MECHANIZATION AND EMPLOYMENT IN BRAZILIAN AGRICULTURE, 1950-1971.

John H. Sanders Jr.

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University of Minnesota

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MECHANIZATION AND EMPLOYMENT IN BRAZILIAN AGRICULTURE, 1950-1971

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JOHN HOUSTON SANDERS, JR.

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John H. Sanders
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ABSTRACT

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The agricultural mechanization decision in many developing countries is complicated by the existence of a large agricultural population, high rural-urban migration rates since the Second World War, and a capital intensive industrialization process. All of these factors reduce the ability of the non-agricultural sector to absorb labor. Moreover, many developing countries may have affected the mechanization decision in agriculture by their intervention in factor and product markets.

Brazil is an ideal country to examine the determinants and effects of agricultural mechanization. Brazilian mechanization has occurred at an extremely rapid rate in the post-War period and Brazil has actively intervened in its factor markets.

The major results of the thesis are:

1. Time series analysis indicated that the subsidized financing was the statistically most significant variable determining investment in tractors and its effect swamped the relative price variables.

This financing of the Bank of Brazil was provided at negative, real interest rates.

2. The elasticity of substitution between labor and tractors was statistically significant and greater than one in most cases hence shifts in relative factor prices have had a large effect upon factor proportions. The factor proportions choice between tractors and labor was statistically associated with agricultural wages, the level of bio-chemical expenditures per hectare, the crop mix, and the distribution of crop farm size. Concentrations of crop area on large farms increased the tractor-labor ratio hence there was evidence that the use of machinery was not neutral with regard to farm size.

3. Capital inputs were dichotomized into labor absorbing and labor releasing with biological and chemical inputs in the former category and mechanical inputs in the latter. Mechanization enabled a substantial expansion in crop area per worker. Reductions in the subsidy on the machinery price would have resulted in more labor absorption in Sao Paulo agriculture.

4. The private rate of return per hectare to mechanized land preparation was high. This was a surprising result as the primary effect of mechanization was expected to result from increasing the crop area per worker. This high rate of return to mechanized land preparation was due to a reduction in the number of cultivations required and increased yields from improved soil preparation.

In summary, machinery either replaced labor or prevented an increase in labor absorption. However, there was a yield effect of 10 to 20 percent from improved land preparation. More labor could have been absorbed in Brazilian agriculture if the capital price had not been subsidized. However, less than 20 percent of Sao Paulo mechanization was associated with the distorted factor price evaluated. Moreover, the private rate of return for mechanized land preparation was high even for small farmers. The public rate of return to mechanization will depend upon the weighting of the labor replacing, yield increasing, and other effects of mechanization by Brazilian policy makers. The social cost of labor released from agriculture still remains to be measured.

Approval by Major Advisor: ______________________ (Signature) ______________ (Date)

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CHAPTER I

INTRODUCTION

In this chapter the literature applicable to the policy debate on agricultural mechanization is reviewed and applied to the Brazilian case. Then the primary issues to be considered are summarized. The problem of the choice of agricultural technology has been discussed in detail in recent literature on agricultural development.[1] The "appropriate" technology is emphasized for the machinery input due to its potential labor replacing and income distribution consequences. In the Western industrialized countries with a small sector of the labor force in agriculture the development of agricultural mechanization has been encouraged by the supply inelasticity of labor relative to land.[2] It has been suggested that some developing countries through

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[1] A. K. Sen, Choice of Technique, An Aspect of the Theory of Planned Economic Development (Oxford University Press: London; 1962), 90-97; B. F. Johnston and J. Cownie, "The Seed-Fertilizer Revolution and Labor Force Absorption," American Economic Review 49 (September 1969), 569-583; Y. Hayami and V. W. Ruttan, Agricultural Development: An International Perspective (Johns Hopkins Press: Baltimore; 1971), 118-136; M. Yudelman, G. Butler, and R. Banerji, Technological Change in Agriculture and Employment in Developing Countries (OECD: Paris; 1971), 69-128.

[2] Y. Hayami and V. W. Ruttan, op. cit., 133.

factor market and other policies have been encouraging the introduction of mechanical technology even though their initial factor endowments are very different from those in the Western countries and their agricultural sector is a much larger component of the total labor force.

Brazil is an ideal country to evaluate the introduction of agricultural machinery as mechanization has occurred at a very rapid rate since World War II. Except for some limited use in Rio Grande do Sul and Sao Paulo the introduction of tractors in Brazilian agriculture is a post-World War II phenomenon.[3] (see Appendix D) From 1950 to 1970 the Brazilian tractor stock increased from 8,372 to 156,592.

