rates, shows the largest increase (an increase which is at least partially due to the very low wage rate of the base period). The prices Rio Grande do Sul crop farmers received for their products were relatively lower than tractor prices from 1959 through 1965.

More meaningful perhaps, is an examination of tractor prices relative to the prices farmers received for those specific crops readily lending themselves to mechanization. Figure 4 is derived from estimates of the approximate quantity of wheat, soybeans, and rice required to cover the purchase price of a medium-size tractor. The graph clearly indicates (for the years included) medium-size tractors were least

TABLE 4

AVERAGE PRICE OF MEDIUM-SIZE TRACTORS (36-45 HP) IN BRAZIL AND UNITED STATES FOR SELECTED YEARS, 1935-1970

Year	Brazil: Brazilian Cruzeiros[a]	Brazil: U.S. Dollar Equivalent[b]	United States: U.S. Dollars[c]
1935	37[d]		
1940	43[d]		
1945	55[d]	2,750	3,300
1950	90[d]	2,813	
1953	89[e,f]	1,986	
1954	155[e,f]	2,456	3,250
1955	209[e,f]	2,819	
1956	245[e]	3,305	3,366
1957	268[e,f]	3,484	3,258
1958	273[e]	2,069	3,388
1959	628[e,f]	3,922	
1960	655[e,f]	3,449	
1961	993[g,h,i]	3,414	
1962	1,703[g,h]	3,256	3,560
1963	3,274[g,h]	3,626	
1964	6,470[g,h]	4,213	
1965	8,924[g,h]	4,648	3,655
1966	10,733[h]	4,850	
1967	13,330[j]	4,661	
1968	15,464[j]	4,570	
1969	19,069[k]	4,676	4,855
1970	20,976[l]	4,545	4,881

[a]The Brazilian cruzeiro was revalued in 1966; 1,000 old cruzeiros became 1 new cruzeiro. The values given here are new cruzeiros.

[b]The 1945-1967 and the 1968-1970 values were derived using exchange rates given in: Revista de Administracao de Empresas, Vol. XI, No. 2 (Rio de Janeiro, June, 1971), pp. 87-88; and Conjuntura Economica Vol. XXV, No. 1 (Rio de Janeiro, 1971), pp. 21-22.

TABLE 4--Continued

[c]Suggested retail values for similar tractors sold to U.S. farmers as given by: Massey-Ferguson, Regional Office, Columbus, Ohio, January 4, 1972; and Official Guide--Tractors and Farm Equipment, Fall, 1971, edition, National Farm and Power Equipment Dealers Association, St. Louis, Missouri. Much of the between-year fluctuation results from different makes and models being considered, but in each instance the suggested price is for diesel models since nearly all Brazil's tractors are of this type. (Diesel models generally cost U.S. $600 to U.S. $700 more than the equivalent gasoline model.) The suggested retail prices may average up to 10 percent or more above the actual selling price.

The increase in U.S. tractor prices in the late 1960's was probably due to the mild inflation the economy was experiencing and to the extra features (semi-automatic transmissions, two power-take-offs, power steering, etc.) that became standard.

[d]N. Martins, Capacidade, Custo de Utilizacao e Selecao das Maquinas Agricolas, FAV, Universidade Federal do RGS, 1966, p. 18.

[e]Prices derived from information for Sao Paulo farmers: Desenvolvimento da Agricultura Paulista, Instituto de Economia Agricola (Sao Paulo, March, 1971), pp. 105,337, 344.

[f]These prices are 4, 14, 40, 40, 37, and 56 percent below the prices given by Martins (op. cit.) respectively.

[g]Contribuicao Ao Estudo do Preco dos Tratores Nacionais--1965, Department Economico, Ministerio da Agricultura, Brazil, Table I.

[h]"Motomecanizacao da Agricultura no Brasil," Estudos APEC, A Economia Brasileira e Suas Perspectivas, Vol. VI (Rio de Janeiro, 1967), p. 108.

[i]This price is 31 percent above the 1961 price derived from Desenvolvimento da Agricultura Paulista (op. cit.).

[j]Average prices paid by Sao Paulo, Parana, Santa Catarina, and Rio Grande do Sul farmers: Precos Pagos Pelos Agricultores, Centro de Estudos Agricolas, Fundacao Getulio Vargas, Brasil (August, 1969).

[k]Average price paid by Sao Paulo and Rio Grande do Sul farmers: Precos Pagos Pelos Agricultores, Centro de Estudos Agricolas, Fundacao Getulio Vargas, Brasil (April, 1970).

[l]Estimated price based on an 11 percent increase over 1969: Industria e Desenvolvimento (March, 1971), p. 15. Sao Paulo farmers paid Cr$19,092 for a 44 HP tractor produced by Massey-Ferguson do Brasil: "Precos Pagos Pela, Agricultura Paulista," Mecados Agricolas (December, 1970).

TABLE 5

INDICES OF PRICES PAID FOR TRACTORS AND OTHER INPUTS (INCLUDING LABOR) AND OF PRICES RECEIVED BY FARMERS IN SELECTED AREAS OF BRAZIL, 1948-1952 = 100 (1940-1970)

Year	Index of Prices Received by RGS Crop Farmers[a]	Index of Prices Paid for Medium-Size Tractor, Brazil (1950 = 100)	Index of Prices Paid for Fertilizer by Sao Paulo Farmers[b]	Index of Minimum Wage in RGS[c]
1940-43		48 (1940)		48
1944-47		61 (1945)		77
1948	83		91	77
1949	97		93	77
1950	90	100	94	77
1951	90		108	77
1952	139		114	192
1953	167	99	105	192
1954	201	172	128	353
1955	243	232	178	433
1956	306	272	206	589
1957	340	29[illegible]	203	745
1958	396	303	222	745
1959	528	697	230	1,202
1960	694	728	343	1,292
1961	833	1,104	687	2,019

TABLE 5--Continued

Year	Index of Prices Received by RGS Crop Farmers[a]	Index of Prices Paid for Medium-Size Tractor, Brazil (1950 = 100)	Index of Prices Paid for Fertilizer by Sao Paulo Farmers[b]	Index of Minimum Wage in RGS[c]
1962	1,590	1,892	1,229	2,835
1963	2,444	3,638	2,152	4,399
1964	5,431	7,188	4,347	8,065
1965	7,472	9,916	8,001	13,486
1966	13,028	11,926	7,998	17,728
1967	16,125	14,811	8,358	22,455
1968	18,917	17,182	10,970	26,961
1969	23,729	21,188	12,546	32,115
1970	27,590	23,307	13,321	38,654

[a]J. Oliveira, Aspectos Produtivos e Economicos das Dez Principais Culturas do Rio Grande do Sul, 1948-1969, IEPE, Universidade Federal do Rio Grande do Sul, Porto Alegre, 1971, p. 13.

[b]Desenvolvimento de Agricultura Paulista, Instituto de Economia Agricola (Sao Paulo, 1971), p. 95.

[c]Correio do Povo: Suplemento Rural (Porto Alegre, June 19, 1971, and July 10, 1971).

Figure 4.--Metric Tons of Wheat, Soybeans, and Rice Required to Equal the Price of a Medium-Size Tractor, Rio Grande do Sul, 1953-1969

Source: Appendix Table 32.

expensive in terms of production in 1953. These tractors were most expensive in terms of tons of wheat and soybeans in 1959 and in terms of rice in 1966. Between 1959 and 1965 when tractor prices were relatively higher than the prices received by Rio Grande do Sul crop farmers it took an average of 45, 93, and 65 metric tons of wheat, soybeans, and rice, respectively, to purchase a medium-size tractor. Prior to this only 32, 68, and 45 metric tons were required. And from 1966 through 1969 it took 43, 76, and 64 metric tons of these commodities to purchase a similar tractor.

Little correlation is apparent between the number of tractors imported and produced domestically (Figure 3) and their price (Table 4 and Figure 4). While the nominal and relative prices of tractors reached a low in 1953 and were followed by a very significant increase in imports in 1954, the relationship is not observed again. In fact, almost the opposite is observed. The high tractor prices of 1959 were followed also by a significant increase in tractor imports. The expected relationship appears to be no more apparent during the 1960's after the national tractor industry came into production. This is not to say price is unimportant but rather that there are (have been) other factors influencing the farmers' decisions.

3. Government Policies. A variety of governmental policies have influenced the level and distribution of mechanization in Brazil. While many of the policies have apparently been based on the belief that mechanization is an essential ingredient for developing Brazil's agriculture, some of these policies and others have curtailed rather than

stimulated its adoption and use. Policies dealing with the establishment of the national tractor industry, imports, taxation, credit, and product subsidies are examined here.

a. National Tractor Industry: Its Establishment. Although GEIA (Grupo Executivo da Industria Automobilistica), the board which formulated the plans for Brazil's automobile industry, was severely criticized for not including tractors in their final scheme, the "Plano Nacional da Industria de Tratores Agricolas de Rodas" was not adopted until December of 1959. The arguments for earlier establishment centered around the economies gained by installing the auto, truck, and tractor industries simultaneously, the need for obtaining much higher levels of mechanization, the near complete lack of parts and service for the majority of Brazil's numerous makes and models of tractors, and the large quantity of scarce foreign exchange used in importing tractors (a quantity amounting to approximately $145 million for the 1953-57 five-year period).[8] GEIA and others, however, felt the auto parts industry was overloaded and incapable of economically supplying tractor parts before 1959. They maintained a tractor industry could not afford to pay the high prices charged by the auto parts industry arising from

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[8]Of the 9,312 tractors recorded on farms producing more than nine hectares of rice in Rio Grande do Sul during the 1968-69 season, 9,233 were of 39 different makes and the remaining 79 were classed as "others." Two hundred and nine different models were specified and no model was specified for 10 percent of the tractors. Many of these tractors were imported not because they suited the demand but because trade agreements could be made or currencies were available. (Anuario Estatistico do Arroz, Safra 1968-69, op. cit., p. 60.)

the latter's low level of efficiency and desire to recover installation charges as rapidly as possible.[9]

One month after the Plano was officially adopted, twenty project proposals for producing conventional four-wheel tractors were presented. Ten of these were selected and were to produce 31,000 tractors within the first two years (by July of 1962). Delays in licensing, etc. slowed the momentum, however, and four of the firms did not establish facilities.[10] The remaining six invested approximately $23 million and two began production in December, 1960. By the end of 1962, the industry had produced only 30 percent of the quota.

The industry has continually fallen well below the original expectations, and in turn, faced high per unit fixed costs. Production was 8,121 units in 1965, while the projections called for sales of 25,000.[11] The high per unit cost problem was created when the original plan was formulated. Those who were instrumental in its formulation were more concerned about taking advantage of the economies of the auto industry's infrastructure than about the market and the number of firms it could support.[12] They also believed Brazil needed three sizes of tractors and

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[9]"Industria de Tratores," Correio de Manha (Rio de Janeiro, November 19, 1961); "Oportuna a Fabricacao de Tratores no Brasil," Desenvolvimento and Conjuntura, Ano II, No. 4 (Rio de Janeiro, April, 1958), pp. 81-86; and "Boas Perspectivas Para a Industria de Tratores no Pais," O Estado do Sao Paulo (Sao Paulo, March 3, 1964).

[10]"Industria de Tratores," op. cit.

[11]"Industria do Trator em Situacao Dificil," Journal do Comercio (Porto Alegre, June 17, 1969).

[12]"Motomecanizacao da Agricultura no Brasil," A Economia Brasileira e Suas Perspectivas VI, Estudos APEC (Rio de Janeiro, July, 1967), p. 99.

that strong competition should exist within the industry. As a consequence, none of the six facilities had sufficient capacity to absorb the high fixed costs, nor was their installed capacity fully employed.[13] (In 1966 the six facilities had an estimated annual capacity of 19,300 and 33,775 tractors employing one shift and two shifts respectively. The 1966 production was 9,069.[14])

Another aspect of this same problem was created by the decision to produce as many of the component parts of the tractors in Brazil as rapidly as possible. The firms were allowed to import nearly all of the equipment they would need. Import tariffs were removed, lower foreign exchange rates were put into effect, credit in foreign currency was made available, etc. for machinery going into tractor production facilities.[15] But in line with this policy, the original plan stipulated that 70 percent (by weight) of the tractor components would be national products from the start, and 95 percent by January 1, 1962. Due to a series of circumstances, however, these requirements were modified by GEIMAR (Gropo Executivo da Industria de Maquinas Agricolas e Rodoviarias, a board created early in 1961 by Government Decree #50519 to relieve the previous board). The initial 70 and 95 percent requirements were

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[13] N. Martins, "Mecanizacao Agricola," op. cit., p. 33.

[14] "Motomecanizacao da Agricultura no Brasil," op. cit., p. 106.

[15] Idem, p. 100.

delayed until September of 1961 and June of 1963, and 85 percent of the components were to have been national products by July, 1962.[16,17]

The severely inflated demand expectations, the installation of six separate facilities, and the production of three sizes of tractors, together with the policy to use nationally produced components, created a paradoxical situation wherein the farmers felt the prices were too high and the industry was unable to lower its price due to the low volume of sales. In an attempt to break this cycle, a variety of plans and actions were pursued. In general, however, the plans and actions provided only limited relief at best from the problem and consequently only Massey-Ferguson do Brasil, Valmet, and Companhia Brasileira de Tratores were actively producing conventional agricultural tractors in 1971. Ford discontinued its production in 1967, Fendt in 1969, and Deutz produced only two tractors during December, 1970.[18] The capacity of the three active facilities employing one shift stood at 16,000.[19]

A similar pattern evolved in the establishment of facilities for producing the small four-wheel and two-wheel tractors (microtratores and motocultivadores) and track-type tractors. The capacities of the

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[16]"Mais Financiamento Para Deslanchar," Coopercotia (Sao Paulo, March, 1964), pp. 18-22.

[17]Approximately 98 percent (by weight) of the tractor components were national products by the end of 1967. The value of the 98 percent approximated 82 to 85 percent.

[18]Letter from Ilo Soares Nogueira, Director de Relacoes Publicas, Massey Ferguson do Brasil, dated July 21, 1971.

[19]"Analise do Setor de Tratores, Respostas e Informacoes ao Questionario IPEA," Sindicato Nacional da Industria de Tratores, Caminhoes, Automoveis e Veiculos Similares (Sao Paulo, no date--late 1970 or early 1971). (Mimeographed.)

three remaining small-tractor facilities with one shift were 900 and 6,000 respectively (compared with 1970 production of 409 and 2,065).[20]

b. Imports. The government's attitude regarding the importing of tractors and agricultural machinery prior to the establishment of the national industry was generally quite favorable so long as foreign exchange was available. From the earliest imports, the policy was one of extending financial guarantees and exchange assistance. In 1944 the Brazilian government involved itself much more by providing the Ministry of Agriculture with extra funds for importing tractors and equipment directly. Starting in 1946, with the special credit concessions available for the "Campanha do Trigo" (wheat campaign), new machinery imports were made by the Ministry. And while a portion of the machinery was kept by the Ministry, most was resold to farmers at cost, over time, without interest. This became so popular that a limit had to be put on the size of the rotating fund used for these transactions. Special funds were then obtained and applied to importing much larger quantities of agriculture machinery, and the availability of long-term, low-interest credit created an extraordinary demand for this machinery.[21]

In addition to facilitating the import of agricultural tractors and equipment in the manner described above, the Brazilian government maintained an exchange rate subsidy policy for these items until the

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[20] Idem.

[21] "Agricultura, A Mecanizacao da Lavoura," Conjuntura Economica (Rio de Janeiro, October, 1952).

national industry was established.[22] For some years, tractors were imported at an exchange rate of 28 cruzeiros (.028 new cruzeiros) per U.S. dollar. The rate was doubled in November of 1956 (by Decree #40260), and was held at this new level for several years. In the unsupported market, 74 old cruzeiros exchanged for $1 in 1956. During the previous four years the rate stood at 30, 34, 45, and 63 old cruzeiros respectively. In 1957 and 1958, 77 and 132 old cruzeiros were required to obtain $1 in the open market.[23]

Upon the establishment of the national tractor industry, the policies which had been used to facilitate and encourage the importing of agricultural machinery were, of course, dropped and soon after replaced with import tariffs.[24] At the beginning of 1971, 30 percent "ad valorem" was being collected on imports which were similar to those produced by the local industry.[25]

c. Taxes. Also following in the wake of the industry's establishment was a wide array of taxes levied on locally produced tractors and

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[22]"A Racionalizacao da Industria de Tratores e Fundamental Para a Tecnificacao da Nossa Agricultura Passo Decisivo na Retomada do Desenvolvimento Economico do Pais," reprint from Industria Automotiva, No. 106 (Sao Paulo, April, 1968), p. 9.

[23]"Oportuna a Fabricacao de Tratores no Brasil," op. cit., pp. 82-83; and Revista Administracao de Empresas (Rio de Janeiro, June, 1971), pp. 87-88.

[24]The writer could not discover the date when these tariffs were first levied. It is known, however, that while GEIMAR had proposed a 30 percent tax, it was not yet in effect in April, 1963. (Unclassified Airgram to U.S. Department of State, American Embassy, Rio de Janeiro, April 23, 1963).

[25]"Analise do Setor de Tratores, Respostas e Informacoes ao Questionario IPEA," op. cit., p. 3.

equipment and on their components. The Ministry of Agriculture reported that in 1962 eight types of taxes were being paid by the industry's suppliers, fifteen by the factories themselves, and seven by the dealers (not including income tax). Together, these taxes represented 30 percent or more of the price the farmer paid for a tractor.[26] (Some of these taxes were also being paid on imported machinery.)

The most controversial taxes were the ICM sales tax and the IPI manufacturing tax. These two taxes, while having been partially relaxed from time to time, generally accounted for the largest tax incidence on domestically produced machinery. Until exempted of the ICM tax in September of 1970, the incidence of this one tax alone was 15 to 18 percent.[27] The 5 percent IPI tax was relaxed on agricultural machinery late in 1967, and on the components and materials used in manufacturing this machinery in August, 1970.[28] The exemptions were made by government decree and were to remain in effect through 1974.[29]

While such exemptions reduce the price the farmer paid, he was also given a fiscal incentive beginning in 1970. This was in the form of an

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[26] Contribuicao Ao Estudo do Preco dos Tratores Nacionais, 1965, Departamento Economico, Ministerio da Agricultura, Brasil, pp. 4-7.

[27] This exemption does not apply to the materials and components used in producing the machinery and, as such, was expected to reduce the price of a tractor by 8 or 10 percent.

[28] "Tratores e Maquinas Agricolas sem IPI," Correio do Povo (Porto Alegre, August 12, 1970); and "Maquina Agricola sem IPI," O Estado de Sao Paulo (Sao Paulo, September 4, 1970).

[29] "Auto-Suficiencia em Trigo--Grande Opcao," Correio do Povo (Porto Alegre, November 27, 1970).

investment credit allowance which permitted him to subtract up to 80 percent of his investment from his income for federal tax.[30]

d. Credit. Credit has generally been available for the purchase of agricultural machinery (and most other agricultural inputs) at concessional rates. During the initial phase of the "Campanha do Trigo" when the Ministry of Agriculture was importing and reselling machinery, farmers were allowed to extend their payments over several years without paying any interest or monetary correction. And a little later, with special funds the Ministry obtained, farmers could obtain long-term, low-interest financing. They paid 25 percent down and the remainder in semiannual payments. The annual rate of interest was 7 percent, versus 12 or 15 in the open market.[31]

From 1961 through 1964 when Brazil was entwined in a spiraling rate of inflation (which peaked at an annual rate of 100 percent during the first half of 1964), the interest charge on tractor loans with no monetary correction was 8 to 12 percent. (Open market credit carried charges of 50 to 70 percent at the inflation's peak.) In 1965 interest rates on agricultural loans rose to 15 and then to 24 percent before dropping back to 15 percent at year's end. The rate of inflation fell to 45 percent in the same period. An 18 percent rate of interest went into effect in May of 1966. Two years later the rate was lowered to 15

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[30] "Isencao do ICM Vai Baixar o Preco do Trator de 8 a 10%," Lavoura Arrozeira (Porto Alegre, March/April, 1970), p. 48.

[31] Idem; and "Agricultura, A Mecanizacao da Lavoura," op. cit.

percent.[32] These rates of interest and the annual rates of inflation, along with the differences, or the real rates of interest, are set forth in Table 6.

Starting in 1966 loans were made for 80 to 100 percent of the purchase price of national tractors. These loans were generally granted for four and five years. They carried annual payments of 10 percent, 30 percent, 30 percent, and 30 percent, or 15 percent, 25 percent, 30 percent, and 30 percent in the cases of the four-year loans and 10 percent, 15 percent, 20 percent, 25 percent, and 30 percent for the five-year loans.[33]

e. Price Supports. Product subsidies and price supports, while generally employed in combination with other production stimulating policies, have influenced the level and especially the distribution of mechanization as much as any other government action. The rice and particularly the wheat subsidization policies have been the most costly and controversial, even though minimum prices have been set annually for a number of crops since the early 1960's. The rice subsidy was designed to increase exports by lowering its price in the world market, while import substitution was the motive behind the wheat subsidy.

Wheat has preoccupied the Brazilian government for many years. It has been the second most important import in recent years, and previously

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[32]"A Racionalizacao da Industria de Tratores e Fundamental Para a Tecnificacao da Nossa Agricultura Passo Decisivo na Retomada do Desenvolvimento Economico do Pais," op. cit., pp. 8-10; and Resolutions 2, 8, 44, 59, 140 of the Banco Central do Brasil and decisions of Brazil's Conselho Monetario Nacional.

[33]Idem.

TABLE 6

AVERAGE RATES OF INTEREST (ON MACHINERY LOANS), AVERAGE RATES OF INFLATION AND "REAL RATES OF INTEREST," 1961-1970, BRAZIL

Year	Average Nominal Rate of Interest[a]	Average Rate of Inflation	"Real Rate of Interest"
1961	8%	43%	-35%
1962	9%	53%	-44%
1963	11%	81%	-70%
1964	11%	87%	-76%
1965	16%	45%	-29%
1966	18%	41%	-23%
1967	18%	28%	-10%
1968	16%	24%	- 8%
1969	15%	21%	- 6%
1970	15%	22%	- 7%

[a]Interest rates for imported tractors in recent years have generally been 2 or 3 percent above those quoted here.

Source: Idem and Conjuntura Economica, Vol. XXV, No. 7 (Rio de Janeiro, 1971), p. 168.

alternated with crude oil for first place. In the ten-year period, 1960-1969, imports of this commodity averaged U.S. $166 million annually.[34] To ease the demand the wheat imports place on foreign exchange, Brazilian farmers have been paid prices 60 to 70 percent above those in the world market.[35]

The political and economic reasons for wanting to reduce the dependence on foreign markets and the demand on foreign exchange are quite evident. Additionally, it is argued that the wheat subsidy program should be continued because: (1) wheat production results in substantial improvements in production techniques; (2) the efficiency of wheat production cannot be considered separately from that of other crops, particularly soybeans; (3) other countries also subsidize wheat production; and (4) resources have been invested in machinery, marketing facilities, and production technology, and this investment along with the people who depend upon it should not be abandoned.[36]

Some of the above arguments may not be valid, but certainly, the last should be considered when the cost of the subsidy program is being evaluated. How much emphasis will be placed on this argument and others in the future is a difficult guess. It appears, however, even though

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[34]P. Knight, "Import Substitution in Brazilian Agriculture: The Production of Wheat in Rio Grande do Sul" (paper presented at Workshop on Price and Trade Policy and Agricultural Development, Purdue University, August, 1971), p. 14.

[35]The Brazilian government also stands the cost of transporting the production from the southern-most states to the major consumption centers. This probably increases the cost of domestic wheat an additional 20 percent.

[36]P. Knight, "Import Substitution in Brazilian Agriculture: The Production of Wheat in Rio Grande do Sul," op. cit., pp. 21-25.

the President of Brazil stated publicly in 1970 that "We need to produce more wheat at any price," the degree to which wheat production is supported will continue to be reduced.[37] Between the 1969-70 and 1970-71 seasons, when the general price index rose 22 percent, the price of wheat was increased only 8.8 percent (and that of rice only 10 percent cent).[38]

Prior to 1970, based on the Federation of Wheat Cooperative's cost of production studies and in line with the import substitution policy, the price of wheat was set to allow a 30 percent profit margin. The 1970-71 price, however, was set before the study was completed. This study indicated the price of wheat should have been increased 18 or 19 percent, not 8.8 percent.[39] The action, while causing a great amount of heated debate, was consistent with the original proposal to meet half Brazil's wheat demand with domestic production (a goal which was achieved with the 1970-71 harvest). This action was also consistent with proposals suggesting world prices be considered when minimum prices are set, and with the finance minister's comments (i.e., "We are ready to help farmers help themselves and help Brazil"; "Farmers must think about production, not protection and subsidies"; and "Subsidies hide high

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[37]"Trigo, da Terra Nasce a Fartura," Correio do Povo (Porto Alegre, August 13, 1970).

[38]"Preco do Trigo Objeto de Criticas no Legislativo," Correio do Povo (Porto Alegre, August 6, 1970).

[39]"Deputado Pede Novo Criterio Para Preco Minimo do Trigo," Correio do Povo (Porto Alegre, September 9, 1970).

social costs, low productivity, and irrational allocation of resources").[40]

Thus, in summary, it is quite apparent that government policies have had both positive and negative influences on agricultural mechanization in Brazil. The availability of long-term, zero, and low-interest credit and extra foreign exchange for the purchase of tractors and machinery during the "Campanha do Trigo" was undoubtedly responsible for the large number of tractor imports in the early 1950's (Figure 3). Low tractor prices, it is recalled, appear to have been responsible for the 1954 high. The prices farmers paid for imported tractors and equipment fluctuated with the exchange rate subsidy policies of the Brazilian government. Climaxing in 1964, the low nominal rates of interest on mechanization coupled with the rampant inflation of the early 1960's was likely responsible for the relatively high demand for tractors during this period. The upsurge noted at the end of the 1960's and the beginning of the 1970's was being brought on by a combination of factors including: (1) the price support program for wheat and a rapidly increasing market for soybeans, (2) the reduction of the excess capacity that plagued the national tractor industry during most of the 1960's, (3) the relaxation of the sales and manufacturing taxes on tractors and equipment, and (4) the investment credit allowance/fiscal incentive given on the purchase of tractors and equipment.

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[40] Metas e Bases Para a Acas de Governo, Presidencia da Republica, Brasilia (September, 1970), p. 90; and "Agricultura Cumprira seu papel," Estado de Sao Paulo (Sao Paulo, October 11, 1970).

CHAPTER IV

DATA SOURCE AND METHODOLOGY

Labor and mechanization are factor substitutes. However, as seen in previous studies, mechanization does not necessarily reduce labor use in every situation. In fact, substantial employment increases along with other positive effects sometimes accompany the introduction of this capital intensive technology.

Mechanization, particularly in Southern Brazil, is occurring at a rapid rate under a wide range of resource conditions. Government policies and concessions aimed almost exclusively at increasing output have done much to encourage the purchase of farm tractors and equipment.

This simultaneous growth of mechanized agriculture under varying resource conditions in contiguous areas presents a unique opportunity to analyze the impact of mechanization. In this study, the effects of mechanization on employment, land and labor productivity, and production efficiency are examined in three different resource situations.

To place the mechanization process and its effects in perspective, the setting from which the samples were drawn and the manner in which the observations were selected are described first in this chapter. This is followed by a discussion of the analytical procedures.

The Data and Its Setting

1. Area Description. The sample observations come from the municipios (counties) of Carazinho, Nao Me Toque, and Sao Borja in Rio Grande do Sul and the municipio of Turvo in Santa Catarina (Figure 5).[1] Rio Grande do Sul and Santa Catarina are Brazil's two southern-most states and together with Parana and Sao Paulo make up the region known as Southern Brazil.

a. Brazil and Southern Brazil. Brazil is a country of immense size and diversity. Covering nearly one-half of South America it extends some 39 degrees from the tropical zone of the northern hemisphere to the temperate zone in the southern hemisphere. Its size and location along with its topographical composition affords Brazil a great variety of climatic conditions and vegatation.[2] Added to this are very skewed patterns of income distribution and related socio-political powers.

Economically, Brazil has made significant progress in recent years.[3] In 1970, the industrial, transportation and communications, and commercial sectors grew 11.1 percent, 15.0 percent, and 9.0 percent respectively, while agriculture, showing the smallest increase, grew 5.6

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[1]This study was undertaken as part of a larger research project entitled "Analysis of Capital Formation and Technological Innovation at the Farm Level in Less Developed Countries." The general objective of this project was to determine and evaluate capital formation and to relate this process to technological change and economic development. Extensive farm level data collection in several different areas of Brazil constituted a very essential part of the research efforts. Mechanization was just one of several issues of concern in this U.S. Agency for International Development/Ohio State University project.

[2]Brazil Today, Fundacao IBGE (Rio de Janeiro, 1967).

[3]While inflation has been substantially reduced, at 22 percent in 1970, it continued to be a major socio-economic problem.

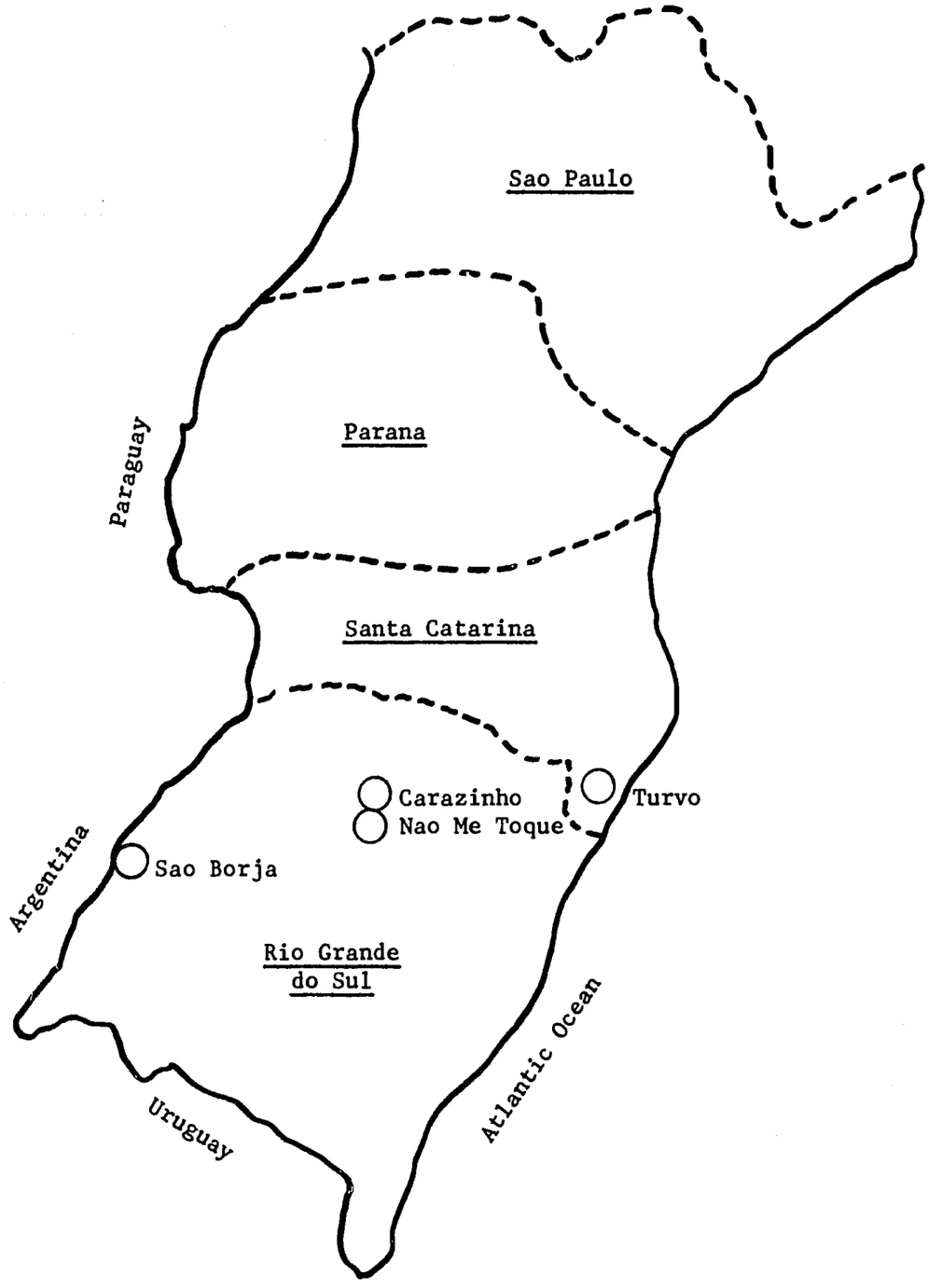

Figure 5.--Location of Four Municipios in Southern Brazil from which Samples Were Taken

percent. This latter sector which sometimes carries a laggard connotation, employs slightly less than 50 percent of the economically active population, generates approximately 70 percent of the country's export earnirgs, but accounts for only 22 percent of the national product.[4] Increasing area rather than crop yields have traditionally accounted for most of the increases in agricultural output.

Southern Brazil is the most populous and most economically and agriculturally advanced region of the country. It includes only 10 percent of Brazil but generates nearly 50 percent of its agricultural income. Approximately 40 percent of the country's inhabitants, 45 percent of its cultivated land, and 30 percent of its cattle are found in this region.[5]

b. Rio Grande do Sul and Santa Catarina. In Rio Grande do Sul and Santa Catarina where about half the ten million inhabitants are rural, agriculture accounts for approximately one-third of the net domestic

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[4]"Governo Estimula a Producao Rural e Aumenta Produtividade com Technologia," Correio do Povo (Porto Alegre, November 21, 1970).

[5]"Medici Recebe os Resultados Preliminares do Censo de 70," Correio de Povo (Porto Alegre, December 22, 1970); "IBGE Revela Totais do Censo ate 30 de Outubro," Correio de Povo (Porto Alegre, November 7, 1970); D. M. Sorensen, "Capital Productivity and Management Performance in Small Farm Agriculture in Southern Brazil" (unpublished Ph.D. dissertation, The Ohio State University, 1968), pp. 13-14; Brazil Today, Fundacao IBGE (Rio de Janeiro, 1967), pp. 10, 11, 72-76; Joaquim Engler, "Alternative Enterprise Combinations under Various Price Policies on Wheat and Cattle Farms in Southern Brazil" (unpublished Ph.D. dissertation, The Ohio State University, 1971), pp. 23-24; and John Shotwell, "FY-1970 Agricultural Sector Analysis--Brazil," AID/Brazil/ARDO (July 8, 1969), p. 1. (Mimeographed.)

product.[6] Here, as in the country as a whole, agriculture exhibits a great amount of diversity in terms of farm size and tenure, enterprise combinations, and technology levels. Much of the heterogeneity has resulted from the differing topographical and climatic conditions along with differing settlement patterns and traditions.

Land ownership patterns are very skewed. Sixty percent of the land in the two states is found in some 6 percent of the holdings. These are holdings of 100 hectares (247 acres) or more.[7]

Grazing is by far the most common use made of the land in Rio Grande do Sul and Santa Catarina. Two-thirds of the land in the rural holdings is pastured and one-quarter is used for crop production. Corn, wheat, and soybeans (in that order) are the most important crops.[8]

While substantial increases in the use of modern inputs and technologies have occurred during the past two decades, their use generally remains quite low and extremely uneven. In 1969 Rio Grande do Sul and Santa Catarina farmers applied an estimated 151,161 metric tons of fertilizer nutrients, or only 22 pounds per cultivated acre (23 kilograms per hectare).[9] And although the two states have one-fourth of the

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[6]"IBGE Revela Totais do Censo ate 30 do Outubre," Correio do Povo (Porto Alegre, November 7, 1970); Anuario Estatistico do Brazil, 1970, Fundacao-IBGE (Rio de Janeiro, 1970), p. 114; and Brazil, Series Estatisticas Retrospectivas--1970, Fundacao-IBGE (Rio de Janeiro, 1970), pp. 221-222.

[7]Censo Agricola de 1960, Brasil, Vol. II-1[a] Parte, pp. 22-23.

[8]Anuario Estatistico do Brasil, 1970, op. cit., pp. 14, 123-130.

[9]"Estatisticas Sobre Consumo de Fertilizantes no Brasil," Association Nacional Para Difusao de Adubos (ANDA) (Sao Paulo, Outubro, 1970), p. 6.

country's farm tractors, the majority are concentrated among a relatively small group of farmers in Rio Grande do Sul.

c. Mechanized Crop Production. Mechanization in these two states is most closely associated with the production of wheat, soybeans, rice, and corn. The larger producers generally employ tractors in the plowing and other pre-planting and planting operations, while the much larger number of smaller farmers perform these tasks with the [illegible] of animal-drawn equipment and hand tools. Wheat and soybeans are normally harvested mechanically on the larger farms and with the aid of small stationary threshers on the smaller farms. Both combines and stationary threshers are used in harvesting rice.

In terms of the employment of modern inputs and technologies, rice would have to be ranked at the top. According to Rio Grande do Sul's Rice Institute (IRGA), farmers producing more than 9 hectares (approximately 22 acres) of this crop in 1969 had 1.86 tractors, or 1 tractor for each 90 acres of rice. These same farmers fertilized 58 percent of their rice acreage at a rate of 257 pounds per acre.[10]

Brazil's most intensive area of rice production extends from the southern tip of Santa Catarina and the coastal zone of Rio Grande do Sul across the large central depression of the latter state to the Uruguay River on the western border.[11] Sao Borja and Turvo are included in this area.

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[10] Anuario Estatistico do Arroz--Safra, 1968/69, Instituto Rio Grandense do Arroz (Porto Alegre, 1970).

[11] Production and Export of Corn and Rice in Brazil, Foreign Agricultural Economics Report No. 54, USDA/ERS (Washington, D.C., September, 1969), p. 7.

Large wheat farmers whose numbers have increased rapidly are also relatively heavy users of modern inputs. The production of the "king of the cereals," as it is often referred to, is not new to Southern Brazil. It was first produced on a semi-commercial scale in Rio Grande do Sul starting about 1730. Production continued to expand until disease struck in the early 1800's. During the next hundred years, very little wheat was produced. From 1920 to 1944 Brazil's wheat production remained more or less constant, and then increased from 122,740 metric tons in 1944 to 1,101,315 metric tons in 1955.[12] Production started falling again, reaching a 115,717 metric ton low in 1963. The 1970 wheat crop exceeded 1.7 million metric tons, approximately one-half of Brazil's demand.[13]

The rapid expansion in wheat production in the 1960's was primarily the result of an official semi "self-sufficiency" policy. Direct price and credit subsidies led to increases in numbers of producers, area planted, and yields (Table 7).[14] Approximately four-fifths of Brazil's wheat was produced in Rio Grande do Sul in 1969, and Santa Catarina and Parana accounted for one-fifth (Table 7).

Two fundamentally different production systems are employed in producing wheat on Brazilian farms (Table 7). The system most responsible

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[12]The 1955 figure is probably inflated due to the inclusion of "paper wheat."

[13]Anuario Estatistico do Trigo--Safra, 1969/70, Ministerio da Agricultura (Porto Alegre, 1970); Atuais Regioas Agro-Pastoris do RGS, Instituto Gaucho de Reforma Agraria (Porto Alegre, 1965), p. 13; and J. Engler, op. cit., pp. 5-7.

[14]Very favorable weather along with a wheat breeding program have also contributed to the production increases.

TABLE 7

NUMBER OF FARM UNITS GROWING WHEAT, AREA PLANTED IN WHEAT, AND SELECTED MEASURES OF TENURE, TECHNOLOGICAL USE AND PRODUCTION AMONG WHEAT GROWERS, BRAZIL, 1963, 1966, AND 1969

	1963	1966	1969
Farm Units Growing Wheat and Distribution by States			
Brazil (number)	15,820	33,578	93,663
Rio Grande do Sul (%)	77	81	70
Santa Catarina (%)	18	15	15
Parana (%)	5	4	15
Area Planted in Wheat and Distribution by States			
Brazil (hectares)	302,122	384,960	1,299,519
Rio Grande do Sul (%)	92	89	80
Santa Catarina (%)	5	7	5
Parana (%)	3	4	15
Percentage of Area Rented			
Rio Grande do Sul	49	40	37
Santa Catarina	16	14	13
Percentage of Area Mechanized			
Rio Grande do Sul	78	77	79
Santa Catarina	5	4	4
Percentage of Units Mechanized			
Rio Grande do Sul	26	21	22
Santa Catarina	1	1	1
Fertilizer Used Per Hectare			
Rio Grande do Sul (kg)	N.A.	182	184
Santa Catarina (kg)	N.A.	3	5
Production Per Hectare			
Rio Grande do Sul (kg)	371	862	1,043
Santa Catarina (kg)	502	820	762

Source: Ministerio da Agricultura, Anuario Estatistico do Trigo--Safra, 69/70 (Porto Alegre, 1970).

for Brazil's production and most responsive to the subsidies is carried out on the gently rolling grass lands of Rio Grande do Sul and Parana. These areas have absorbed large numbers of tractors and combines and large quantities of fertilizer and lime in as much as they lend themselves to high levels of mechanization and their soils are acidic and low in plant nutrients. The non-mechanized system utilized by the majority of Brazilian wheat producers is normally found on the smaller farms in the hilly and previously forested areas of the three states. Fertilizer and lime, if used, are applied to these more fertile soils in smaller quantities.[15]

Sao Borja, Carazinho, and Nao Me Toque are among Rio Grande do Sul's largest wheat producing municipios. Nearly all of the wheat grown in these three municipios is produced with the aid of tractors and combines.

Soybean production, like wheat production, has expanded at a very rapid rate, is a very important source of agricultural income, and takes place under two fundamentally different production systems.[16]

Thousands of small farmers of European descent plant soybeans and corn together in the hilly areas of Southern Brazil. Mechanized soybean production is concentrated in the gently rolling plateau grass lands, and is closely associated with the mechanized production of wheat. In these plateau areas the climatic conditions allow wheat to be grown

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[15] P. Knight, Brazilian Agricultural Technology and Trade, A Study of Five Commodities (New York: Praeger Publishers, 1971), pp. 40-41.