The Brazilian government has been active in some of the factor markets primarily in the capital market and in the labor

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[3] Tractors and agricultural machinery are used interchangeably here. One study of technological change has termed the tractor as "the single most important mechanical innovation in agriculture." Y. Hayami and V. W. Ruttan, op. cit., 124.

Except for tractors there has been little systematic data collection on agricultural machinery. A recent exception is M. I. A. Schuh, "Some Aspects of Recent Trends in Brazilian Agriculture," mimeo prepared for EAPA/SUPLAN, Ministerio de Agricultura, October 1972, 121 pages.

market. Capital subsidies have become one of the primary instruments of Brazilian government policy to increase output in manufacturing, agriculture, and other sectors.[4] Besides machinery other inputs such as fertilizer have also been subsidized. Labor has not been subsidized. Rather its price has been increased by various regulations and minimum wages. For those obtaining the subsidies on the machinery price the choice of factor proportions between machinery and labor will be affected as long as the choice of technology is not fixed.[5]

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[4]From 1954 to 1961 exchange rate subsidies reduced the tractor price by 17 to 18 percent (see Appendix B). With the commencement of the Brazilian tractor industry in 1960 agricultural credit and in particular machinery credits were expanded rapidly at very favorable terms. (see Chapter 2 - B)

For an evaluation of the use of capital subsidies to stimulate industrialization in the Northeast see D. E. Goodman, J. F. Ferreira Sena, and R. Cavalcanti de Albuerque, "Os incentivos financeiros a industrializacao do Nordeste e a escolha de tecnologias," Pesquisa e Planejamento, (IPEA: Rio de Janeiro; Dezembro 1971), 329-365; for a review of the importance of these subsidies in Brazilian agricultural policy see G. W. Smith, "Brazilian Agricultural Policy, 1950-1967," in H. S. Ellis (ed.), The Economy of Brazil (University of California Press: Berkeley; 1969), 213-265.

[5]It has been argued that the choice of technique may be fixed in the short run for many types of products hence developing countries must imitate the capital intensive development process of developed countries since they can't afford to develop their own technology. See R. S. Eckaus, "The Factor Proportions Problem in Underdeveloped Areas," in N. A. Agarwala and S. P. Singh (ed.), The Economics of Underdevelopment (Oxford Press: New York; 1963), 328-380. This is not an especially convincing case for agricultural production due to the range of techniques observed in (continued on next page)

Since capital subsidies are provided on such favorable terms that rationing is required, the economy can be dichotomized conceptually into the subsidized and the unsubsidized sectors. In a simple two sector model the introduction of the subsidies results in a movement of labor from the subsidized to the unsubsidized sector and in an efficiency loss in the capital market.[6] The average productivity and wage rate of labor will fall as capital will be used less productively. For the productivity of labor to increase after migration from the subsidized sector it is necessary to introduce rigidities in the functioning of the labor or other markets.[7]

Brazilian agriculture and in other countries. In any event the elasticity of substitution for Brazilian agriculture is estimated in Chapter 3. The lowest cost technology in developed countries such as the U. S. may not be relevant in developing countries if alternative technologies are available from other countries such as Japan or from earlier periods in the developed, high labor cost countries.

[6] A. C. Harberger, "The Incidence of the Corporate Income Tax," Journal of Political Economy 70 (June 1962), 215-240; P. Mieszkowski, "On the Theory of Tax Incidence," Journal of Political Economy 75 (June 1967), 250-262; W. R. Thirsk, "Income Distribution, Efficiency and the Experience of Colombian Farm Mechanization," Paper No. 33, Program of Development Studies, Rice University, Fall 1972, 54 pages.

[7] C. E. McLure, "The Theory of Tax Incidence with Imperfect Factor Mobility," mimeo, 1968.

A continuing wage rate differential between sectors of the economy implies that there are either barriers to labor migration or variations in labor quality. From 1950 to 1970 there was a substantial income gap between agricultural and non-agricultural incomes.[8] Why doesn't the migration of labor take place in response to this wage differential prior to the substitution of capital for labor in agriculture? One explanation is that those workers replaced by this substitution in agriculture are in the lower educational and skill categories hence they would expect to earn lower than average incomes in the non-agricultural sector.[9] Thirsk has summarized succinctly the

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[8] The average annual incomes by sector in 1950 were 5,500 Cr. in agriculture, 18,500 Cr. in the secondary sector, and 24,000 Cr. in the tertiary sector according to Fundacao Getulio Vargas, "Evolucao de mao-de-obra brasileira," Conjuntura Economica 10 (June 1956), 85. Fishlow reports that the relative income gap between the two sectors, agricultural and non-agricultural, remained constant from 1960 to 1970. See A. Fishlow, "Brazilian Size Distribution of Income," American Economic Review, Papers and Proceedings, 62 (May 1972), 399.