[16] 1970 soybean production exceeded that of the previous year by 38.3 percent. "Trigo Pode Suprir 50%," Estado de Sao Paulo (Sao Paulo, October 11, 1970).

during the cooler months and soybeans in the warmer summer months on the same land. And while this system delays the planting of the soybeans one or two months which results in somewhat lower yields, it enables the farmers to make more complete and efficient use of their land, labor, and equipment.

Although corn is produced in all parts of Southern Brazil, the north-central and the western portions respectively account for the bulk of commercial production in Rio Grande do Sul and Santa Catarina. More agricultural land is devoted to the production of corn than to any other crop in these two states. Relative to rice, wheat, and soybeans, however, the technologies employed in the production of corn are backward. It is customarily grown on smaller farms. The combination of inputs used and the techniques followed in producing corn vary widely today, as they did in the late 1940's and early 1950's when mechanized corn production was associated with wheat in much the same way soybeans and wheat are presently related.

Some corn is produced by most farmers in Carazinho, Nao Me Toque, and Turvo.

3. Situations Studied. Agricultural mechanization is occurring under a wide range of conditions in Southern Brazil. To narrow this range or reduce the heterogeneity so the specific effects of mechanization could be examined, three distinctly different, but characteristic, farm resource situations were selected. They represent varying factor proportions, especially with respect to land and labor. For convenience, they are referred to as the Size Change, Enterprise Change, and No Change

situations. These names are indicative of the change that accompanies mechanization in these three resource situations.

The predominant change accompanying mechanization in the Size Change situation has been size increases among family farms in Carazinho and Nao Me Toque. These increases have occurred through land rental and incremental purchases. Both crops and livestock are generally produced on these farms where most of the labor is provided by the family. This area, which was settled by second and third generation European immigrants in the late 1800's and early 1900's, although undulant, is generally quite suitable for the mechanized production of wheat and soybeans. Under traditional forms of cultivation land and labor are in relative balance, which in part explains the push for farm size expansion to accommodate mechanized agriculture.

Large tracts of grazing land have been brought into crop production through the use of mechanization in the Enterprise Change situation. Contrary to the other two situations, land is generally not a limiting factor in this situation and the dependence on hired labor is much greater. This situation, thus, is somewhat representative of one extreme of the land-labor factor proportion continuum in Brazil.

Sample observations both from Carazinho and Nao Me Toque and from Sao Borja are analyzed to determine the effects of agricultural mechanization in the Enterprise Change situation. Observations from Carazinho and Nao Me Toque not included in the first situation constitute the Enterprise Change #1 category. Enterprise Change #2 includes observations from Sao Borja.

Since the time the Spanish/Portuguese/Latin American Indian ethnic cross first started following and hunting the herds of wild cattle for hides, Sao Borja has been thought of as grazing land, and only recently have rice and wheat been able to compare with livestock in importance. Between 1969 and 1970 alone wheat acreage in this large western frontier municipio expanded 75 percent (Table 8).[17] This upsurge in the importance of rice and particularly wheat is not surprising, however, in view of the Government's commodity subsidy programs and concessional mechanization policies and the municipio's level and gently rolling topography, easily accessible irrigation waters, and relatively fertile soils.[18] The change in enterprise patterns was assured.

In the No Change situation, neither a change in farm enterprise nor size appears to ensue the adoption of mechanization. The farms depicting this situation come from Turvo where the climate is more or less sub-tropical and the soils some of the most fertile in Santa Catarina. The farms are relatively small and partially irrigated. Both livestock and crops are produced on these farms with corn, rice, cassava, and tobacco being the important crops. According to one estimate, Turvo's farmers owned 20 percent of the state's tractors in 1967.[19] It would seem, however, that some of these were purchased more for transportation and social status than for production. Further, the land-labor factor

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[17]"Brazil Esta Abrindo a Porta ao seu Trigo," Correio do Povo (November 13, 1970).

[18]"Os Solos de Trigo do RGS," Correio do Povo (November 20, 1970).

[19]I. Scarabolot, "Conferencia Proferida no Curso de Credito Rural Realizado en Florianopolis no Perido de Setembro de 1967." (Mimeographed.)

TABLE 8

SELECTED DESCRIPTIVE STATISTICS: CARAZINHO, NAO ME TOQUE, SAO BORJA, AND TURVO, 1967-1970

	Carazinho	Nao Me Toque	Sao Borja	Turvo
Area of Municipio (including roads, urban areas, etc.) km^2	1,323	432	5,082	360
Rural Population	14,189	7,113	23,869	N.A.
Number of Rural Properties	2,373	1,593	2,735	1,959
Elevation of Municipio--Meters	592	550	96	N.A.
Precipitation--mm/yr.	1,850	1,850	1,650	N.A.
Rice--ha. in 1969	630	500	13,208	6,720 (1967)
Corn--ha. in 1969	7,450	12,500	1,000	2,700 (1967)
Soybeans--ha. in 1960	15,000	15,000	300	N.A.
Wheat--ha. in 1969	31,661	16,195	56,761	43
Number of Farms Producing Wheat in 1969	631	614	697	10
% of Wheat Farms Employing Mechanization in 1969	64	90	88	80
% of Wheat Area Mechanized in 1969	98	99	99	84
Wheat Yields in 1969, kg/ha.	987	1,152	1,019	780
Number of Cattle	23,923 (1968)	12,460 (1970)	340,000 (1970)	14,995 (1969)

N.A. = not available.

Source: SUDESUL, Ministerio do Interior, Informe Geral da Lavoura--Santa Catarina (December, 1969); "Sao Borja--Historia e Atualidades," Profeitura Municipal, 1970; Anuario Estatistico do Trigo--Safra, 69/70; Carazinho, A Capital da Hospitalidade, Profeitura Municipal, 1971; and information provided by county government offices.

proportions are such that mechanization would have only limited possibilities for improving economic performance.

3. Sampling Procedures. The sampling procedures used to select the observations for examining the effects of mechanization in each of the three situations varied between municipios.[20] Differences in the availability of information were primarily responsible for this variation. In all four municipios, however, the procedure began by subdividing the roll of rural property owners on the basis of the amount of land held.

In Nao Me Toque, the next step involved using the Ministry of Agriculture's roll of wheat producers along with the local wheat cooperative's membership information file to tentatively identify the mechanized farmers. The Ministry's roll identified the farmer's wheat production technique as being mechanized or non-mechanized, and the information file indicated whether a tractor was actually owned by the farmer.[21] Individual mechanized and non-mechanized farmers were then selected at random from each of the size groupings. A similar sampling procedure was used in Carazinho. However, only the Ministry's roll of

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[20]The sampling procedures were not designed to necessarily obtain data representative of the agricultural sectors in the respective municipios.

[21]This selection criterion was based on the premise that nearly all farmers owning tractors would also be producing and selling wheat at its high support price.

wheat producers was available for identifying whether the municipio's farmers were mechanized.[22]

Beyond the roll of rural property owners, no particularly useful information was available for selecting a sample in Turvo. To obtain the necessary information, the main tractor mechanic in this small municipio, using the property roll, was asked to identify those farmers owning tractors. Once this was done, tractor owners were selected at random from each of the size groupings. Then at the time of the interview, the mechanized farmers were asked to identify a neighbor who was operating a similar-sized unit and producing similar crops but who did not own a tractor. These non-mechanized farmers were then interviewed.

The sampling procedure used in Sao Borja deviated to the extent that only farmers owning more than 100 hectares (247 acres) were selected originally and no attempt was made to control the proportion of mechanized and non-mechanized farmers interviewed.[23] While a few farmers renting land from the owners originally selected were also interviewed, the sample represents a fairly complete cross-section of those owning and/or renting 100 hectares or more. The smaller holdings were not included since the primary interest in these farms focuses on the transition from extensive range livestock production to more intensive crop production.

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[22]Thirty-six of the 144 farmers interviewed in Carazinho were included in a similar survey in 1965. The other 108 were randomly selected from each of the size groups.

[23]In 1967, 64 percent of the rural holdings were less than 100 hectares.

To maintain somewhat of a balance (which was admittedly quite difficult) between the number of mechanized and non-mechanized farmers interviewed within size ranges, it was necessary to control the interviewing in the field to a limited extent. This was particularly true in Carazinho and Nao Me Toque where many of the farmers originally selected were renting land and thus fell in size strata different from those for which they were selected to represent. Also, the rolls and other information which were used in the selection were occasionally incorrect or outdated.

The farmers in Sao Borja were interviewed in July, 1970, over their July 1, 1969, to June 30, 1970, operations, while those of the other three municipios were interviewed during the first five weeks of 1970 over their 1969 operations. Most of the interviewing was done by professors and graduate students of agricultural economics in the Federal Universities of Rio Grande do Sul and Santa Catarina, and a great amount of support was provided by the local officials and technical assistance personnel. As the rather extensive questionnaires were collected, they were edited and checked for internal consistency, and the interviewer was asked to correct, by returning to the farm if necessary, any inconsistencies or omissions that were noted.

The Analytical Procedures

The effects of mechanization on (1) employment, (2) land productivity, (3) labor productivity, and (4) production efficiency are examined in this study. These four dependent variables and a larger number of independent variables, along with some measurement terms, are defined

and commented on first. This is followed by a discussion of the three analytical techniques, including the specific models used to measure the effects of mechanization.

1. Terms.

Cruzeiro (Cr$)

The cruzeiro is the monetary unit of exchange in Brazil. Its exchange value at the time of the interviews was about U.S. $.23 or alternatively, $1 would have been equal to about 4.35 cruzeiros. Inflation averaged slightly more than 20 percent in 1969.

Hectare

A hectare is a land measure equal to 2.47 acres.

Kilogram

A kilogram is a weight measure equal to 2.205 pounds.

Man Equivalent

One man equivalent is equal to 300 days of adult male labor. Males under 18 and over 59 and females were weighted according to age and sex to reflect differences in capabilities.

2. Variables. The variables included in the analysis are divided into the four general categories of land, labor, capital, and production.

a. Land Variables.

Farm Size

Farm size is used interchangeably with "land operated" and "size" and refers to the amount of land included in the farming operation. This measure includes the land owned plus the land rented from others minus the land rented to others. It is a very important measure in the analysis in that it is used in obtaining the per hectare labor, capital, and production variables, the land per man values, and the land-use intensity ratios.

Land-Use Intensity

Land-use intensity, as measured in the analysis, is the portion of the land operated which is in field crops and improved pasture. This ratio does not reflect other intensity differences such as double cropping.

Improved Pasture

Improved pasture is generally an annual crop which is used as a supplementary winter pasture when the native grasses are dormant.

b. Labor Variables.

Employment

Employment and (total) "labor" are used interchangeably in reference to the amount of family and hired labor employed on the farm during the year.

The variable is measured in man equivalents and is normally standardized on the basis of 1 or 100 hectares. Unless specifically noted, family and hired labor are considered jointly in the analysis.

Due to some difficulty in ascertaining the precise amount of labor actually utilized on the farms, the labor values must be interpreted as being the amount of labor available and not necessarily the amount utilized. There is no doubt some unemployed and underemployed labor included in the labor values.

The difference between the amount of labor available and the amount actually utilized would probably be minimal in the case of hired labor. With family labor, however, the difference is likely much greater, especially on the smaller farms where little or no labor is hired. The fluctuating seasonal demand for farm labor and the limited number of off-farm employment opportunities in rural areas would be largely responsible for the differences when and where they exist.

c. Capital Variables. Two basic types of capital exist. Capital stocks include productive items that are not used up in one season, such as livestock, tractors, and equipment. Capital flows are reoccurring expenditures, such as livestock, machinery, and crop expense.

Crop Expense

The crop expense variable includes such annual inputs as seed, fertilizer, and pesticides, but does not include labor, rental, machine, and similar costs incurred in producing crops.

Livestock Expense

Purchased feed and minerals, veterinary fees, medication and vaccines, breeding expenses, and livestock supplies are included in the livestock expense variable.

Livestock Investment

Livestock investment is the total value of all the livestock on the farm.

Machine Cost

Machine cost contains both capital stock and flow variables. It is the summation of machine depreciation, machine expense, and machine rental payments minus any custom machine hire receipts. Fuel, lubricant, parts, and repair charges make up the machine expenses, and depreciation is calculated at 12.5 percent of the mechanized and non-mechanized equipment investment. The mechanized equipment category includes tractors, implements used with tractors, and equipment providing its own power for field operations (i.e., irrigation pumps and self-propelled combines).

Non-Land Cost

Non-land cost is a composite capital variable used in obtaining the measure of production efficiency. This cost is the summation of the crop, hired labor, water rental, and livestock expenses plus the machine cost plus a family labor charge computed at the average minimum wage rate (Cr$1,903 for Sao Borja and Cr$1,737 for the others).

Credit

The total value of loans and time purchases received during the year is used as a measure of credit.

d. Production Variables.

Farm Output

Farm output is the value of the crops and livestock produced on the farm during the year, and is used in deriving other production variables. It includes sales of crops and livestock produced on the farm, values of crops paid in kind, value of production consumed by the family and increases in livestock inventories less livestock purchases.

Land Productivity

The land productivity variable is obtained by dividing farm output by farm size.

Labor Productivity

Labor productivity is farm output divided by the total number of man equivalents of family and hired labor.

Production Efficiency

Production efficiency is a proxy for average value production costs. It is non-land cost divided by the sum of farm output and custom machine hire receipts. A lower value is indicative of a higher level of efficiency. Due to the difficulty in obtaining accurate estimates of the costs (cash and opportunity) involved in owning land, only the non-land costs were used.

Net Income

Net income is equal to crop and livestock sales plus land and machine rental receipts minus machine depreciation, livestock purchases, and total operating expenses (including livestock, machinery, machine rent, crops, and hired labor expenses, real estate taxes, and improvement expenditures, crop insurance premiums, cooperative membership fees, etc.).

3. Analytical Techniques. To study the relationships existing between mechanization and (1) employment, (2) land productivity, (3) labor productivity, and (4) production efficiency in each of the three

resource situations, three analytical techniques are used. Tabular analysis is used first to compare the mechanized sample observations with the non-mechanized sample observations. These observations, which are identified according to tractor ownership, are further divided on the basis of machine cost incurred per hectare during the year. This classification scheme allows for a more complete comparison as it gives a breakdown of five levels of mechanization leading from low and moderate machine costs on the non-mechanized farms to generally succeedingly higher levels on the mechanized farms.

Covariance analysis is the second analytical technique utilized. It is employed to remove or isolate the influence of size in the relationships between mechanization and the dependent variables. As a final step regression analysis is used to measure the extent to which mechanization and other input variables influence employment, land and labor productivity, and production efficiency on the non-mechanized and the mechanized sample farms.

In addition to providing some tentative answers to the questions (relationships) being studied, the first analytical technique serves to introduce characteristics of the sample farms. This characterization facilitates the interpretation of the results of the covariance analysis and the least squares regression analysis.

Since the mechanized and non-mechanized samples differ not only in tractor ownership and annual machine cost, but also in farm size and capital investment and expense patterns, it is necessary to separate the influence of mechanization from the influence of the other variables. Covariance analysis is used to isolate the influence of size differences

so the relationships between mechanization (tractor ownership) and employment, land and labor productivity, and production efficiency and also land-use intensity might be examined more closely. Preliminary analysis indicated the differences in the capital investment and expense patterns of the sample farms were generally reflected in their size and mechanized/non-mechanized system of production, and as such, no attempt was made to isolate the influence of these capital differences.

Mechanization is respecified as annual machine cost, a continuous variable, in the least squares regression analysis. Specified in this manner, better approximations of the relationships existing between mechanization and the four dependent (employment, land and labor productivity, and efficiency) variables are expected, but only within the individual mechanized and non-mechanized samples. The differences between the two types of farms are too great to permit them to be examined simultaneously in the same regression. In this step of the analysis, the four dependent variables are regressed on measures of size, crop expense, livestock investment and expense, and labor, in addition to machine cost.

a. Covariance Models. The covariance analysis model used to separate the influence of farm size from that of tractor ownership is:

$$Y_i = f\ (X_1, X_2)$$

where:

Y_1 = Employment (labor per 100 hectares)

Y_2 = Land productivity (farm output per hectare)

Y_3 = Labor productivity (farm output per man equivalent)

Y_4 = Production efficiency

Y_5 = Land-use intensity

X_1 = -1; does not own a tractor

+1; owns a tractor

X_2 = Farm size

This linear model yields an intercept value (b_o) and b_i coefficients for X_1 and X_2. A positive tractor ownership coefficient (b_1) indicates the amount those owning tractors are above average and the amount the non-owners are below average. (A negative coefficient indicates the opposite for both groups.) Of interest is the difference between the two groups.

b. Regression Models. To assess the influence of machinery within the mechanized and the non-mechanized samples, the following models are used:

$$Y_1 = f\ (X_2, X_3, X_4, X_5, X_6)$$

$$Y_2 = f\ (X_2, X_3, X_4, X_5, X_6, X_7)$$

$$Y_3 = f\ (X_8, X_9, X_{10}, X_{11}, X_{12})$$

$$Y_4 = f\ (X_2, X_3, X_4, X_5, X_6)$$

where:

(Y_1, Y_2, Y_3, Y_4, and X_2 are the same as in the covariance model)

X_3 = Crop expense per hectare

X_4 = Machine cost per hectare

X_5 = Livestock investment per hectare

X_6 = Livestock expense per hectare

X_7 = Labor per hectare

X_8 = Land per man equivalent

X_9 = Crop expense per man equivalent

X_{10} = Machine cost per man equivalent

X_{11} = Livestock investment per man equivalent

X_{12} = Livestock expense per man equivalent

Both linear and logarithmic (Cobb-Douglas) algebraic forms of the regression models are used in estimating the relationships. In the Enterprise Change situations, where natural pasture is shifted to more intensive uses as additional machine inputs are added, land is not a constraint. Consequently there is little reason to believe a diminishing product or influence would be forthcoming, and as such, the linear forms of the models are used. In the Size Change and No Change situations where the amount of land that could be transferred to crop production from less intensive uses is generally limited, the logarithmic forms of the models are employed to reflect the diminishing product or influence expected from additional machine inputs.

In the linear form, the least squares regression models yield b_i coefficients that are interpreted as the physical relationships between the dependent and independent variables: a one unit increase in X_i, on the average, results in a change in Y of b_i units. Cobb-Douglas coefficients are interpreted as elasticities independent of the units of measurement: a one percent increase in X_i, on the average, results in a b_i percent change in Y. The elasticities are transformed into physical unit relationships by using the following formula:[24]

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[24] D. Sorensen, op. cit., p. 58.

$$\frac{\Delta Y}{\Delta X_i} = b_i \frac{\overline{Y}}{\overline{X}_i}$$

where:

$\frac{\Delta Y}{\Delta X_i}$ = The physical unit relationship between X_i and Y

b_i = The regression coefficient (elasticity) of log X_i

$\overline{Y}$ = The geometric mean of Y

$\overline{X}_i$ = The geometric mean of the ith independent variable

In addition to the b_i coefficients and the values derived from them, several other statistics are presented for each of the models. One of these is the net effect statistic which indicates the relative importance of the independent variable in explaining the variation in the dependent Y variable. It is a summation of direct and indirect effects, and when added to the net effects of the other variables is equal to the unadjusted R^2.

The results of the analysis of each of the data sets follow. Presented in Chapter V are the results of the tabular, covariance, and least squares regression analyses for the Size Change situation. Results of the Enterprise Change and No Change data analyses are presented in Chapter VI and VII respectively. And the results of analyses of all the data sets are summarized in Chapter VIII.

CHAPTER V

MECHANIZATION ACCOMPANIED BY CHANGES IN FARM SIZE

The sample farms representing the Size Change situation came from the municipios of Carazinho and Nao Me Toque in the state of Rio Grande do Sul. Increases in farm size have normally been the predominate change associated with mechanization in this area. Typically small farmers begin by renting some machine services, and later through land rental or incremental purchases they enlarge the size of their farms emough to justify the ownership of a few key pieces of mechanized equipment. Wheat and soybeans are the most important crops and are generally double cropped when mechanization is used.

Sample Description and Comparison

The data set consisting of 75 non-mechanized and 81 mechanized farms is classified in five groups based on machine cost per hectare. In accordance with these groupings the mathematical means of a variety of variables are presented in Table 9. These statistics serve to characterize the sample observations and provide a basis for comparing farms differing in their levels of mechanization.

A comparison of the means in Table 9 reveals mechanization appears to result in a decrease in employment and an increase in land productivity, labor productivity, and production efficiency in the Size Change

TABLE 9

AVERAGE VALUES OF SELECTED INPUT VARIABLES AND PRODUCTIVITY MEASURES, SIZE CHANGE SITUATION, CARAZINHO AND NAO ME TOQUE, R.G.S., 1969

Item	Farm Type and Machine Cost Per Hectare[a]						
	Non-Mechanized			Mechanized			
	Up to Cr$25	Cr$25 or More	Total	Up to Cr$50	Cr$50 to Cr$100	Cr$100 or More	Total
Number of Observations	49	28	75	10	27	44	81
Land (Hectares)							
Owned	32.3	25.9	29.9	56.1	113.2	55.8	75.0
Operated	30.6	28.3	29.7	71.4	156.6	92.2	111.0
Cultivated Land and Improved Pasture	17.0	19.7	18.0	55.0	116.8	79.3	88.8
Land-Use Intensity	0.57	0.7	0.62	0.72	0.75	0.87	0.81
Crop Areas[b]							
Wheat	3.4	9.5	5.7	29.6	89.4	70.1	67.9
Soybeans	8.6	9.8	9.0	33.9	80.0	59.9	59.2
Others	8.0	9.7	8.6	15.4	3.4	3.9	5.2
Labor (Man-Equivalents)							
Family	2.43	2.68	2.53	3.01	3.07	2.52	2.77
Hired	0.04	0.06	0.05	0.51	0.92[c]	0.64[c]	0.71[c]
Total	2.47	2.75	2.57	3.52	3.99	3.16	3.48
Total Per Hectare	0.097	0.103	0.099	0.053	0.035	0.043	0.042

TABLE 9--Continued

Item	Farm Type and Machine Cost Per Hectare[a]						
	Non-Mechanized			Mechanized			
	Up to Cr$25	Cr$25 or More	Total	Up to Cr$50	Cr$50 to Cr$100	Cr$100 or More	Total
Capital (Cr$[a])							
Investment							
Draft Livestock	756	690	734	475	572[c]	251	386[c]
Production Livestock	2,749	2,531	2,668	3,162	4,447	2,593[c]	3,281
Non-Mechanized Equipment	746[c]	738	743	575	1,073[c]	490[c]	695[c]
Mechanized Equipment	535[c]	1,062	732[c]	20,520[c]	51,308	54,484	44,343
(Tractor Horsepower)	0	0	0	37	112[c]	86	89[c]
Total Non-Land Investments[d]	5,585	5,717	5,634	28,082[c]	62,289	55,212	54,222
Total Non-Land Investment Per Hectare[d]	197	220	206	364	398	629	520
Land and Buildings	25,591	26,914	26,085	46,610	114,841	56,182	79,985
Total Investment[d]	31,176	32,631	31,719	74,693	177,130	121,394	134,207
Expenses							
Livestock	297[c]	429[c]	347[c]	727[c]	628[c]	395[c]	514[c]
Machinery	75[c]	485[c]	228[c]	2,588[c]	5,648	6,070	5,500
Machine Rent	145[c]	923[c]	436[c]	149[c]	906[c]	1,238[c]	993[c]
Crop	778[c]	2,038	1,248[c]	7,128	16,971	13,251	13,735
Hired Labor	59[c]	84[c]	69[c]	735[c]	1,618[c]	1.116[c]	1,236[c]
Total[e]	1,612	4,354	2,636	13,864[c]	29,910	25,509	25,538
Total Per Hectare[e]	55	151	91	156	182	287	237
Credit							
Loans and Time Purchases Received During Year	1,072[c]	2,482[c]	1,598[c]	10,905[c]	38,663	29,496	30,257[c]

TABLE 9--Continued

Item	Farm Type and Machine Cost Per Hectare[a]						
	Non-Mechanized			Mechanized			
	Up to Cr$25	Cr$25 or More	Total	Up to Cr$50	Cr$50 to Cr$100	Cr$100 or More	Total
Production (Cr$)							
Total Farm Output	5,417	8,543	6,854	26,592	54,995	2,242	44,561
Total Per Hectare	191	311	236	327	340	484	416
Total Per Man Equivalent of Hired and Family Labor	2,391	4,061	3,015	7,232	16,015	15,161	14,467
Wheat Yield (Kilograms Per Hectare of Crop)	898 (34)	1,123 (28)	1,000 (62)	1,110 (10)	1,106 (27)	1,134 (43)	1,122 (80)
Efficiency[f]	1.23	1.05	1.16	0.76	0.79	0.85	0.82
Net Income	3,705	3,824	3,750	11,831	14,247	8,447[c]	11,018[c]

[a]One Brazilian cruzeiro (Cr$) exchanged for U.S. $.23 at the time the interviews were taken.

[b]The "cultivated land and improved pasture" is not expected to equal the summation of the "crop areas" since (1) the former was measured at the time of the interview while the latter represents the year being studied, (2) double cropping is sometimes practiced and (3) improved pasture is not included in the latter.

[c]Standard deviation exceeds mean (standard deviation was not derived for "crop areas" or yields).

[d]Includes investment in vehicles not itemized above.

[e]Includes real estate taxes and improvement expenditures, crop insurance, cooperative membership fees, etc. not itemized above.

[f]Non-land cost divided by farm output plus custom machine receipts (small values are preferred).

situation.[1] A combination of larger yields, expanded acreage, and higher land-use intensities is associated with mechanization and is the probable medium through which the productivity and efficiency increases were exerted.

The land acquisition patterns that accompany mechanization are partially reflected in the data. Beyond the size differences, the importance of rental is noted. One-third of the land being farmed by the mechanized farmers was rented. Further, the mechanized farm units were each composed of three or more individual land purchases and land rental agreements.

Land-use intensity (the percent of land in crops and improved pasture) is observed to increase significantly as the level of mechanization increases. A greater degree of double cropping of wheat and soybeans further enhanced the intensity at which the land was used (i.e., it appears that about 17 percent of the cultivated land was being double cropped on the least mechanized farms versus 69 percent on the most highly mechanized farms). The differences in the intensity ratios and the amount of double cropping are very apparent in the per hectare operating expenses and non-land investment figures. These differences are also exemplified in the use of credit.

Combining the much higher levels of capital usage with land and labor brought forth higher levels of productivity. An increase in output per hectare (land productivity) of 76 percent is noted between the

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[1]The reader is reminded of the difficulty which was sometimes encountered in distinguishing the amount of labor actually utilized from the amount available for use. A discussion of this is found in Chapter IV in the section devoted to defining the variables.

non-mechanized and mechanized farms. Labor productivity (output per man equivalent), however, is observed to have been nearly four times higher on the mechanized farms as compared to those where no tractors were owned. These land and labor productivity differences are noted to have been even greater when the lowest and the most mechanized groups are compared. Higher net incomes and greater production efficiencies also accompanied the higher capital inputs on the mechanized farms.

The higher levels of capital expenses and investments, while resulting in increased land and labor productivities, net farm incomes, and production efficiency, appear to have served as a substitute for labor. The mechanized sample included 58 percent less labor per hectare than the non-mechanized observations. Noteworthy, however, is that hired employees constituted 20 percent of the total labor input on the farms in the mechanized sample versus only 2 percent in the non-mechanized sample.

Covariance Analysis

Removing the influence of farm size differences in the Size Change survey data does not alter the basic relationships noted above: Mechanization results in decreases in employment, and increases in land productivity, labor productivity, production efficiency, and land-use intensity.

The coefficients of the covariance analysis models (Table 10) do indicate, however, that the differences between the levels of employment, labor productivity, and production efficiency of the mechanized and non-mechanized farmers are smaller than those observed above. Differences

TABLE 10

COEFFICIENTS AND RELATED STATISTICS OF THE COVARIANCE ANALYSIS MODELS, SIZE CHANGE SITUATION, CARAZINHO AND NAO ME TOQUE, R.G.S., 1969

	Labor Per 100 Hectares	Output Per Hectare	Output Per Man Equivalent	Production Efficiency	Land-Use Intensity
	(Coeff.)	(Coeff.)	(Coeff.)	(Coeff.)	(Coeff.)
Tractor Ownership (Mechanized/ Non-Mechanized)	-1.911	103.54	3,171	-.13709	.10702
Size (Hectares)	-.023	-.32[a]	63	-.00082[b]	-.00028[b]
Intercept	8.671	349	4,317	1.047	.737
Mean of Y	6.922	330	8,961	.983	.720
Standard Error of Y	5.228	155	9,595	.426	.183
R^2	.3672	.3568	.5028	.1729	.2834
Standard Error of Y.X	4.185	125	6,810	.390	.156

[a]Not significant at .05 but at .10.

[b]Not significant at .10 but at .20.

in land productivity and land-use intensity increased between the two types of farmers when the size variable was isolated.

For the specific interpretation of the results of the models, attention focuses on the top row of coefficients in Table 10. A positive b_i coefficient, it is recalled, signifies the mechanized observations are b_i units above the average (mean of Y) and the non-mechanized are below the average by an equal amount. A negative coefficient has the opposite meaning. Thus, the implication of the first coefficient is that, on the average, mechanized farms, in the Size Change situation, employ 3.822 [(-1.911) + (-1.911)] fewer man equivalents of family and hired labor per hundred hectares than non-mechanized farms. Stated differently, mechanization releases 3.822 man equivalents of labor per hundred hectares.

The other coefficients imply that on the average the tractor owners produced Cr$207 and Cr$6,342 more output per hectare and per man equivalent, were nearly 25 percent more efficient, and used their land approximately 35 percent more intensively than those farmers not owning tractors.

Regression Analysis

Combining additional machine inputs with the existing land and other capital inputs of the already mechanized farms, while having little or no effect on labor, would not have increased production enough to cover the added expense. Efficiency and profits would have consequently been reduced.

In the case of the non-mechanized observations, however, employment production, efficiency, and profits could (on the average) all have been increased by adding extra machine inputs.

These results were obtained from the Size Change observation data when mechanization was respecified as annual machine cost, a continuous variable and analyzed in a least squares regression framework. Employment, land and labor productivity, and production efficiency were regressed on machine cost and several other independent variables in an attempt to more nearly identify the specific relationships between agricultural mechanization and these dependent variables. The mechanized and non-mechanized observations were analyzed separately due to their differences. The coefficients and related statistics of the logarithmic least squares regression models for the Size Change situation are presented in Tables 11 through 14.

1. Employment. While size and livestock investment are the most important variables explaining the variation in employment among both sets of observations in the labor models, machine cost is also important in explaining this variation within the non-mechanized set. The machine cost coefficient for the latter indicates a 1 percent increase in machine inputs would, on the average, have led to a .134 percent increase in employment on the non-mechanized farms in the Size Change situation. Translated into physical units; for each additional cruzeiro of machine cost incurred per hectare, an additional .0659 man equivalents or 20 man days per year would have been employed per hundred hectares.

TABLE 11

COEFFICIENTS AND RELATED STATISTICS OF LOGARITHMIC LEAST SQUARES REGRESSION ANALYSIS, LABOR PER 100 HECTARES, SIZE CHANGE SITUATION, CARAZINHO AND NAO ME TOQUE, R.G.S., 1969

	Non-Mechanized			Mechanized		
	Effect	Coefficient	Units	Effect	Coefficient	Units
Size (Hectares)	.161	-.368	-.1168	.421	-.5889	-.0221
Crop Expenses/Ha.	.006[d]	.034[c]	.0129	-.013[d]	.0758[c]	.0025
Machine Cost/Ha.	.059	.134	.0659	-.007[d]	-.1308[c]	-.0046
Livestock Investment/Ha.	.283	.404	.0318	.031	.0569[c]	.0060
Livestock Expense/Ha.	-.023	-.056[c]	-.0957	.011[d]	.0162[c]	.0233
Constant (Intercept)		.625[a]			3.927	
Mean of Y	2.130			1.252		
Standard Error of Y	.590			.635		
R^2	.4858			.4431		
Standard Error of Regression	.438			.491		

[a]Not significant at .05 but at .10.

[b]Not significant at .10 but at .20.

[c]Not significant at .20.

[d]Standard error of regression increased when variable entered.

TABLE 12

COEFFICIENTS AND RELATED STATISTICS OF LOGARITHMIC LEAST SQUARES REGRESSION ANALYSIS, OUTPUT PER HECTARE, SIZE CHANGE SITUATION, CARAZINHO AND NAO ME TOQUE, R.G.S., 1969

	Non-Mechanized			Mechanized		
	Effect	Coefficient	Units	Effect	Coefficient	Units
Size (Hectares)	.029	-.112[b]	.888	.059	-.193	-.830
Crop Expenses/Ha.	.168	.110	1.041	.265	.299	1.123
Machine Cost/Ha.	.339	.225	2.763	.120	.166[a]	.656
Livestock Investment/Ha.	.012[d]	.055[c]	.108	.020[d]	.035[c]	-.416
Livestock Expense/Ha.	.045	.048[b]	2.049	(n.e.)[e]		
Labor/Ha. (Man Equivalents)	.058	.124[b]	309.63	-.001	-.074[c]	-822.22
Constant (Intercept)		4.707			4.536	
Mean of Y	5.349			5.940		
Standard Error of Y	.509			.387		
R^2	.6503			.4628		
Standard Error of Regression	.314			.294		

[a]Not significant at .05 but at .10.

[b]Not significant at .10 but at .20.

[c]Not significant at .20.

[d]Standard error of regression increased when variable entered.

[e]Variable was below .01 minimum F-level and did not enter model.

TABLE 13

COEFFICIENTS AND RELATED STATISTICS OF LOGARITHMIC LEAST SQUARES REGRESSION ANALYSIS, OUTPUT PER MAN EQUIVALENT, SIZE CHANGE SITUATION, CARAZINHO AND NAO ME TOQUE, R.G.S., 1969

	Non-Mechanized			Mechanized		
	Effect	Coefficient	Units	Effect	Coefficient	Units
Hectares/Man	.241	.388	81.51	.353	.485	197.44
Crop Expenses/Man	.167	.107	1.013	.257	.234	.791
Machine Cost/Man	.286	.225	2.757	.232	.261	1.026
Livestock Investment/Man	.006[d]	.060[c]	.118	-.004[d]	-.023[c]	-.259
Livestock Expense/Man	.044	.049[b]	2.094	-.001[d]	.006[c]	.462
Constant (Intercept)		4.438			3.865	
Mean of Y		7.825			9.291	
Standard Error of Y		.603			.741	
R^2		.7433			.8384	
Standard Error of Regression		.316			.308	

[a]Not significant at .05 but at .10.

[b]Not significant at .10 but at .20.

[c]Not significant at .20.

[d]Standard error of regression increased when variable entered.

TABLE 14

COEFFICIENTS AND RELATED STATISTICS OF LOGARITHMIC LEAST SQUARES REGRESSION ANALYSIS, PRODUCTION EFFICIENCY,[a] SIZE CHANGE SITUATION, CARAZINHO AND NAO ME TOQUE, R.G.S., 1969

	Non-Mechanized			Mechanized		
	Effect	Coefficient	Units	Effect	Coefficient	Units
Size (Hectares)	(n.e.)[b]			-.045	.121[c]	.0011
Crop Expenses/Ha.	.002	-.014[e]	-.0006	.010	.039[e]	.0003
Machine Cost/Ha.	.024	-.117	-.0073	.044	.119[d]	.0010
Livestock Investment/Ha.	-.045	-.237	-.0023	.015	.028[e]	.0007
Livestock Expense/Ha.	.006	.042[d]	.0091	.005	.006[e]	.0020
Labor/Ha. (Man Equivalents)	.457	.566	7.2012	.245	.262	6.0444
Constant (Intercept)		2.888			-.726[d]	
Mean of Y	.069			-.236		
Standard Error of Y	.396			.289		
R^2	.4441			.2734		
Standard Error of Regression	.305			.257		

[a]Lower values imply higher levels of efficiency.

[b]Variable was below .01 minimum F-level and did not enter model.

[c]Not significant at .05 but at .10.

[d]Not significant at .10 but at .20.

[e]Not significant at .20.

Employment could also have been increased on the non-mechanized farms by expanding the livestock enterprises. The increase in employment would, on the average, have been .404 percent for each 1 percent increase in the livestock investment.

Size had a negative effect on employment among both the mechanized and non-mechanized observations. A 1 percent size increase would have been expected to result in .37 and .59 percent decreases respectively in employment per hectare among the two types of observations. Yet due to the differences in sizes and levels of employment, a much larger quantity of labor was released (.1168 versus .0221 man equivalents per hundred hectares) when the non-mechanized farms were increased by one hectare as contrasted to the same increase among the mechanized observations. This undoubtedly stems in part from some "normal" amount of family labor being available on most farms independent of size and need, and the inability to adequately distinguish this available labor from what was actually utilized. Figure 6 is presented as an aid in visualizing and understanding the relationships between the size, labor, and mechanization variables among the Size Change observations.

2. Land Productivity. Machine cost is the most important variable explaining the variation in land productivity among the non-mechanized observations and is second only to crop expenses among the mechanized observations (Table 12). The non-mechanized farmers, on the average, could have increased their production .225 percent by increasing their machine inputs (costs) by 1 percent. In monetary units this is a Cr$2.76 return for each additional cruzeiro of cost incurred. The

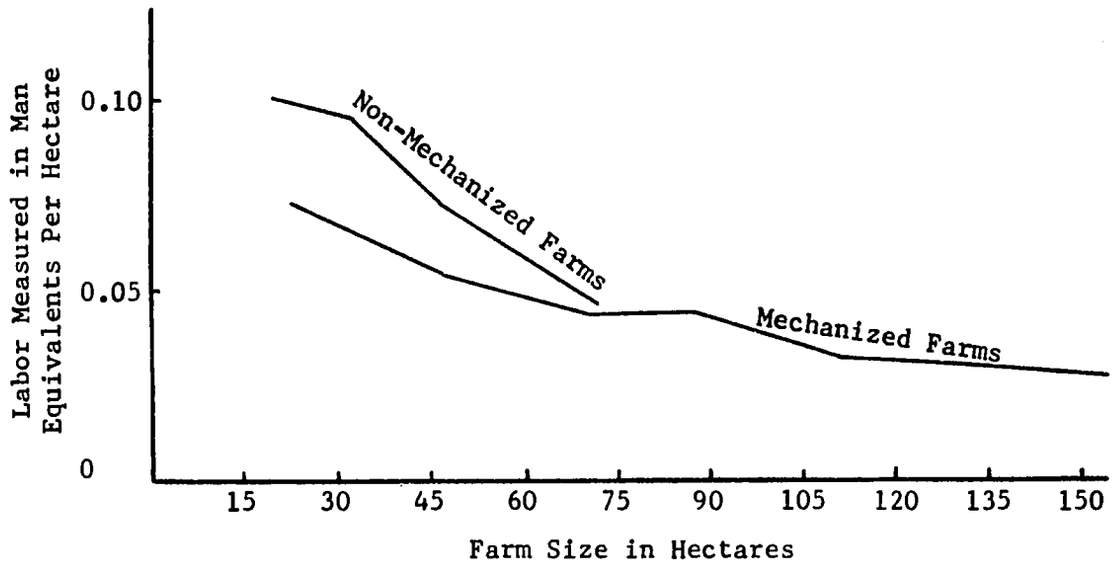

Figure 6.--Relationship Between Size, Labor, and Mechanization, Size Change Situation, Carazinho and Nao Me Toque, R.G.S., 1969

mechanized farmers, however, had evidently passed the point of profit maximization (where the marginal return of mechanization was equal to its marginal cost). By increasing their machine inputs above the existing level, they could have expected a return of only Cr$.66 per cruzeiro of machine cost incurred.

At the existing levels of prices and input combinations, both sets of farmers, on the average, could have increased their profits only slightly by spending more on fertilizer, lime, seed, etc., and, while it appears the non-mechanized farmers could have increased their land productivity by expanding their size, livestock enterprises, and labor inputs, these increases would have been small.

3. Labor Productivity. The land, crop expense, and machine cost variables explain a large proportion of the variation in labor productivity. Machine inputs again appeared to have offered the largest return on the non-mechanized farms. (For each additional cruzeiro of machine cost incurred, a Cr$2.76 return should have followed.) The product of additional machine inputs per man equivalent on mechanized farms was approximately equal to its cost.

Labor productivity could have generally been increased on the mechanized farms by expanding the sizes of the farms further. Land was a limiting input and would have yielded an 18.5 percent annual marginal return (based on the average land value given by the mechanized observation farmers). Additional land investments would have returned 9.34 percent annually to the non-mechanized farmers.

4. Production Efficiency. While much of the variations in production efficiency was left unexplained, labor is by far the most important variable in both regressions (Table 14). The coefficients, however, indicate efficiency decreased as the labor input was increased. A 1 percent increase in labor decreased efficiency by .57 and .26 percent among the non-mechanized and mechanized observations respectively. Stated in physical units, increasing the amount of labor per hectare by .01 man equivalents (3 man days per year) would have decreased production efficiency (raised the cost/output ratio) by .07 and .06.

A 1 percent increase in machine inputs would have increased efficiency .12 percent in the non-mechanized sample and decreased it by an equal amount in the mechanized sample.

These results are consistent with what was observed in the land and labor productivity models and support the premise that some "normal" amount of family labor was available on most farms independent of size and need.

Summary

Among the observations selected to characterize the Size Change situation, mechanization was associated with higher levels of land productivity, labor productivity, and production efficiency. The relationship between mechanization and employment is not as clear.

The amount of labor employed per hundred hectares was observed to be 4.18 and 9.89 man equivalents on the mechanized and non-mechanized farms respectively. When the influence of size was isolated, the difference was reduced by one-third to 3.82 man equivalents per hundred

hectares. Further, the results of the regression analysis indicate that employment on the non-mechanized farms could have been increased substantially by adding additional machine inputs. On the mechanized farms, however, the machine cost coefficient in the model, although not significant, is negative and probably indicates machine inputs had been applied beyond the range where mechanization can lead to higher levels of employment.

Land productivity, labor productivity, and production efficiency were all observed to be significantly higher for the mechanized observations. Isolating the influence of size, while narrowing or widening the differences between the two types of farms, did not alter what was observed originally.