[9] Even in the U. S. those with little education or skills have difficulty obtaining non-farm employment when they are displaced from agriculture. See F. R. Marshall, "Some Rural Economic Development Problems in the South," American Economic Review, Papers and Proceedings (May 1972), 206.

implications of the case in which the primary inducement to mechanization is the distortions in the factor markets.

> Private savings in labor costs from mechanizing farm operations would exceed the value of the extra output produced elsewhere by the labor released. In this situation the benefits of mechanization captured by farmers would exceed those accruing to society.[10]

It is possible that mechanization replaces rural workers who have already left for the urban areas or substitutes for labor in areas such as the frontier which face an inelastic labor supply. However, as long as there continues to be a backlog of low income individuals in the Northeast and other regions the potential labor supply to the developed agricultural sector would be elastic. Some evidence for this elasticity of the labor supply is the constant real wage in Sao Paulo agriculture since the Second World War in spite of substantial increases in capital-labor ratios, rural-urban migration from Sao Paulo agriculture, rural-rural migration to Sao Paulo agriculture, and other transformations in agriculture and industry in the state.[11] With an elastic supply of labor,

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[10] W. R. Thirsk, "The Economics of Colombian Farm Mechanization," unpublished Ph. D. dissertation, Yale University, 1972, p. 8.

[11] Cited in G. E. Schuh, "Patterns of Equity Under Agricultural Development in Latin America," in A. G. Ball and E. A. Heady (ed.), Externalities in the Transformation of Agriculture: The Distribution of Benefits and Costs from Development (Iowa State University Press: Ames), forthcoming, from Secretaria da Agricultura, Desenvolvimento da Agricultura Paulista (Instituto de Economia Agricola: Sao Paulo; 1972).

employment in Sao Paulo agriculture will be determined by the demand for labor. The impact of machinery subsidies then becomes of much greater social consequence than if Sao Paulo agriculture faced an inelastic supply of labor.[12]

In areas of recent settlement or rapid development such as the frontier areas of northern Parana, Goias, and Mato Grosso there may be more difficulty in attracting labor than in rural Sao Paulo. Hence in the short run the labor supply may be

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[12] In the Hayami-Ruttan "induced innovation" theory mechanical technology is introduced in response to relative factor supply inelasticities. These factor supply elasticities are reflected by changing relative factor prices over time. Public and private agencies respond by adapting or producing capital inputs to substitute for the relatively scarce factor. Hence, the optimal technological change in agriculture becomes endogenous in this theory. See Y. Hayami and V. W. Ruttan, op. cit., 111-135.

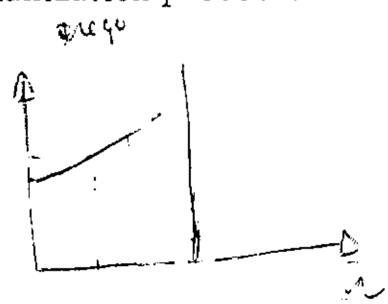
In the Sao Paulo case the labor supply is perfectly elastic; however, the subsidies on the machinery price may distort the process of optimal technological change as visualized by Hayami and Ruttan by giving the wrong signals through the relative factor prices to private and public agencies. These agencies then may produce or adapt capital inputs in response to the distorted factor prices rather than the real opportunity cost of these factors.

No caso de S. Paulo a oferta de [illegible] é perfeitamente elástica, embora os subsídios aos preços de maquinas possam distorcer o processo de otimização da mudança tecnológica com visualizado por H e R por inelastic in these frontier areas. In the case of an elastic land supply and an inelastic labor supply mechanization can relieve a constraining bottleneck to increases in agricultural output; however, measures to facilitate in-migration of labor are a potential alternative to mechanization and mechanization will reduce the labor absorption potential of frontier settlement. Nevertheless, on the frontier the short run supply inelasticities of labor may be felt as a much more pressing constraint to agricultural development due to the very rapid expansion of cropland and output growth.