In addition to increasing levels of employment, the non-mechanized farmers could have greatly enhanced their land and labor productivities and production efficiency by employing additional machine inputs. One cruzeiro spent on machine inputs would have been expected to return Cr$2.76 on the margin. The mechanized farmers, on the contrary, had apparently gone slightly beyond the point where a profit would be returned from additional machine inputs.

These results strongly suggest that tractor owners should have seriously considered performing some custom hire services and the non-mechanized farmers should have considered even more seriously hiring these machine services. Both types of farmers stood to benefit, particularly the non-mechanized. Society, too, stood to gain through additional employment, increased land and labor productivity, and higher production efficiency.

CHAPTER VI

MECHANIZATION ACCOMPANIED BY CHANGES IN FARM ENTERPRISE

Two separate sets of observations are used to determine the effects of mechanization in the Enterprise Change situation. The observations included in the Enterprise Change #1 category came from the municipios of Carazinho and Nao Me Toque. Observations from the municipio of Sao Borja constitute the Enterprise Change #2 category. Agricultural mechanization in this latter municipio and surrounding region is generally accompanied by a fundamental change in farm organization from extensive cattle grazing on open range land to crop farming. The same fundamental change accompanies mechanization on the largest farms in the region that includes Carazinho and Nao Me Toque. Wheat is the principal crop on these farms with soybeans being produced in Carazinho and Nao Me Toque, and rice, sunflowers, and flax in Sao Borjo. Since many of the farms are too large to effectively crop the total area, combinations of crop and livestock enterprises often exist on the same farm. In the wake of mechanization, improved pasture has been introduced and has grown in importance.

Sample Description and Comparison

The examination of mechanization in the Enterprise Change situation begins by delineating the two sets of observations into groups according

to tractor ownership, rice acreage, and per hectare machine costs.[1] The means of variety of input and production variables are presented in Tables 15 and 16 for each of the groups. These statistics, while serving to characterize the observation farms, also provide a basis for comparing the various groups.

Comparison of the means in Tables 15 and 16 generally indicates that in the Enterprise Change situation agricultural mechanization (1) results in rather sizable increases in land and labor productivity, (2) is compatible with higher levels of employment, and (3) has an initial positive influence in production efficiency. The principal element responsible for these favorable results appears quite definitely to be the much more intensive land-use practices that accompany mechanization in this situation.

1. Enterprise Change #1. Two-thirds of the land farmed by the mechanized Enterprise Change observations in Carazinho and Nao Me Toque was in crops or improved pasture. This contrasts with one-fourth in the case of the non-mechanized observations. The intensity at which land was used on the mechanized farms increased with added machine inputs and was enhanced further through the double cropping of wheat and soybeans.

Accompanying the higher land-use intensities were higher capital requirements. On a per hectare basis, the non-land investments, the expenses, and the borrowings of the mechanized farmers were two, three, and thirteen times greater than those of the non-mechanized observations. The land investments of the mechanized farmers were, however,

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[1]Persons having more than 20 percent of their land or 100 hectares in rice are considered to be rice farmers.

TABLE 15

AVERAGE VALUES OF SELECTED INPUT VARIABLES AND PRODUCTIVITY MEASURES, ENTERPRISE CHANGE SITUATION #1, CARAZINHO AND NAO ME TOQUE, R.G.S., 1969

Item	Farm Type and Machine Cost Per Hectare[a]				
		Mechanized			
	Non-Mechanized[c]	Up to Cr$50	Cr$50 to Cr$100	Cr$100 or More	Total
Number of Observations	11	11	14	9	34
Land (Hectares)					
Owned	90.4	550.2[d]	261.6	48.0[d]	298.5[d]
Operated	105.1	592.0	434.2	275.6	443.3
Cultivated Land and Improved Pasture	24.4[d]	289.7	270.2	252.9	272.0
Land-Use Intensity	0.25	0.55	0.65	0.89	0.68
Crop Areas[b]					
Wheat	7.2	151.6	195.1	230.3	190.3
Soybeans	4.7	76.6	166.5	205.6	147.8
Others	11.7	49.2	16.6	26.8	29.8
Labor (Man Equivalents)					
Family	0.98	1.36	1.67	1.52	1.53
Hired	0.38[d]	2.56[d]	3.26	3.50	3.08
Total	1.36	3.92	4.93	5.02	4.63
Total Per Hectare	0.019	0.009	0.015	0.023	0.015

TABLE 15--Continued

Item	Farm Type and Machine Cost Per Hectare[a]				
	Non-Mechanized[c]	Mechanized			
		Up to Cr$50	Cr$50 to Cr$100	Cr$100 or More	Total
Capital (Cr$[a])					
Investment					
Draft Livestock	918	645[d]	400[d]	122[d]	405[d]
Production Livestock	9,051[d]	34,069[d]	11,532[d]	2,168	16,344[d]
Non-Mechanized Equipment	1,123[d]	1,053	931[d]	3,226[d]	1,578[d]
Mechanized Equipment	106[d]	63,545	105,009	111,522	93,315
(Tractor Horsepower)	0	145	196	190	178
Total Non-Land Investments[e]	14,954	109,166	132,014	140,260	126,805
Total Non-Land Investment Per Hectare[e]	186	193	338	594	359
Land and Buildings	91,236	262,909	235,893[d]	90,089	206,038[d]
Total Investment[e]	106,190	372,075	367,907	230,349	332,843
Expenses					
Livestock	509[d]	1,401[d]	561[d]	176[d]	731[d]
Machinery	664[d]	10,959	17,182	25,970	17,495
Machine Rent	175[d]	445[d]	562[d]	2,234[d]	967[d]
Crop	865[d]	27,766	42,970	39,444	37,118
Hired Labor	753[d]	4,890[d]	5,334	6,577	5,519
Total[f]	3,844	52,802	75,675	83,512	70,349
Total Per Hectare[f]	56[d]	90	179	294	181
Credit					
Loans and Time Purchases Received During Year	1,194	38,967[d]	72,466	80,008[d]	63,625

TABLE 15--Continued

Item	Farm Type and Machine Cost Per Hectare[a]				
		Mechanized			
	Non-Mechanized[c]	Up to Cr$50	Cr$50 to Cr$100	Cr$100 or More	Total
Production (Cr$[a])					
Total Farm Output	7,342	97,942	137,113	140,886[d]	125,439
Total Per Hectare	79	172	313	466	308
Total Per Man Equivalent of Hired and Family Labor	5,116	26,030	27,188	24,702	26,155
Wheat Yield (Kilograms Per Hectare of Crop)	580 (5)	976 (11)	1,197 (14)	1,042 (9)	1,084 (34)
Efficiency[g]	0.80	0.67	0.69	0.76	0.70
Net Income	4,787[d]	28,968[d]	44,542[d]	38,032[d]	37,780[d]

[a]One Brazilian cruzeiro (Cr$) exchanged for U.S. $.23 at the time the interviews were taken.

[b]The "cultivated land and improved pasture" is not expected to equal the summation of the "crop areas" since (1) the former was measured at the time of the interview while the latter represents the year being studied, (2) double cropping is sometimes practiced and (3) improved pasture is not included in the latter.

[c]Only two of the non-mechanized observations had per hectare machine costs of Cr$25 or more.

[d]Standard deviation exceeds mean (standard deviation was not derived for "crop areas" or yields).

[e]Includes investment in vehicles not itemized above.

[f]Includes real estate taxes and improvement expenditures, crop insurance, cooperative membership fees, etc. not itemized above.

[g]Non-land cost divided by farm output plus custom machine receipts (small values are preferred).

TABLE 16

AVERAGE VALUES OF SELECTED INPUT VARIABLES AND PRODUCTIVITY MEASURES, ENTERPRISE CHANGE SITUATION 02, SAO BORJA, R.G.S., 1969/70

Item	Farm Type and Machine Cost Per Hectare[a]							
	Non-Mechanized[c]	Mechanized				Mechanized Rice		
		Up to Cr$50	Cr$50 to Cr$100	Cr$100 or More	Total	Up to Cr$200	Cr$200 or More	Total
Number of Observations	58	16	21	8	45	8	7	15
Land (Hectares)								
Owned	444.0[d]	1,401.0	354.5[d]	82.5[d]	678.0[d]	747.3[d]	11.1[d]	403.7[d]
Operated	405.4[d]	1,908.9	551.6	346.5	997.8[d]	948.5[d]	232.6	614.5[d]
Cultivated Land and Improved Pasture	9.5	515.7	278.0[d]	286.1	364.0	310.2	210.9	263.8
Land-Use Intensity	0.04	0.30	0.54	0.64	0.51	0.62	0.85	0.73
Crop Areas[b]								
Wheat	3.7	312.9	251.8	254.0	273.9	96.3	51.0	75.2
Rice	.4	13.7	4.9	14.0	9.6	152.9	108.6	132.2
Others	3.6	104.6	67.8	48.2	77.4	23.0	.6	12.5
Labor (Man Equivalents)								
Family	1.53	1.54	1.64	1.89[d]	1.65	1.83	1.33	1.59
Hired	0.61	6.23	4.41[d]	3.65[d]	4.92	10.86	5.95	8.57[d]
Total	2.15	7.76	6.05	5.54	6.57	12.70	7.27	10.17
Total Per Hectare	0.010	0.006	0.013	0.015	0.011	0.023	0.049	0.035

TABLE 16--Continued

Item	Farm Type and Machine Cost Per Hectare[a]							
	Non-Mechanized[c]	Mechanized				Mechanized Rice		
		Up to Cr$50	Cr$50 to Cr$100	Cr$100 or More	Total	Up to Cr$200	Cr$200 or More	Total
Capital (Cr$[a])								
Investment								
Draft Livestock	2,468[d]	5,589[d]	1,307[d]	188[d]	2,631[d]	1,250[d]	294[d]	804[d]
Production Livestock	63,535[d]	208,872	32,338[d]	4,885	90,225[d]	89,614[d]	4,981[d]	50,119[d]
Non-Mechanized Equipment	852[d]	2,087[d]	1,905[d]	2,900	2,147[d]	1,980[d]	5,767[d]	3,747[d]
Mechanized Equipment	210[d]	127,019	104,502	124,941	116,142	165,988	119,571	144,327
(Tractor horsepower)	0	171	163	181	169	284	148	220
Total Non-Land Investments[e]	71,178[d]	368,491	157,038	152,970	231,498	273,706[d]	144,614	213,463[d]
Total Non-Land Investment Per Hectare[e]	161	207	326	428	302	396	652	515
Land and Buildings	148,116[d]	538,275[d]	147,950[d]	58,459[d]	270,823[d]	95,375[d]	30,943[d]	65,307[d]
Total Investment[e]	219,294[d]	906,766	304,987	211,429	502,317[d]	369,081	175,557	278,770
Expenses								
Livestock	1,024[d]	4,386[d]	1,736[d]	336[d]	2,430[d]	16,790[d]	105[d]	944[d]
Machinery	699[d]	26,443	19,649	29,275	23,776	23,478	47,412	29,980
Machine Rent	272[d]	3,084[d]	4,158	813[d]	3,182[d]	5,000[d]	1,083[d]	3,172[d]
Crop	412[d]	38,306	32,455[d]	30,542	34,195	32,364	23,257	28,114
Hired Labor	1,098[d]	11,361[d]	7,877[d]	6,592[d]	8,887[d]	24,308[d]	12,593	18,842[d]
Total[f]	4,654[d]	91,925	73,378[d]	70,027	79,377	118,890	75,175	98,490
Total Per Hectare[f]	12[d]	56	134	195	117	213	376	289
Credit								
Loans and Time Purchases Received During Year	2,633[d]	116,277	77,319	82,860	92,156	95,019	68,996	82,875

TABLE 16--Continued

Item	Farm Type and Machine Cost Per Hectare[a]							
	Non-Mechanized[c]	Mechanized				Mechanized Rice		
		Up to Cr$50	Cr$50 to Cr$100	Cr$100 or More	Total	Up to Cr$200	Cr$200 or More	Total
Production (Cr$[a])								
Total Farm Output	15,768[d]	217,084	135,606	142,668	165,832	239,827	128,174	187,722
Total Per Hectare	46	128	260	409	240	407	696	542
Total Per Man Equivalent of Hired and Family Labor	7,507	33,953	24,085	31,740	28,955	19,468	21,442	20,390
Wheat Yield (Kilograms Per Hectare of Crop)	694 (8)	1,153 (16)	1,072 (21)	1,129 (8)	1.111 (45)	998 (6)	962 (3)	986 (9)
Efficiency[g]	0.68	0.52	0.73	0.63	0.64	0.64	0.73	0.68
Net Income	14,861[d]	76,506	30,605	11,764	43,576[d]	56,860[d]	8,394[d]	34,243[d]

[a]One Brazilian cruzeiro (Cr$) exchanged for U.S. $.22 at the time the interviews were taken.

[b]The "cultivated land and improved pasture" is not expected to equal the summation of the "crop areas" since (1) the former was measured at the time of the interview while the latter represents the year being studied and (2) improved pasture is not included in the latter.

[c]Only three of the non-mechanized observations had per hectare machine costs of Cr$25 or more.

[d]Standard deviation exceeds mean (standard deviation was not derived for "crop areas" or yields).

[e]Includes investment in vehicles not itemized above.

[f]Includes real estate taxes and improvement expenditures, crop insurance, cooperative membership fees, etc. not itemized above.

[g]Non-land cost divided by farm output plus custom machine receipts (small values are preferred).

lower due to the importance of renting. On the smaller, highly mechanized observation farms, almost all of the land was rented; an indication that some farm operators were getting started in agriculture by investing personal resources in machinery while acquiring land through renting.

Hired labor was much more important on the mechanized than on the non-mechanized observation farms. As a group, however, the mechanized farms absorbed about 20 percent less family and hired labor per hectare than the non-mechanized farms. Yet within the group of mechanized observations, the amounts of labor absorbed per hectare increased as the level of mechanization increased. The most highly mechanized farms employed 20 percent more family and hired labor than the non-mechanized farms.[2]

Higher levels of productivity resulted from the higher levels of inputs accompanying mechanization. Yields, land productivity, and labor productivity were approximately two, four, and five times greater on the farms where tractors were owned. The tractor owners were slightly more efficient and enjoyed net incomes eight times larger than the non-mechanized farmers. As higher levels of machine inputs were reached, however, efficiency decreased.

2. Enterprise Change #2. Even though the farms are generally substantially larger, many of the differences and relationships noted in

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[2]The inconsistency that shows up here may have arisen from the labor measurement problem discussed in Chapter IV. Some of the labor that was included, although available, may not have been fully utilized, especially on the smaller, non-mechanized farms where little or no outside labor was hired.

the Enterprise Change #1 data set are also observed among the Sao Borja observations.

The level of land-use intensity showed significant increases as mechanization was increased among the observation farms of the #1 data set. This increase is even larger among the observations of the Enterprise Change #2 data set. On the non-mechanized farms, 4 percent of the land was used for the production of crops and improved pasture. This is contrasted to 51 percent on the mechanized farms and 84 percent on the most highly mechanized farms.

Higher capital requirements accompanied the more intensive uses. While non-land investment differences between the mechanized and non-mechanized farms were small due to the livestock inventory of the latter, differences in expenses and the usage of credit on a per hectare basis were quite large. The magnitudes of these differences were ten and fourteen times respectively.

Contrary to what was observed in the #1 data set, mechanized farmers in the Enterprise Change #2 sample employed 10 percent more family and hired labor per hectare than their non-mechanized counterparts, which suggests the rather dramatic increase in land-use intensity resulting from the change in enterprises created an expansion effect that more than offset the substitution effect of mechanization for labor. Additionally, as machine inputs were increased on the mechanized farms, much larger quantities of labor were absorbed.

Higher levels of production resulted from the greater quantity of capital and labor inputs. Yields were 60 percent higher and labor and land productivity were approximately four and five times higher on the

mechanized farms. Among the mechanized observations, land productivity increased substantially as the level of mechanization increased. More than a threefold difference is noted between the lowest and most highly mechanized groups.

While the mechanized farmers on the average had net incomes three times larger than the non-mechanized producers, a closer examination of these and the efficiency statistics in Table 16 generates a number of questions: i.e., Are those farmers who are incurring the higher machine costs over mechanized? Is much of the profit being transferred to the landowners through rent payments? or Is the complementarity between the livestock and crop enterprises responsible for the high income and efficiency levels noted in the mechanized group incurring machine costs of less than Cr$50/hectare?

The quantity of capital and labor inputs employed in producing rice under irrigated conditions is considerably higher than the quantity normally needed to produce wheat and higher still than the quantity used in producing livestock under range conditions. For this reason the rice farmers were separated from the other observations in the Enterprise Change #2 data set. The input and production statistics (means) presented for the other observations are also presented for the fifteen rice farmers included in the sample. These statistics provide an opportunity to take a glimpse at mechanization in a more intensive setting.[3]

Although the average size of the fifteen rice farms was quite large (615 hectares), three-quarters of the acreage was in crops and improved

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[3]The mechanized rice observations are not included in the covariance analysis and least squares regression analysis.

pasture (versus 51 percent on the other mechanized farms and 4 percent on the non-mechanized farms). In addition to rice, 60 percent of the mechanized rice farmers also grew wheat and a majority raised livestock.

Land rental was important, particularly among those rice farmers incurring the machine costs of Cr$200 or more per hectare, where less than 5 percent of the land was owned.

The higher levels of capital and labor inputs of the mechanized rice farms are revealed in Table 16. Per hectare credit usage, expenses, and non-land investments were one-third to two-and-one-half times larger than on the other mechanized farms. The amount of labor employed per hectare on these more intensive operations exceeded the amounts absorbed on the other mechanized and non-mechanized farms by three and three-and-one-half times respectively. Eighty-five percent of the labor was hired on the mechanized rice farms.

Higher land productivity levels but slightly lower levels of labor productivity accompanied the extra capital and labor inputs on the mechanized rice farms. Land productivity was two-and-one-quarter times greater for the mechanized rice farmers than for the other mechanized farmers.

The net incomes of the mechanized rice farmers, while being 2.3 times larger but 22 percent smaller on the average than the net incomes of the non-mechanized farmers and the other mechanized farmers, showed a great amount of variation. This variation again raises the questions about over-mechanization, profit transfers via rental charges, and complementarity between crop and livestock enterprises.

Covariance Analysis

The coefficients and related statistical results of the covariance analysis models for the Enterprise Change #1 and Enterprise Change #2 observations are presented in Tables 17 and 18. These models, which make it easier to observe and measure the relationships between agricultural mechanization and the dependent variables by removing or isolating the influence of farm size, produced results that, with one possible exception, are generally consistent with those noted in the preceeding tabular analysis. The possible exception is the relationship between mechanization and production efficiency. While this relationship initially appeared positive, the tractor ownership coefficient is not significant in the efficiency models for either of the Enterprise Change data sets.

The basic results of the models indicate that agricultural mechanization yielded rather sizable increases in land and labor productivity and was quite compatible with higher levels of employment. Much higher land-use intensity levels were made possible by mechanization in this situation and were responsible for the results.

While the tractor ownership coefficient is not significant in the labor model for the #1 data set, it is in the second and implies that on the average, adjusting for size, the mechanized farms employed 38 percent more man equivalents of family and hired labor per hectare than the non-mechanized farms. (The fifteen mechanized rice farms which apparently absorbed much higher levels of labor were not included in this analysis).

TABLE 17

COEFFICIENTS AND RELATED STATISTICS OF THE COVARIANCE ANALYSIS MODELS, ENTERPRISE CHANGE SITUATION #1, CARAZINHO AND NAO ME TOQUE, R.G.S., 1969

	Labor Per 100 Hectares	Output Per Hectare	Output Per Man Equivalent	Production Efficiency	Land-Use Intensity
	(Coeff.)	(Coeff.)	(Coeff.)	(Coeff.)	(Coeff.)
Tractor Ownership (Mechanized/ Non-Mechanized)	.0168[c]	126.6	7,874	-.04104[c]	.23941
Size (Hectares)	-.0015	-.076[c]	16.56	-.00019	-.00021
Intercept	2.148	215	10,942	.8275	.5347
Mean of Y	1.621	257	21,241	.735	.591
Standard Error of Y	.985	164	17,572	.222	.255
R^2	.3075	.3681	.3756	.1719	.5305
Standard Error of Y·X	.839	133	14,220	.206	.179

[a]Not significant at .05 but at .10.

[b]Not significant at .10 but at .20.

[c]Not significant at .20.

TABLE 18

COEFFICIENTS AND RELATED STATISTICS OF THE COVARIANCE ANALYSIS MODELS, ENTERPRISE CHANGE SITUATION #2,[a] SAO BORJA, R.G.S., 1969/70

	Labor Per 100 Hectares	Output Per Hectare	Output Per Man Equivalent	Production Efficiency	Land-Use Intensity
	(Coeff.)	(Coeff.)	(Coeff.)	(Coeff.)	(Coeff.)
Tractor Ownership (Mechanized/ Non-Mechanized)	.16368	110.4	9,531	.01626[d]	.25986
Size (Hectares)	-.00044	-.049	4.166	-.00012	-.00010
Intercept	1.367	178	15,272	.737	.348
Mean of Y	1.038	133	17,113	.648	.254
Standard Error of Y	.713	134	17,503	.449	.295
R^2	.2705	.6134	.4126	.0491	.7008
Standard Error of Y·X	.615	84	13,553	.443	.163

[a]Does not include 15 mechanized rice farms.

[b]Not significant at .05 but at .10.

[c]Not significant at .10 but at .20.

[d]Not significant at .20.

Mechanized farmers, according to the coefficients, produced Cr$253 and Cr$221 more output per hectare and Cr$15,748 and Cr$19,062 more output per man than those farmers not owning tractors in the Enterprise Change #1 and #2 data sets respectively. The land productivity differences are slightly larger and the labor productivity differences slightly smaller than those observed without isolating the influence of size. The differences between the mechanized and non-mechanized observations with respect to land-use intensities are also slightly larger than those noted when the influence of size was not isolated.

Regression Analysis

Respecifying the principal independent variable as annual machine cost, the relationships between mechanization and employment, land and labor productivity, and efficiency are examined for the mechanized observations in the Enterprise Change #1 data set and for the non-mechanized and mechanized observations in the Enterprise Change #2 data set. Due to their differences and the analytical technique being used, these three groups of observations are examined separately. The non-mechanized observations of the first data set and the mechanized rice farms of the second are not analyzed by regression since they number only eleven and fifteen respectively.

The results of the least squares regression analysis in the Enterprise Change situation indicate that on the average (1) employment was increased on the mechanized farms when additional machine inputs were used and (2) land and labor productivity increased on the mechanized and non-mechanized farms when additional machine inputs (jointly with

additional crop inputs) were applied. A sizable profit potential existed and should have encouraged the heavier use of machine, crop, and labor inputs.

1. Employment. Machine cost is the most important variable explaining the variation in the levels of employment among both sets of mechanized farms (Table 19). The coefficients being positive imply that, on the average, increasing per hectare machine inputs (costs) by one cruzeiro would have resulted in the addition of approximately three man days of labor per hundred hectares (one year of 300 work days x .0102 = 3.06 days, and 300 x .0085 = 2.55 days). Likewise, a ten cruzeiro increase in machine inputs would have generated thirty days of employment, etc. on the mechanized farms. Among the non-mechanized observations, none of the variation in employment is explained by machine inputs, and the coefficient is not significant.

Crop expenses, although showing no importance in any of the employment regressions for the three groups of observations, are highly correlated with machine cost.[4] This correlation suggests crop and machine inputs would have needed to expand simultaneously to have increased employment.

Farm size is the most important and second most important independent variable with respect to the level of employment in the non-mechanized and mechanized farms. In all instances the relationship is

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[4]The correlation coefficients between the crop expense and machine cost variables on a per hectare basis are .66, .82, and .76 respectively for the three groups as they appear in Tables 19 through 22. On a per man equivalent basis, the coefficients are .75, .82, and .84.

TABLE 19

COEFFICIENTS AND RELATED STATISTICS OF LINEAR LEAST SQUARES REGRESSION ANALYSIS, LABOR PER 100 HECTARES, ENTERPRISE CHANGE SITUATIONS, CARAZINHO AND NAO ME TOQUE, R.G.S., 1969 AND SAO BORJA, R.G.S., 1969/70

	Enterprise Change Situation #1		Enterprise Change Situation #2			
	Mechanized		Non-Mechanized		Mechanized	
	Effect	Coefficient	Effect	Coefficient	Effect	Coefficient
Size (Hectares)	.280	-.0012	.272	-.0007	.153	-.0002[b]
Crop Expenses/Ha.	-.014[d]	-.0010[c]	(n.e.)[e]		-.076[d]	-.0041[c]
Machine Cost/Ha.	.298	.0102	-.001[d]	-.0032[c]	.287	.0085
Livestock Investment/Ha.	-.015	.0069[c]	.012	.0013[c]	.045[d]	-.0022[c]
Livestock Expense/Ha.	.031	.1026[c]	.002[d]	.0059[c]	.103	.0544
Constant (Intercept)		.9642		1.1011		.8581
Mean of Y	1.509		.991		1.090	
Standard Error of Y	.962		.735		.669	
R^2	.5802		.2861		.5119	
Standard Error of Regression	.6766		.6458		.504	

[a]Not significant at .05 but significant at .10.

[b]Not significant at .10 but significant at .20.

[c]Not significant at .20.

[d]Standard error of regression increased when variable entered.

[e]Variable was below .01 minimum F-level and did not enter model.

negative; as size increased, employment levels decreased. The decrease was largest among the mechanized observations of the #1 data set and was minimal for the mechanized observations of the second.

2. Land Productivity. A major proportion of the variation in land productivity is explained by crop expenses and machine costs (Table 20). These two independent variables are not considered separately, however, due to the fairly high levels of correlation that exists between them. On the average, a mechanized farmer in the Enterprise Change #1 or #2 data set could have expected a return of Cr$1.30 to Cr$1.50 for each cruzeiro spent on additional crop and machine inputs. The non-mechanized farmers, on the average, would have expected two cruzeiros or more to be returned for each cruzeiro they expended on these inputs.

Of the remaining independent variables, only livestock investment in the non-mechanized sample and labor in the #2 mechanized sample are important. The coefficients in both instances suggest that they were potentially profitable alternatives. Labor, in the latter instance, would have been expected to yield double its cost at the minimum wage rate.

3. Labor Productivity. Among the mechanized farms, much of the variation in labor productivity is attributable to different crop and machine input levels (Table 21). These variables have coefficients sufficiently larger than unity to make them very attractive. The amount of land operated by each man is also important in explaining the variation in labor productivity among the mechanized farms in the first data

TABLE 20

COEFFICIENTS AND RELATED STATISTICS OF LINEAR LEAST SQUARES REGRESSION ANALYSIS, OUTPUT PER HECTARE, ENTERPRISE CHANGE SITUATIONS, CARAZINHO AND NAO ME TOQUE, R.G.S., 1969 AND SAO BORJA, R.G.S., 1969/70

	Enterprise Change Situation #1		Enterprise Change Situation #2			
	Mechanized		Non-Mechanized		Mechanized	
	Effect	Coefficient	Effect	Coefficient	Effect	Coefficient
Size (Hectares)	-.027	.051[c]	.003[d]	-.0011[c]	-.021[d]	.0043[c]
Crop Expenses/Ha.	.417	1.53	.661	4.30	.098[d]	.598[c]
Machine Cost/Ha.	.350	1.27	-.043[d]	-.304[c]	.499	2.17
Livestock Investment/Ha.	.014[d]	-.170[c]	.116	.152	-.027[d]	.149[c]
Livestock Expense/Ha.	-.006[d]	1.49[c]	.024	1.47[c]	.005	-2.91[c]
Labor/Ha. (Man Equivalents)	.023[d]	967.08[c]	.029	607[a]	.124	4,323[b]
Constant (Intercept)		26.02[c]		5.99[c]		15.52[c]
Mean of Y	307.97		45.10		239.69	
Standard Error of Y	148.26		32.75		133.78	
R^2	.7712		.7898		.6779	
Standard Error of Regression	78.41		15.94		83.18	

[a]Not significant at .05 but significant at .10.

[b]Not significant at .10 but significant at .20.

[c]Not significant at .20.

[d]Standard error of regression increased when variable entered.

[e]Variable was below .01 minimum F-level and did not enter model.

TABLE 21

COEFFICIENTS AND RELATED STATISTICS OF LINEAR LEAST SQUARES REGRESSION ANALYSIS, OUTPUT PER MAN EQUIVALENT, ENTERPRISE CHANGE SITUATIONS, CARAZINHO AND NAO ME TOQUE, R.G.S., 1969 AND SAO BORJA, R.G.S., 1969/70

	Enterprise Change Situation #1		Enterprise Change Situation #2			
	Mechanized		Non-Mechanized		Mechanized	
	Effect	Coefficient	Effect	Coefficient	Effect	Coefficient
Land (Hectares)/Man	.188	62.79[a]	(n.e.)[e]		.057	11.55[c]
Crop Expenses/Man	.349	1.51	.180	3.22	.283	1.25
Machine Cost/Man	.281	1.87	-.025[d]	-.279[c]	.323	1.83
Livestock Investment/Man	.009[d]	.44[c]	.716	.179	.190	.344[b]
Livestock Expense/Man	-.001	-14.74[b]	.005[d]	.139[c]	-.037	-5.28[c]
Constant (Intercept)		-2,826.79		1,547		2,533
Mean of Y	26,155		7,507		28,955	
Standard Error of Y	17,028		6,304		18,567	
R^2	.8256		.8757		.8166	
Standard Error of Regression	7,720		2,312		8,569	

[a]Not significant at .05 but significant at .10.

[b]Not significant at .10 but significant at .20.

[c]Not significant at .20.

[d]Standard error of regression increased when variable entered.

[e]Variable was below .01 minimum F-level and did not enter model.

set, but does not appear to have offered returns as high as crop and machine inputs.

Among the mechanized observations in the second Enterprise Change data set, livestock investment is an important explanatory variable which offered a fairly sizable return. This same variable explains 72 percent of the variation in labor productivity on the non-mechanized farms. For the latter group of farms, however, crop and machine inputs (considering the high degree of correlation) appear to have offered a much better alternative for increasing labor productivity.

4. Production Efficiency. The results of the production efficiency regressions for the Enterprise Change data sets appear in Table 22. Beyond the observation that efficiency decreased on the non-mechanized farms as labor was added (at the minimum wage), there is little of economic relevance to be attained from these regressions. This lack of relevance is consistent with what was observed earlier, and suggests the measure of efficiency is not adequate in this situation.[5]

Summary

The Enterprise Change situation was examined in this chapter. Two data sets were used to analyze the effects of mechanization in this

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[5]One possible explanation for the inadequacy of the measure of efficiency [non-land costs ÷ (farm output and custom machine hire receipts)], is the very wide variation in the importance of land in the various input mixes. In an extensive range grazing enterprise, land would represent the principal cost, and consequently the "non-land costs" would be minimal. In an intensive crop enterprise, however, the "non-land costs" would be relatively large compared to the land costs and production. Thus, wide extremes in crop and livestock enterprise mixes would produce wide extremes in production efficiency ratios.

TABLE 22

COEFFICIENTS AND RELATED STATISTICS OF LINEAR LEAST SQUARES REGRESSION ANALYSIS, PRODUCTION EFFICIENCY, ENTERPRISE CHANGE SITUATIONS, CARAZINHO AND NAO ME TOQUE, R.G.S., 1969 AND SAO BORJA, R.G.S., 1969/70

	Enterprise Change Situation #1		Enterprise Change Situation #2			
	Mechanized		Non-Mechanized		Mechanized	
	Effect	Coefficient	Effect	Coefficient	Effect	Coefficient
Size (Hectares)	.148	-.00017	(n.e.)[e]		(F)[f]	
Crop Expenses/Ha.	(F)		.008[d]	-.0196[c]	.162	.00385
Machine Cost/Ha.	(F)		.003[d]	.0163[c]	(F)	
Livestock Investment/Ha.	(F)		.046	-.0019[a]	(F)	
Livestock Expense/Ha.	(F)		.005[d]	-.0145[c]	.020	.01235[c]
Labor/Ha. (Man Equivalents)	(F)		.269	40.035	(F)	
Constant (Intercept)		.7754		.577		.408
Mean of Y	.701		.680		.637	
Standard Error of Y	.170		.550		.311	
R^2	.1483		.3308		.1823	
Standard Error of Regression	.159		.473		.289	

[a]Not significant at .05 but significant at .10.

[b]Not significant at .10 but significant at .20.

[c]Not significant at .20.

[d]Standard error of regression increased when variable entered.

[e]Variable was below .01 minimum F-level and did not enter model.

[f]Variable was excluded from model because the F ratio of the regression fell below .05 when it was entered.

situation where large tracts of open range land have been brought into crop production through the use of tractors and mechanized equipment. The observations of both Enterprise Change data sets support what was observed in the Size Change situation (Chapter V) with respect to the very positive influence mechanization has on land and labor productivity. However, in the Enterprise Change situation where land is not limiting, mechanized farmers, on the average, would have been able to apply additional machine inputs at a profit. In both the Size Change and Enterprise Change situations, higher levels of machine inputs would have been expected to yield rather handsome returns on the non-mechanized farms.

While the mechanized farms in the Enterprise Change #1 sample had 20 percent fewer man equivalents of labor per land unit than the non-mechanized farms, a comparison of the mechanized farms having different levels of machine inputs suggests the likelihood of family labor redundancy on the non-mechanized farms. Labor and machine inputs increased simultaneously on the mechanized farms.

Among the observations of the second Enterprise Change sample, however, the expansion effect of mechanization clearly offset its substitution effect on labor. Employment levels were observed to be 10 and 350 percent higher on the mechanized and mechanized rice farms respectively than on the non-mechanized farms. Using covariance analysis to isolate the influence of size, the difference between the mechanized and non-mechanized farms rose to 38 percent. Machine inputs (costs) was the most important explanatory variable in the regressions pertaining to labor utilization among the mechanized farms in both Enterprise Change

samples. The coefficients of this variable, consistent with the above, indicated a positive relationship between labor and mechanization.

Production efficiency was observed to be slightly higher for the mechanized than for the non-mechanized farmers, but as machine inputs increased among the mechanized farmers, efficiency was observed to decrease. No meaningful results were obtained from the covariance and regression analysis models for production efficiency.

CHAPTER VII

MECHANIZATION ACCOMPANIED BY NEITHER CHANGES IN FARM SIZE NOR ENTERPRISES

Forty-five mechanized and 37 non-mechanized observations from the municipio of Turvo in Santa Catarina were selected to depict the No Change situation. Neither a change in farm size nor farm enterprise appears to accompany the adoption of mechanization on these rather small, partially irrigated, family-size operations. Both crops and livestock are produced, with rice, corn, tobacco, and cassava being the most important crops.

Sample Description and Comparison

The observations in the No Change sample were divided on the basis of tractor ownership and per hectare machine cost. A comparison of the mathematical means of various input and production variables for the sub-samples reveals that the influence of agricultural mechanization in this situation is generally small (Table 23).

Slightly higher levels of land and labor productivity are noted among the mechanized observations and apparently resulted from slightly more intensive land usage and from larger acreages.[1]

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[1]While the mechanized farms in this sample are 75 percent larger than the non-mechanized observations, renting (as noted in Table 23) and incremental land purchases are not part of the dynamics of the introduction of mechanization in the No Change situation.

TABLE 23

AVERAGE VALUES OF SELECTED VARIABLES AND PRODUCTIVITY MEASURES, NO CHANGE SITUATION, TURVO, S.C., 1969

Item	Farm Type and Machine Cost Per Hectare[a]						
	Non-Mechanized			Mechanized			
	Up to Cr$25	Cr$25 or More	Total	Up to Cr$50	Cr$50 to Cr$100	Cr$100 or More	Total
Number of Observations	20	17	37	5	22	18	45
Land (Hectares)							
Owned	38.7	22.9	31.4	126.9	65.9	29.8	58.2
Operated	38.5	24.0	31.8	112.9	62.4	31.0	55.4
Cultivated Land and Improved Pasture	15.8	13.7	14.8	35.4	29.8	20.6	26.8
Land-Use Intensity	0.44	0.68	0.54	0.35	0.51	0.70	0.57
Crop Areas[b]							
Corn	3.8	5.9	4.8	6.8	6.3	6.3	6.4
Rice	7.0	5.7	6.4	23.6	17.8	11.6	16.0
Others	4.2	1.8	3.1	2.4	4.4	1.7	3.1
Labor (Man Equivalents)							
Family	2.16	1.81	2.00	3.30	2.64	2.35	2.60
Hired	0.31[c]	0.37[c]	0.33[c]	0.88[c]	0.88[c]	0.38	0.68[c]
Total	2.47	2.18	2.33	4.18	3.52	2.73	3.28
Total Per Hectare	0.074	0.122	0.097	0.043	0.066	0.100	0.077

TABLE 23--Continued

Item	Farm Type and Machine Cost Per Hectare[a]						
	Non-Mechanized			Mechanized			
	Up to Cr$25	Cr$25 or More	Total	Up to Cr$50	Cr$50 to Cr$100	Cr$100 or More	Total
Capital (Cr$[a])							
Investment							
Draft Livestock	710	644[c]	680	610	548	492	532
Production Livestock	2,143	2,516	2,314	4,758	4,462	3,403	4,071
Non-Mechanized Equipment	785	783	784	244	788	668	680
Mechanized Equipment	340[c]	47[c]	205[c]	21,160	22,[illegible]08	21,141	21,939
(Tractor Horsepower)	0	0	0	49	51	43	47
Total Non-Land Investments[d]	4,152	4,430	4,280	29,372	30,261	29,955	30,040
Total Non-Land Investment Per Hectare[d]	116	207	158	292	528	1,086	725
Land and Buildings	53,300	38,918	46,692	94,400	83,277	55,583	73,436
Total Investment[d]	57,452	43,348	50,972	123,772	113,538	85,538	103,475
Expenses							
Livestock	115[c]	179[c]	144[c]	173	163	181[c]	171
Machinery	52	188[c]	114[c]	1,931[c]	1,504	2,830[c]	2,082[c]
Machine Rent	331	604	457	0	55[c]	165[c]	93[c]
Crop	621[c]	573	599[c]	1,106[c]	862[c]	726	835[c]
Hired Labor	426[c]	521[c]	470[c]	1,474[c]	1,197[c]	662	1,014[c]
Total[e]	2,148	2,682	2,393	7,166[c]	5,274	6,213	5,860
Total Per Hectare[e]	57	126	89	54	80	215	132
Credit							
Loans and Time Purchases Received During Year	2,010[c]	2,447[c]	2,211[c]	4,000	10,831[c]	8,964[c]	9,325[c]

TABLE 23--Continued

Item	Farm Type and Machine Cost Per Hectare[a]						
	Non-Mechanized			Mechanized			
	Up to Cr$25	Cr$25 or More	Total	Up to Cr$50	Cr$50 to Cr$100	Cr$100 or More	Total
Production (Cr$[d])							
Total Farm Output	6,832	6,668	6,757	16,049	13,101	10,649	12,528
Total Per Hectare	201	332	261	159	227	382	281
Total Per Man Equivalent of Hired and Family Labor	3,156	3,243	3,196	3,973	4,080	4,302	4,157
Corn Yield (Kgs./Ha. of Crop)	1,963 (19)	1,787 (17)	1,880 (36)	1,967 (5)	2,964 (21)	2,268 (17)	2,133 (43)
Rice Yield (Kgs./Ha. of Crop)	2,193 (20)	2,047 (16)	2,128 (36)	2,114 (5)	2,029 (22)	2,030 (18)	2,039 ([illegible])
Efficiency[f]	0.92	0.95	0.93	0.85	0.94	1.04	0.97
Net Income	4,428	3,928	4,198	5,685	3,940	1,834[c]	3,291[c]

[a]One Brazilian cruzeiro (Cr$) exchanged for U.S. $.23 at the time the interviews were taken.

[b]The "cultivated land and improved pasture" is not expected to equal the summation of the "crop areas" since (1) the former was measured at the time of the interview while the latter represents the year being studied and (2) improved pasture is not included in the latter.

[c]Standard deviation exceeds mean (standard deviation was not derived for "crop areas" or yields).

[d]Includes investment in vehicles not itemized above.

[e]Includes real estate taxes and improvement expenditures, crop insurance, cooperative membership fees, etc. not itemized above.

[f]Non-land cost divided by farm output plus custom machine receipts (small values are preferred).

Considerably higher capital requirements accompanied the slightly higher levels of productivity. The expenses, borrowings, and non-land investments of the mechanized farmers were one-and-one-half, two-and-one-half, and four-and-one-half times larger per hectare respectively than of the non-mechanized observations. These differences were almost entirely attributable to the mechanization itself. Consequently, the mechanized farmers ended up being slightly less efficient and having net incomes which were 22 percent below those of the non-mechanized farmers.

As machine inputs (costs) were increased among both the mechanized and non-mechanized observations, land productivity, land-use intensity, and of course capital requirements showed sizable increases. Due, however, to an inverse relationship between farm size and machine inputs in both the mechanized and non-mechanized groups, labor productivity was only slightly higher on the more highly mechanized farms in the two groups. Production efficiency and net incomes, while decreasing slightly on the non-mechanized farms, decreased by rather significant amounts on the mechanized farms when higher levels of machine inputs were reached.

A relationship between mechanization and employment is not immediately suggested by a comparison of the labor statistics in Table 23. While the mechanized farms absorbed 20 percent less labor than the non-mechanized farms, higher levels of machine inputs within both the mechanized and non-mechanized categories were associated with higher levels of employment.

These somewhat contradictory relationships are at least partially accounted for by size differences and the negative relationship between size and employment in this situation. This negative relationship is very apparent in Figure 7. Equally apparent is the slightly higher level of labor found on the mechanized farms than on the non-mechanized farms.

The rather strong negative relationship observed here between farm size and employment undoubtedly is due in part to some "normal" amount of labor being available on most farms independent of size and need.

Covariance Analysis

The results of the covariance analysis models (Table 24) indicate that an average of 25 percent more was produced per hectare and per man equivalent on the mechanized than on the non-mechanized farms when differences in sizes were accounted for. The level of intensity at which the land was used was 18 percent higher for the mechanized observations, and undoubtedly was responsible for some of the difference in the land and labor productivities. Tractor ownership had no significant effect on either employment or production efficiency.