The above discussion has concentrated on the impact of mechanization on labor use. Besides its substitution effect for labor machinery may also serve as a substitute for land by increasing yields especially in land preparation. Moreover, mechanization may be introduced to reduce risks such as the introduction of harvesting equipment in order to reduce the probability of crop loss from bad weather.

Determination of the appropriateness of mechanization in the present context of Brazilian agricultural development then requires a systematic analysis of the various factors encouraging mechanization and the effects of mechanization. In Chapters

2 and 3 a statistical analysis of the determinants of Brazilian agricultural mechanization is made with time series and cross sectional aggregate data. In Chapter 4 the effect of mechanization on labor use is evaluated. In Chapter 5 farm data are employed to estimate the private rate of return to mechanized land preparation. The concluding chapter pulls together the policy implications primarily of the earlier chapters to consider the pros and cons of agricultural mechanization at the present stage of Brazilian economic development. There are also six Appendices providing background data and analysis of the mechanization process.



CHAPTER 2

FINANCIAL SUBSIDIES AND THE GROWTH OF THE BRAZILIAN TRACTOR STOCK, 1950-1971

The impact of subsidies upon the mechanization decision depends upon who can capture the rent arising from a subsidized input. In extreme cases this rent could be captured by the seller, the buyer, or the rationing agent. In less extreme cases the rent would be divided among these three. For the purpose of this study it is only necessary to test for the impact of these subsidies upon the tractor investment decision by the farmer. In the first section of the chapter the growth of the Brazilian tractor stock is evaluated statistically by estimating the association of aggregate tractor investment with relative prices, financing conditions, previous stock, and the shift from importing tractors to domestic production. In the second section the specific details of recent subsidization of credit for purchasing machinery inputs are reviewed and analyzed.

A. Statistical Analysis of the Aggregate Demand for Tractors:

Tractor imports fluctuated substantially in the fifties but the stock increased rapidly from 8, 372 to 61, 345. (See Table 1) In 1960 the Brazilian domestic tractor industry began

Table 1

Brazilian Wheel Tractor Imports and Sales of Domestically Produced Wheel Tractors

Year	Imports	Domestic Sales	Total Disappearance
1950	8,375	---	8,375
1951	10,967	---	10,967
1952	7,363	---	7,363
1953	2,154	---	2,154
1954	12,258	---	12,258
1955	5,345	---	5,345
1956	4,117	---	4,117
1957	6,810	---	6,810
1958	7,135	---	7,135
1959	4,597	---	4,597
1960	12,702	19	12,721
1961	6,382	1,645	8,027
1962	1,714	7,336	9,050
1963	1,330	9,368	10,698
1964	1,341	12,032	13,373
1965	374	8,072	8,446
1966	639	9,214	9,853
1967	342	6,470	6,812
1968	990	9,263	10,253
1969	423	9,671	10,094
1970	60	14,343	14,403
1971	50[E]	21,732	21,782

Source: See Appendices B and C.

E: estimate

to operate. The growth of domestic tractor sales was not as rapid as anticipated by the industry and reached a low point in 1967. After 1967 tractor sales expanded substantially. The 1970 Agricultural Census reported a stock of 156,592 operative agricultural tractors. In this section some of the primary variables determining aggregate investment in tractors will be evaluated.

The Model:

There has been a large number of empirical studies employing stock adjustment and investment demand models to explain the growth of tractor stocks and tractor sales in the U. S. and England.[1] These studies contain four types of

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[1]Z. Griliches, "The Demand for a Durable Input: Farm Tractors in the United States, 1921-1957," in A. C. Harberger (ed.), The Demand for Durable Goods (University of Chicago Press: Chicago; 1960), 184 f.f.; A. J. Rayner and K. Cowling, "Demand for a Durable Input: An Analysis of the United Kingdom Market for Farm Tractors," Review of Economics and Statistics 49 (November 1967), 590-598; A. J. Rayner and K. Cowling, "Demand for Farm Tractors in the United States and the United Kingdom," American Journal of Agricultural Economics 50 (November 1968), 896-913; A. J. Rayner, "Price-Quality Relationships in a Durable Asset: Estimation of a Constant Quality Price Index for New Farm Tractors, 1948-1965," Journal of Agricultural Economics 29 (May 1968); K. Cowling and A. J. Rayner, "Price, Quality and Market Share," Journal of Political Economy 78 (November-December 1970) 1292-1309; L. P. Fettig, "Adjusting Farm Tractor Prices for Quality Changes, 1950-1962," Journal of Farm Economics 45 (August 1963) 599-611; E. O. Heady and L. G. Tweeten, Resource Demand and Structure (continued next page)