Regression Analysis

Increasing the level of mechanization on the mechanized farms in the No Change situation would not affect employment, would not increase production by an amount sufficient to cover the added cost, and accordingly, would decrease production efficiency. An expansion of machine inputs in the case of the non-mechanized farms in this same situation, however, would increase production by an amount sufficient to return a

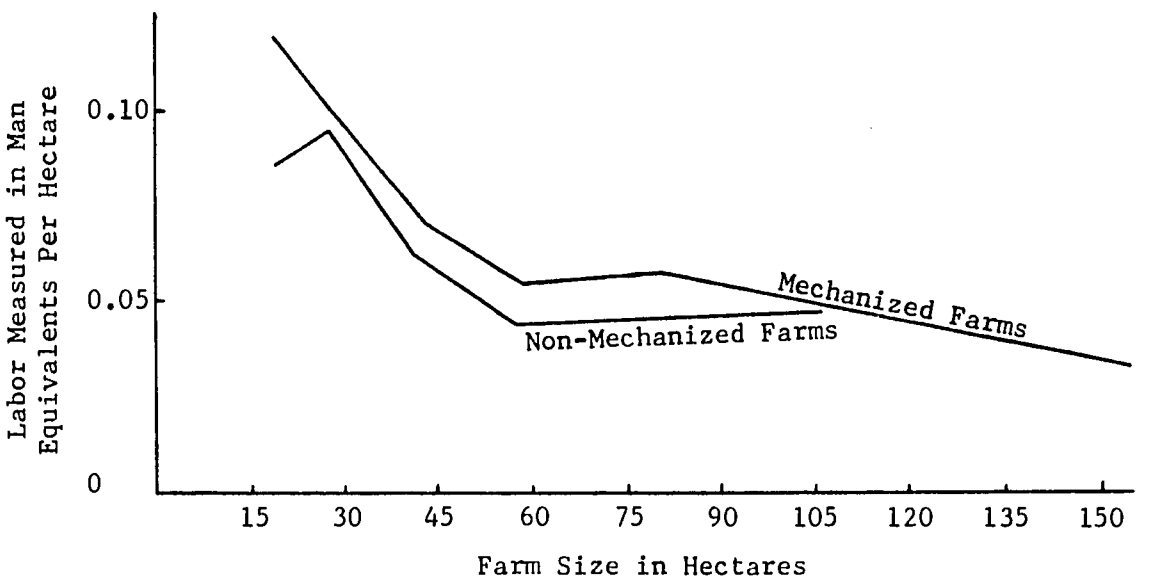

Figure 7.--Relationship Between Size, Labor, and Mechanization, No Change Situation, Turvo, S.C., 1969

TABLE 24

COEFFICIENTS AND RELATED STATISTICS OF THE COVARIANCE ANALYSIS MODELS, NO CHANGE SITUATION, TURVO, S.C., 1969

	Labor Per 100 Hectares	Output Per Hectare	Output Per Man Equivalent	Production Efficiency	Land-Use Intensity
	(Coeff.)	(Coeff.)	(Coeff.)	(Coeff.)	(Coeff.)
Tractor Ownership (Mechanized/ Non-Mechanized)	-.1883[c]	32.1	400	.0327[c]	.0454
Size (Hectares)	-.0663	-1.84	6.81[b]	-.0014[b]	-.0028
Intercept	11.53	351	3,379	1.009	.678
Mean of Y	8.544	272	3,723	.952	.556
Standard Error of Y	5.554	147	1,542	.333	.203
R^2	.2174	.2090	.1084	.0242	.2563
Standard Error of Y·X	4.975	133	1,570	.333	.1776

[a]Not significant at .05 but at .10.

[b]Not significant at .10 but at .20.

[c]Not significant at .20.

sizable profit and would likely have a positive effect on employment. These conclusions are based on the results obtained when mechanization was respecified as machine cost and analyzed in a least squares regression framework.

1. Employment. Mechanization explains none of the variation in employment among the mechanized farms but 9 percent in the case of the non-mechanized farms. And while the coefficient for the latter is fairly large and positive, it is not significant (Table 25).

Utilizing available land more intensively by expanding the investment in livestock and by increasing crop inputs would have led to higher levels of employment on the mechanized farms.

Size is by far the most important variable explaining the level of employment among both groups of farms. As would be expected from what was observed in Figure 7 however, the coefficients are negative, and the one for the non-mechanized observations is considerably larger. This again strongly suggests some labor was underemployed on many of these observation farms.

2. Land Productivity. While not being the most important variable, machine inputs (costs) are fairly important in explaining the variation in output per hectare among the mechanized and non-mechanized farms in the No Change data set (Table 26). The coefficients of this independent variable imply that, on the average, the mechanized farmer would have expected a return of only one-half the value of an additional machine input expenditure as contrasted to the non-mechanized farmer who would have expected a return of two-and-one-half times the amount he expended.

TABLE 25

COEFFICIENTS AND RELATED STATISTICS OF LOGARITHMIC LEAST SQUARES REGRESSION ANALYSIS, LABOR PER 100 HECTARES, NO CHANGE SITUATION, TURVO, S.C., 1969

	Non-Mechanized			Mechanized		
	Effect	Coefficient	Units	Effect	Coefficient	Units
Size (Hectares)	.464	-.678	-.2147	.322	-.421	-.0630
Crop Expenses/Ha.	(n.e.)[a]			.100	.152	.0843
Machine Cost/Ha.	.092	.183[d]	.0669	-.010[e]	-.028[d]	-.0020
Livestock Investment/Ha.	.055[e]	.105[d]	.0084	.169	.316	.0233
Livestock Expense/Ha.	-.040	-.057[d]	-.1723	-.024[e]	.039[d]	.1091
Constant (Intercept)		3.278			1.843[c]	
Mean of Y	2.081			1.887		
Standard Error of Y	.638			.550		
R^2	.5695			.5564		
Standard Error of Regression	.445			.390		

[a]Variable was below .01 minimum F-level and did not enter model.

[b]Not significant at .05 but at .10.

[c]Not significant at .10 but at .20.

[d]Not significant at .20.

[e]Standard error of regression increased when variable entered.

TABLE 26

COEFFICIENTS AND RELATED STATISTICS OF LOGARITHMIC LEAST SQUARES REGRESSION ANALYSIS, OUTPUT PER HECTARE, NO CHANGE SITUATION, TURVO, S.C., 1969

	Non-Mechanized			Mechanized		
	Effect	Coefficient	Units	Effect	Coefficient	Units
Size (Hectares)	(n.e.)[a]			.169	-.165[b]	-.999
Crop Expenses/Ha.	.123	.135[b]	2.28	.227	.167	3.75
Machine Cost/Ha.	.188	.245[b]	2.52	.118	.171	.495
Livestock Investment/Ha.	.015[e]	.029[d]	.065	.088	.141[b]	.420
Livestock Expense/Ha.	.090	.068[d]	5.77	.013	-.0125[d]	-1.41
Labor/Ha. (Man Equivalents)	.220	.317	890	.176	.192	777
Constant (Intercept)		4.911			4.902	
Mean of Y	5.415			5.566		
Standard Error of Y	.561			.428		
R^2	.6350			.7642		
Standard Error of Regression	.366			.225		

[a]Variable was below .01 minimum F-level and did not enter model.

[b]Not significant at .05 but at .10.

[c]Not significant at .10 but at .20.

[d]Not significant at .20.

[e]Standard error of regression increased when variable entered.

Readily derived from this is the conclusion that both sets of farmers would have been better off if the tractor owners would have rented machine services to the non-owners.

Crop expenses are important in both regressions and offered profit potentials well worth seeking. Labor is also an important explanatory variable, but on the contrary, did not offer a profit potential. The return on labor employed at the minimum wage rate would have covered approximately half its cost. (Again, as in the employment model, a surplus of labor is implied.)

3. Labor Productivity. In explaining the output per man equivalent, machine cost is the most important variable (Table 27). This is followed by the crop expense variable, and the coefficients of both variables for both sets of observations yield almost identical returns to those noted in the land productivity regressions. Land per man is also an important explanatory variable, but would only have offered about a 3 percent return on investment. Mechanized farmers would have been wise to have considered expanding their livestock enterprises.

4. Production Efficiency. Machine cost and labor are the important variables explaining the variation in production efficiency among the mechanized observations (Table 28). The coefficients of these variables are positive indicating an increase in these inputs, on the average, would have led to a decrease in production efficiency. Labor is the only important variable among the non-mechanized farms, and here too, efficiency would have decreased as labor increased.

TABLE 27

COEFFICIENTS AND RELATED STATISTICS OF LOGARITHMIC LEAST SQUARES REGRESSION ANALYSIS, OUTPUT PER MAN EQUIVALENT, NO CHANGE SITUATION, TURVO, S.C., 1969

	Non-Mechanized			Mechanized		
	Effect	Coefficient	Units	Effect	Coefficient	Units
Hectares/Man	.135	.205[b]	45.92	.137	.153[a]	39.91
Crop Expenses/Man	.177	.135[a]	2.29	.199	.160	3.50
Machine Cost/Man	.195	.246[a]	2.52	.254	.248	.702
Livestock Investment/Man	.015[d]	.030[c]	.067	.100	.171[a]	.499
Livestock Expense/Man	.075	.067[c]	5.83	-.009	-.009[c]	-1.00
Constant (Intercept)		4.905			4.043	
Mean of Y	7.938			8.285		
Standard Error of Y	.534			.387		
R^2	.5964			.6907		
Standard Error of Regression	.3663			.233		

[a]Not significant at .05 but at .10.

[b]Not significant at .10 but at .20.

[c]Not significant at .20.

[d]Standard error of regression increased when variable entered.

TABLE 28

COEFFICIENTS AND RELATED STATISTICS OF LOGARITHMIC LEAST SQUARES REGRESSION ANALYSIS, PRODUCTION EFFICIENCY,[a] NO CHANGE SITUATION, TURVO, S.C., 1969

	Non-Mechanized			Mechanized		
	Effect	Coefficient	Units	Effect	Coefficient	Units
Size (Hectares)	(F)[b]			-.050	.093[e]	.0019
Crop Expenses/Ha.	.039	-.078[e]	-.0050	.015	-.068[d]	-.0052
Machine Cost/Ha.	.007	-.107[e]	-.0042	.207	.239	.0024
Livestock Investment/Ha.	-.006	-.069[e]	-.0006	-.012	-.093[e]	-.0009
Livestock Expense/Ha.	.022	-.046[e]	-.0149	.001	.0042[e]	.0016
Labor/Ha. (Man Equivalents)	.271	.435	4.649	.140	.222	3.077
Constant (Intercept)		1.837			-.334[e]	
Mean of Y	-.155			-.088		
Standard Error of Y	.438			.262		
R^2	.3330			.3018		
Standard Error of Regression	.386			.236		

[a]Lower values imply higher levels of efficiency.

[b]Variable was excluded from model because the F ratio of the regression fell below .05 when it was entered.

[c]Not significant at .05 but at .10.

[d]Not significant at .10 but at .20.

[e]Not significant at .20.

Summary

The influence of mechanization among the No Change sample observations was small. In this situation where neither a change in farm size nor enterprise accompanied mechanization, land and labor productivity were increased slightly, production efficiency was decreased, and employment was not observably affected by the use of this input.

CHAPTER VIII

SUMMARY

Agricultural mechanization is proceeding at a rapid rate in Southern Brazil. Government policies and concessions aimed almost exclusively at increasing output have done much to encourage this expansion of mechanized agriculture. However, little or no concern about the substitution of mechanization for labor or about any other undesirable aspect seems to have existed. Thus, it was hypothesized that the resource endowments or factor proportions in Southern Brazil are such that the positive effects of agricultural mechanization have greatly overshadowed its substitution for labor and other negative effects.

The major objective of this study has been to examine some of the key economic consequences that are generally associated with agricultural mechanization. Specifically, the analysis was designed to determine what effects rapidly induced mechanization has had on (1) employment, (2) land productivity, (3) labor productivity, and (4) production efficiency under three different resource situations in Southern Brazil. A supplemental objective was that of drawing policy insights for other regions of Brazil and other developing countries.

Tabular, covariance, and regression analyses were used with cross-sectional farm survey data from Rio Grande do Sul and Santa Catarina to determine the effects of mechanization. The observations were first characterized and compared by categorizing them on the basis of tractor

ownership and land unit machine cost. Covariance analysis was employed next to provide a better estimate of the differences due to mechanization between the mechanized (owners of tractors) and the non-mechanized observations by isolating the influence of farm size. As a last step, least squares regression analysis was used to measure the extent to which mechanization and other inputs influenced employment, land and labor productivity, and production efficiency on the two types of sample farms in the different situations.

Since agricultural mechanization, like many technologies, was assumed to be location specific in that its impact is likely to vary from one situation to another, three distinctly different, yet characteristic, farm resource situations were examined. They are:

(1) Size Change: a situation wherein the predominant change accompanying the mechanization of agriculture has been size increases in family farms. The increases occurred through land rental and incremental purchases. Both crops and livestock are generally produced on these farms where most of the labor is provided by the family. Wheat and soybeans are the principal crops and are generally produced under a system of double cropping. The observation farms depicting this situation came from the municipios of Carazinho and Nao Me Toque in the state of Rio Grande do Sul.

(2) Enterprise Change: a situation wherein mechanization has been accompanied by a fundamental change in the farm organization from extensive cattle raising on open range

land to intensive crop farming. Contrary to the other two situations, the dependence on hired labor is much greater in this situation and land is generally not limiting. In fact, many of the farms are too large to be totally cropped and cattle continue to be grazed on extensive areas of unimproved native pasture. Two data sets were used in examining the effects of mechanization in this situation. The Enterprise Change #1 data set includes Carazinho and Nao Me Toque farms where wheat and soybeans were the predominant crops. The Enterprise Change #2 data set consists of farms from Sao Borja in Rio Grande do Sul. Wheat was the principal crop among the farms included in this latter data set.

(3) No Change: a situation wherein neither a change in farm size nor enterprise ensues the adoption of mechanization. The farms depicting this situation came from Turvo, a coastal plain municipio in the state of Santa Catarina. Both crops and livestock were generally produced on these smaller partially irrigated family farms. Rice and corn were grown on nearly all the farms, and cassava and tobacco were also important crops.

The Results

Summary results of the analysis to determine the effects of agricultural mechanization on employment, land and labor productivity, and production efficiency are presented in Table 29. For the comparison (tabular analysis) and covariance analysis the percentage figures indicate the amount by which the values of the mechanized observations were larger or smaller than those of the non-mechanized observations. The results of the regression analysis indicate the change that would be expected from increasing machine inputs by Cr$1.00 per hectare in the cases of employment and land productivity, Cr$1.00 per man equivalent for labor productivity, and 1 percent for production efficiency. Blank spaces indicate the variable was not important or its coefficient was not significant.

Several generalizations concerning agricultural mechanization in Southern Brazil can be made: (1) the effects of agricultural mechanization have been mixed; (2) mechanization has generally had a very positive impact on land and labor productivity; (3) it would have been profitable for most farmers to have increased their machine inputs; (4) mechanization in specific situations can result in increases in production efficiency; and (5) mechanization, again in specific situations, can lead to higher levels of employment.

Although the differences were considerable, the effects of mechanization on land and labor productivity, as expected, were positive in all of the situations. The effects of this technology on employment and production efficiency, however, were positive in some instances and

TABLE 29

SUMMARY RESULTS OF ANALYSIS: THE EFFECTS OF AGRICULTURAL MECHANIZATION ON EMPLOYMENT, LAND PRODUCTIVITY, LABOR PRODUCTIVITY, AND PRODUCTION EFFICIENCY IN THE SIZE CHANGE, ENTERPRISE CHANGE, AND NO CHANGE SITUATIONS, SOUTHERN BRAZIL, 1969-1970

Analytical Technique and Situation	Dependent Variable: Employment — Hired and Family Labor/100 Hectares (man days/year)	Land Productivity — Farm Output Per Hectare	Labor Productivity — Farm Output Per Man Equivalent	Production Efficiency — Relationship Between Output and Non-Land Costs
	(Change Due to Mechanization)			
Comparison[a] (Observed Difference)				
Size Change	-58%	+ 76%	+380%	+29%
Enterprise Change Ø1	-21%[e]	+290%	+411%	+13%
Enterprise Change Ø2	+10%[e]	+422%	+286%	+ 6%
No Change	-21%[f]	+ 8%	+ 29%	- 4%
Covariance[b] (Estimated Difference)				
Size Change	-43%	+ 91%	+216%	+26%
Enterprise Change Ø1		+195%	+118%	
Enterprise Change Ø2	+38%	+957%	+251%	
No Change		+ 27%	+ 24%	
Regression[c] (Estimated Effect)				
Mechanized				
Size Change		+ Cr$.66[g]	+Cr$1.03	- .12%[h]
Enterprise Change Ø1[d]	+ 3 days	+Cr$1.27	+Cr$1.87	
Enterprise Change Ø2[d]	+ 3 days	+Cr$2.17	+Cr$1.83	
No Change		+ Cr$.50	+ Cr$.70	- .24%
Non-Mechanized				
Size Change	+20 days	+Cr$2.76	+Cr$2.76	+ .12%
Enterprise Change Ø2[i]				
No Change		+Cr$2.52[g]	+Cr$2.52[g]	

[a]Observed difference between mean of mechanized observations and mean of non-mechanized observations; i.e., the mechanized observations in the Size Change situation employed 58 percent less labor than the non-mechanized observations. (The statistical differences of the observed means were not tested.)

[b]Estimated difference between mean of mechanized observations and mean of non-mechanized observations when the influence of size was removed.

[d]If the influence of machine and crop inputs would be considered together due to their fairly high degrees of correlation, all of the regression model results presented for the mechanized Enterprise Change observations would be reduced somewhat except that of land productivity for the Ø1 data set.

[e]Among the mechanized observations in both of the Enterprise Change data sets, the most highly mechanized groups were observed to be employing two-and-one-half times more family and hired labor per hectare than the least mechanized groups.

[f]A comparison of equal size farms showed the amount of family and hired labor employed was higher on the mechanized than on non-mechanized farms (Figure 7).

[g]The coefficient was not significant at .05 but was significant at .10.

[h]The coefficient was not significant at .10 but was significant at .20.

[i]Since only a very small number of machine costs were incurred on the non-mechanized Enterprise Change farms it is not surprising the coefficients for this variable were not significant.

negative in others.[1] For example, only in the second Enterprise Change situation were the mechanized observations employing more family and hired labor than their non-mechanized counterparts. Additional employment, on the other hand, could have been generated on the non-mechanized Size Change farms and the first as well as the second set of mechanized Enterprise Change farms.[2]

Higher land-use intensities were primarily responsible for the positive results when and where they accompanied mechanization. This technology, resulting in more timely completion of critical tasks, allowed more land to be cropped and a greater percentage to be double cropped. An increase in complementary inputs and perhaps better land

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[1]The conclusiveness of the analysis of the mechanization/production efficiency relationship is limited, especially among the Enterprise Change observations, by a specification problem. Production efficiency as measured in this study is a ratio of non-land cost to farm output plus custom machine rental receipts. (Lower values imply higher levels of efficiency.) Since no charge was included for land, the measure is inadequate where a wide variation in the importance of land in the different input mixes exists. In an extensive range grazing enterprise, the "non-land costs" would be minimal, whereas in an intensive crop enterprise these costs would be large relative to the land costs and farm output.

[2]Although the results of the labor analysis are noteworthy, there is reason to believe they may be biased in varying degrees. The bias, if and where it exists, stems from the difficulty encountered in measuring the amount of labor actually utilized, and from the limited number of available employment alternatives. On most farms there is probably some "normal" amount of family labor available independent of the farm size and need. Additionally, seasonal variations in the demand for labor create a situation where there may not be a surplus of workers but where there could well be a surplus of labor. The relative amount of labor that was unemployed or underemployed on the observation farms undoubtedly varied. On those farms where much of the labor was hired (75 percent among the mechanized observations in the second Enterprise Change category), the amount of excess labor would have been minimal. However, on the farms where almost all the labor was provided by the family (only 2 percent of the labor among the non-mechanized Size Change observations was hired), unemployment and particularly underemployment were probably much greater.

preparation and harvesting techniques resulted in slightly higher yields as well. The generally larger sizes of the mechanized farms also contributed to the positive effects in certain instances. Finally, incentive policies have been quite instrumental in accelerating the use of agricultural mechanization in Southern Brazil. Thus, the cumulative impact of this technology is the result of a composite of elements including resource endowments (land-labor factor proportions), production alternatives, and government policies.

To better understand the interactions of these elements and the subsequent impact of mechanization in different situations, the following theoretical interpretation is presented.

For purposes of discussion, diminishing substitutability of mechanization for labor as a source of power for a given level of aggregate agricultural output is assumed. This assumption implies varying combinations of labor and mechanization can be used to produce equal quantities of output. The optimum factor combination is determined by the relative price of the two factors within available capital (or other input) constraints. This relationship is depicted in Figure 8 where line PP represents the capital constraint for the employment of power resources (mechanization and labor) and its slope the relative prices of the factors. Therefore, at equilibrium (point A), M_1 units of mechanization and L_1 units of labor are utilized in the production of O_1 units of output for the agricultural sector (Figures 8 and 9).

Shifts in factor use may occur through three general changes: (1) a change in the relative price of labor or mechanization which would alter the price line to say P^1P^1 (substitution effect with new

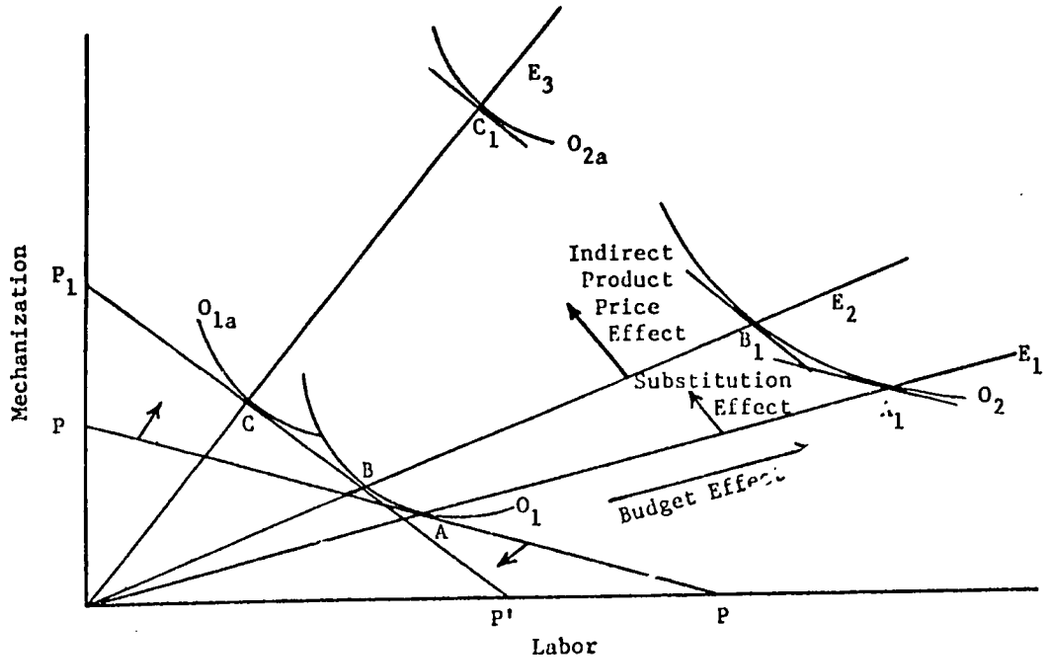

Figure 8.--Changes in Output and Factor Use for Agricultural Sector with Subsidization of Wheat Price and Mechanization and Major Credit Expansion

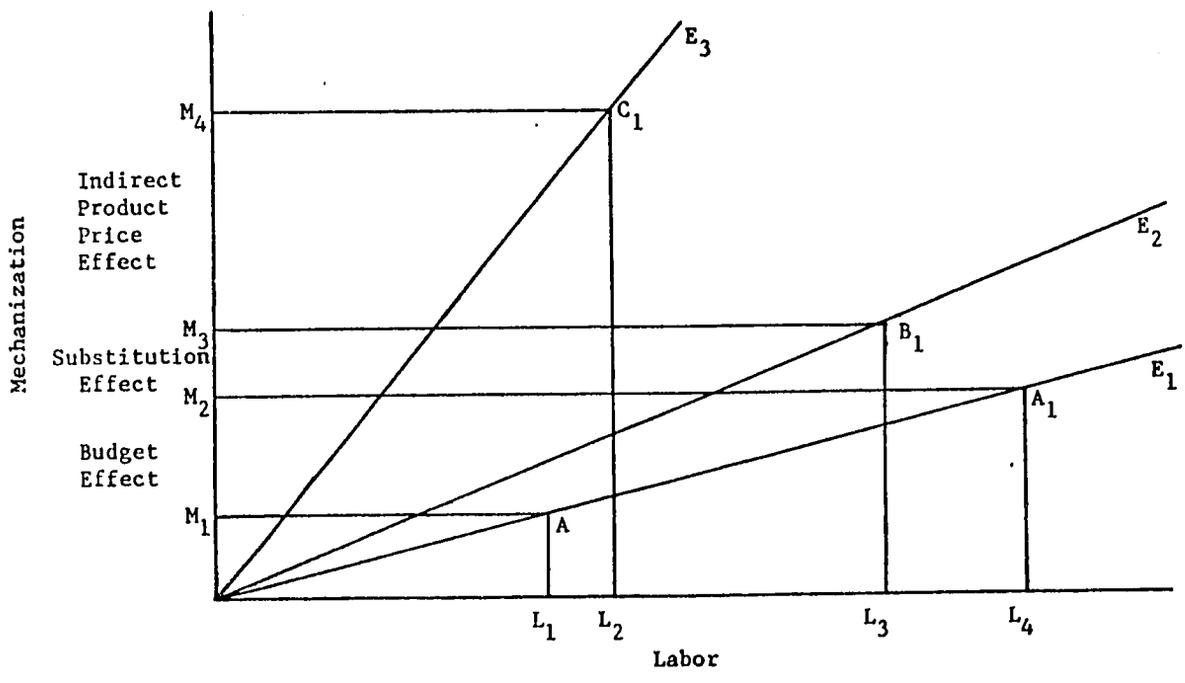

Figure 9.--Net Effects of Policies Depicted in Figure 8

equilibrium at point B), (2) a shift in the shape of the regional production function (O_1 to O_{1a}, with new equilibrium at C), or (3) an expansion in the capital constraint through internal or external financing to allow greater utilization of the production factors (new equilibrium points are then A_1, B_1, or C_1).

Expansion lines E_1, E_2, and E_3 represent paths of growth in output and factor use that could be expected under the three conditions of expansion (1) no change in production function or factor prices, (2) change in factor prices, (3) change in shape of the production function.

Changes in factor prices may result from normal market forces or be induced through subsidy or regulation. Changes in the production function for a region may be the result of a composite of forces including product price movements, that result in changes in enterprise, land mix, or new technology.

It would appear that most of these factors have been operative in the rapid increase in mechanized agriculture in Brazil. Enterprise changes to wheat farming, high wheat prices, credit for mechanization and general credit expension are the most important. Little new technology has been developed.

For purposes of illustration, the Enterprise Change situation depicted by the Sao Borja observations is used as a guide. In this case, a slight increase in employment resulted from mechanization. The new levels of employment and mechanization are noted in Figure 9 as L_2 and M_4 respectively. The question then is what combination of forces caused this significant distortion in factor use.

Conventionally, two effects are considered: (1) an expansion or budget effect that moves equilibrium to a new output level and (2) the substitution effect which causes a shift in the proportion of factors used at the same output level. Since an aggregate production function for a region over time is being considered a third effect is added, namely changes in the shape of the regional production functions. This third effect is the result of changes in product prices, technology, or enterprise mix.

The expansion effect from a major increase in credit and from additional internal funds generated through high wheat prices undoubtedly allowed farmers to move to a much higher output level. With a conventional linear homogeneous production function this would increase labor employment as well as mechanization. This hypothetical situation, given no change in factor prices or the production function and adequate resources, would be represented by A_1 where M_2 and L_4 quantities of factors are utilized.

The increase in employment suggests the substitution effect, in the Enterprise Change situation, is small relative to the other effects. Favorable credit policy, low interest rates, and the limited subsidization of mechanization have altered factor prices in favor of mechanization. In Figures 8 and 9, the substitution effect would shift the expansion path to E_2 with the new equilibrium at B_1 and increase mechanization from M_2 to M_3. However, since the actual change was to C_1, one must assume the major force driving most of the increased budget to the employment of mechanization must result from a fundamental change in the aggregate production function. This is precisely what happened.

High wheat prices altered enterprise combinations from primary livestock to highly specialyzed wheat farming. This created marked distributional seasonal labor and power requirements which were more efficiently met with mechanized equipment. It is probable that seasonal labor shortages and perhaps wage legislation reinforced the shift to mechanization. Thus, in the new production function brought about through artificial product price subsidization, mechanization was more technically feasible than labor methods.

The cumulative effect of all of these forces was a tremendous increase in the use of mechanization and other capital inputs along with a modest increase in employment in the Enterprise Change situation. These larger quantities of inputs and the much higher level of land-use intensity resulted in a dramatic increase in output.

However, the other two situations included in this study represent different factor proportions and consequently exhibited different results. For example, in the No Change situation the supply of labor was sufficient to cultivate most of the land without the aid of mechanization. The relatively balanced land-labor factor endowment in this situation left little latitude for improving economic performance through mechanization. Although partially hidden by the limited employment alternatives, the principal impact was apparently the substitution of mechanization for labor.

The Size Change situation is located on a land-labor factor endowment continuum somewhere between the Enterprise Change and No Change situations. Land and labor in the Size Change situation would also be in a relative balance if a multi-cropping potential did not exist. But

the climatic conditions are such that wheat and soybeans can be double cropped when some of the critical tasks are completed in a timely fashion. Sufficient labor, however, is not readily available to do this and mechanization is used.[3] The increase in output resulting from the more intensive land-use, while large, was not large enough to offset the substitution effect of the mechanization, and consequently some labor was released. This should not be taken to indicate, however, that mechanization should necessarily be avoided in this situation, but rather that the trade-offs between the increase in output, the decrease in employment, and any other effects need to be evaluated more closely.

The Conclusions

In this study the effects of agricultural mechanization in three different, but characteristic, farm resource situations in Southern Brazil have been examined. These situations, while representing only individual points along the land-labor factor endowment continuum, provide some general insights into what the impact of mechanization might be when somewhat similar factor proportions exist.

Where land is abundant relative to labor and the physical, economic, and institutional conditions allow very substantial increases in land-use intensity, there is little reason to be concerned about any negative effects of mechanization. Increases in both employment (if possible) and labor productivity would be expected to accompany a large increase

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[3]To justify the investment in mechanization most farms have found it necessary to increase the size of their operations by renting or buying additional land. This released those who sold or rented their land to seek other employment and for this reason it appears as if more labor was replaced by mechanization in this situation than in the No Change situation.

in output. However, as one moves away from this situation and land becomes increasingly less abundant relative to labor, the potential for using land more intensively declines. Mechanization, rather than breaking seasonal labor bottlenecks and substantially increasing output, begins replacing labor. At this point attention must be given to employment concerns which may well mean tempering the drive for maximum output.

The implication is that while agricultural mechanization has the potential of being a very positive element in a developing economy, it is location specific and must be used selectively. This technology should be encouraged in areas and for activities where it breaks seasonal labor bottlenecks and permits critical tasks to be performed which will result in significant increases in land-use intensity. These increases must be quite substantial (as in the Enterprise Change situation) unless farmers can acquire the machine inputs in small increments (i.e., via renting) or distribute them over large areas. To the extent that the land is being used at a relatively intensive level and/or cannot be used significantly more intensively, the addition of sizable quantities of machine inputs will have a negative effect on employment. Such mechanization should almost always be avoided unless it is essential for meeting minimum production targets.

While acknowledging that the administrative difficulties inherent in a selective mechanization policy would most certainly outnumber those of indiscriminate policies, a more selective and gradual mechanization process would enable less developed countries to obtain other goals

beside an increase in output. Additionally, some of the disadvantageous effects could be mitigated.

An early and perhaps very effective action that could be taken to guard against the non-essential/labor-replacing type of mechanization would be the curtailment of the accidential and deliberate subsidization of large-scale mechanization. This would help bring the prices paid and received by the farmers more in line with their opportunity costs, and should tend to discourage the unilateral use of labor-saving technologies.

Policies designed to expand custom machine hire services among neighbors should curtail unnecessary duplication and lead to the fuller and more effective use of existing mechanization. These small increments of machine inputs, as seen in the analysis, would be expected to yield sizable benefits.

Issues for Further Research

The various policy forces that have encouraged mechanization in Southern Brazil have resulted in significant modernization of agriculture. These policies, however, have also resulted in a great number of factor and product price distortions which hide the true costs of this development technique. No attempt was made to correct any of these distortions in this study. An effort should be made to measure these social costs along with any social benefits that may accrue from mechanization.

Similarly, the total costs and benefits of mechanization should be compared with other alternative uses of scarce capital resources. Would

the same investment in some other technology such as improved varieties of crops or fertilizers produce greater benefits than large-scale mechanization? Or, are there other forms of mechanization that would yield larger payoffs? Much of the mechanization found in most less developed countries is identical to that which is found in the developed countries of the world. Little effort has gone into developing a form that is in line with the factor endowments and stages of development found in Brazil and other less developed countries.

Additionally, what actions can be taken to encourage the selective adoption and use of mechanization? Brazil, like many countries, has adopted a wide range of policies which has indiscriminately encouraged large-scale mechanization.

And lastly, how is the increased production and income resulting from mechanization being distributed? The literature suggests that unless special attention is given to this important issue when policies are formulated, the disparity of incomes will widen.

APPENDIX

TABLE 30

NUMBER OF TRACTORS IMPORTED BY YEARS, BRAZIL

Year	Number	Year	Number	Year	Number
1937	434[a]	1949	4,217[a]	1960	10,547[c]
1938	N.A.[b]	1950	8,375[c]	1961	6,348[c]
1939		1951	10,967[c]	1962	1,836[c]
1940		1952	7,363[c]	1963	1,298[c]
1941		1953	2,698[c]	1964	1,243[c]
1942		1954	14,147[c]	1965	318[c]
1943		1955	5,758[c]	1966	639[e]
1944		1956	4,513[c]	1967	451[d]
1945		1957	7,451[c]	1968	1,127[d]
1946	668[a]	1958	5,973[c]	1969	443[f]
1947	1,692[a]	1959	4,895[c]	1970	395[f]
1948	2,101[a]				

[a]Tractors imported from U.S., U.K., and Canada as reported in: Progress and Economic Problems in Farm Mechanization, FAO/United Nations (Rome, September, 1950), p. 54.

[b]While the exact numbers are not available, the value of the tractor import declined considerably during 1940-45 period. See "Agricultura, A Mecanizacao da Lavora," Conjuntura Economica (Rio de Janeiro, October, 1952), p. 13.

[c]The figures do not include two-wheel tractors (cultivadores motorizados), small four-wheel tractors (micro tratores), or tractors imported for non-agricultural purposes. The source of these data is "Motomecanizacao da Agricultura no Brasil," Estudos APEC: A Economia Brasileira and Suas Perspectivas VI, APEC Editora S.A. (Rio de Janeiro, July, 1967), p. 111. According to a Department of State Airgram (#A1215, Rio de Janeiro, April 23, 1963), 425, 732, and 1,309 small four-wheel and two-wheel tractors were imported in 1960, 1961, and 1962 respectively. (This same source indicates that the total number of tractors imported in these three years were 13,127, 7,114, and 2,923 respectively.) However, the first source (Table XVI) estimates the number of two-wheel tractors imported to have been only 50 in 1955, 210 annually between 1956 and 1960, 50 in 1961, 200 in 1962, 245 in 1963, and 355 in 1964. The

TABLE 30--Continued

number of small four-wheel "micro tratores" imported during this period would have been negligible.

Tractor imports were frequently measured in metric tons; the estimated number of units is obtained by making some assumptions with respect to the average weights of the tractors. This procedure undoubtedly leads to inconsistencies like those noted here.

[d]These figures are estimates based on the 1967 and 1968 January-September tractor imports for agricultural purposes from 13 countries. An additional 1,351 and 1,939 (estimated on first nine months) tractors were imported during these same two years for unspecified purposes: Noticias da ANFAVEA #118, Associacao Nacional dos Fabricantes de Veiculos Automotores (Sao Paulo, February, 1969).

[e]Estimated number of tractors imported for agricultural purposes: J. H. Sanders, "Tractor Stocks in Latin America," Economic Development Center, University of Minnesota (draft, October 11, 1971), Table 4. (This source provides estimates for other years and while they are not identical to those presented above, they are fairly close.)

[f]These values are estimated using import figures for the first eleven months of 1969 and 1970. They are agricultural tractors and do not include track-type tractors: "Analise do Sector de Tratores; Respostas e Informacoes ao Questionario IPEA," Instituto de Planejamento Economico e Social (Rio de Janeiro, approximate date January, 1971), p. 2. (Mimeographed.)

TABLE 31

NUMBER OF TRACTORS PRODUCED IN BRAZIL ACCORDING TO SIZE BY YEARS[a]

Year	Conventional Four-Wheel Tractors				Track-Type Tractors	Small Four-Wheel Tractors "Micro Tratores"	Two-Wheel Tractors "Cultivadores Motorizados"
	Up to 35 HP[b]	35 to 45 HP	More Than 45 HP	Total[c]			
1960	0	37	0	37	0	0	0
1961	25	1,574	80	1,679	0	0	751
1962	1,984	4,779	823	7,586	0	0	1,240
1963	3,990	4,179	1,739	9,908	0	0	1,110
1964	1,329	7,947	2,261	11,537	0	0	1,765
1965	241	5,810	2,070	8,121	0	280	2,403
1966	96	6,668	2,305	9,069	13	291	3,336
1967	57	4,077	2,089	6,223	73	72	2,499
1968	32	4,625	5,014	9,671	106	148	2,465
1969	22	3,387	6,128	9,537	91	334	1,947
1970	0	4,666	9,383	14,049	185	409	2,065
1971				22,122	750	366	2,006
1972				29,142	1,282	858	2,915
Total				138,681	2,500	2,758	24,502

[a]Numbers include tractors used for non-agricultural purposes and the very few that have been exported.

[b]Not included in this category are the small "micro tratores."

[c]The numbers of conventional four-wheel tractors sold for agricultural purposes in 1961 through 1965 were estimated to be 1,144; 6,361; 9,737; 11,501; and 8,161 respectively: "Motomecanizacao da Agricultura no Brasil," op. cit., Table XXI.

Sources: Noticias da ANFAVEA #91, #115, #137, #140, #149, and #161 (Sao Paulo); "Trator a Solavancos," Coopercotia (Guanabara, January, 1970), p. 35; "Motomecanizacao da Agricultura no Brasil," op. cit., Tables X, XVI, XXI, and XXIII; Separata Parcial do Desenvolvimento da Agricultura Paulista, Instituto de Economia Agricola, Secretaria da Agricultura (Sao Paulo, 1971), p. 159; and J. H. Sanders, "Mechanization and Employment in Brazilian Agriculture, 1950-1971" (unpublished Ph.D. dissertation, University of Minnesota, 1973), p. 234.

TABLE 32

PRICES RECEIVED FOR WHEAT, SOYBEANS, AND RICE, AND METRIC TONS AND HECTARES OF WHEAT, SOYBEANS, AND RICE REQUIRED TO EQUAL THE PRICE OF A MEDIUM-SIZE TRACTOR, RIO GRANDE DO SUL, 1948-1963

Year	Prices Received by RGS Farmers (Cr$/Metric Ton)			Metric Tons of Crop Required to Purchase a Medium-Size Tractor			Hectares of Crop Required to Purchase a Medium-Size Tractor		
	Wheat	Soybeans	Rice	Wheat	Soybeans	Rice	Wheat	Soybeans	Rice
1948	2.50	2.10	1.35						
1949	2.50	2.00	1.65						
1950	2.40	1.30	1.65	37.50	69.23	54.55	47.92	49.78	22.53
1951	2.40	1.20	1.70						
1952	2.60	1.50	1.64						
1953	3.50	2.00	3.07	25.54	44.69	29.11	30.11	31.57	10.11
1954	4.00	2.30	3.16	33.63	67.26	48.96	41.18	38.18	16.96
1955	6.50	2.30	3.89	32.10	90.71	53.63	34.97	61.46	21.23
1956	7.00	3.60	5.03	34.94	67.94	48.62	36.47	46.21	17.84
1957	7.40	3.60	6.47	36.25	74.52	41.47	56.05	58.28	15.64
1958	8.50	4.20	5.50	32.13	65.02	49.66	73.91	55.14	17.67
1959	11.60	5.60	8.09	54.10	112.05	77.57	104.62	85.89	32.12
1960	16.40	7.90	9.30	39.95	82.94	70.45	69.60	72.50	26.83
1961	22.40	13.10	25.06	44.35	75.84	39.64	93.53	67.52	15.57
1962	51.40	16.30	26.50	33.13	104.45	64.25	36.10	123.95	24.77
1963	64.70	33.20	54.80	50.61	98.62	59.75	109.76	110.15	24.99

TABLE 32--Continued

Year	Prices Received by RGS Farmers (Cr$/Metric Ton)			Metric Tons of Crop Required to Purchase a Medium-Size Tractor			Hectares of Crop Required to Purchase a Medium-Size Tractor		
	Wheat	Soybeans	Rice	Wheat	Soybeans	Rice	Wheat	Soybeans	Rice
1964	144.60	66.20	88.80	44.74	97.73	72.86	50.85	116.87	31.16
1965	195.40	109.60	121.10	45.67	81.42	73.69	61.33	68.23	27.93
1966	255.20	146.20	131.50	42.06	73.41	81.62	49.64	63.57	30.15
1967	305.60	154.20	218.60	43.62	86.45	60.98	53.52	73.02	21.14
1968	371.14	205.48	291.72	41.66	75.26	53.01	46.89	90.50	17.81
1969	442.49	277.86	310.30	43.09	68.63	61.45	42.37	60.09	20.18

Source: Table 4 and J. Oliveira, Aspectos Produtivos e Economicos das Dez Principais Culturas do Rio Grande do Sul, 1948-1969, IEPE, Universidade Federal do Rio Grande do Sul (Porto Alegre, 1971), pp. 111, 118, 119, 122.

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