variables, relative prices, a finance variable, lagged stock, and descriptive variables for the state of the agricultural sector or the average tractor age. A primary recent concern has been with the adjustment of the dependent and price variables for quality change over time. Without this adjustment the necessary assumption that the observed tractors stocks are a constant function of the unobserved service flows is more difficult to justify. Tractor service flows will be proportional to tractor horse power and other qualitative features and to the utilization of capacity. Unfortunately, several of the components of flow are difficult to measure so stocks are used as a proxy. If the variation in models is substantial over the time period analyzed, the mis-specification of the proxy could be substantial. Hence, much recent concern in estimating investment demand functions has been focused on the qualitative changes in tractor models over time. In the studies cited the dependent variable has been changed from tractor numbers to horsepower or to expenditures on tractors adjusted by a hedonic price index in which both horsepower and the shift from gasoline

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of the Agricultural Industry (Ames: Iowa State University Press, 1963), Ch. 11; W. A. Cromarty, The Demand for Farm Machinery and Tractors (Michigan State University: East Lansing; November 1959) Technical Bulletin 275; A. Fox, Demand for Farm Tractors in the United States-A Regression Analysis, Agricultural Economic Report No. 103 (Economic Research Service, U. S. Department of Agriculture: Washington; November 1966).

to diesel fuel are represented.[2] In the newer tractor models there have been many other refinements of the accessories especially hydraulic systems but also including other features increasing the versatility of tractors with respect to the number of functions which they can perform and implements which canbe added (see Appendix C). Ideally, a hedonic price index could be estimated taking all these changes into account. Sufficient data were not available to do this for Brazil. However, the most important use of tractors in Brazil is for the power demanding, land preparation operation (see Tables D.5, D.6,and D.7). For this operation horsepower is the most important qualitative adjustment and data were available on the horsepower of domestic production in the sixties. Over the entire period 1950-1971 it was necessary to use tractor numbers as the dependent variable.

Two different price variables were tried, the price of tractors relative to the crop output price (lagged one period) and relative to the wage of daily agricultural workers. The output price was lagged by one period because the purchaser of a tractor in time period "t" does not know the output price in the period

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[2] A. J. Rayner and K. Cowling, "Demand for Farm Tractors in the United States and the United Kingdom," op. cit., 900, 901.

of purchase. In any given year both the wage rate and the tractor price are expected to be predetermined.[3]

The finance variables in other studies have been interest rates, investment allowances, or even farmer's equity or profits as a proxy for the ability of the farmer to generate investment funds internally. The credit market in Brazil can be divided into two sectors, the subsidized and the unsubsidized. A weighted interest rate would be the preferred finance variable but data on the quantity and terms of the credit provided by the unsubsidized sector were not available. However, the quantity of subsidized credit can be considered as a proxy for the weighted interest rate. Increasing the quantity of credit in the subsidized sector would force down rates in the non-subsidized sector if shifts in investment opportunities in the non-subsidized sector did not occur. The case for treating the quantity of subsidized credit as exogeneous is strong as the government establishes this quantity by fiat to the banking system and the demand over the relevant range for this subsidized credit would be very elastic because the terms of subsidies were very favorable.

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[3] By predetermined it is assumed that the tractor price is not adjusted in response to sales during the year. This assumption is necessary for a single equation demand model. See Z. Griliches, op. cit., 188, 189.

Measurement of the stock of tractors poses several problems. Economic depreciation as reflected by used tractor prices exhibits the declining balance pattern of AB[4] in the U. S. (see Figure 1). Technical depreciation (AC) however, should reflect the ability of used models to deliver the same level of tractor services as new models. It would not drop rapidly in the first few years as with the declining balance method.[5] The gap XY between these two in the first years may be attributable to a consumer preference for new rather than used models or a taste factor unrelated to the service flow of one year old tractors as compared with new tractors.[6] The service flow would be

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[4] Z. Griliches, "Capital Stock in Investment Functions: Some Problems of Concept and Measurement," in C. F. Christ et al., Measurement in Economics and Econometrics (Stanford University Press: Palo Alto; 1963), 115-137; and Z. Griliches, "The Demand . . . ," op. cit., 197-205.

[5] This is supported by fuel consumption statistics and tractor use by age in P. R. Brodell and A. R. Kendall, Fuel and Motor Oil Consumption and Annual Use of Farm Tractors, F. M. 80 (Bureau of Agricultural Economics, USDA: Washington; 1950).

[6] Another explanation for the rapid drop in the initial years is the "lemon effect." A certain number of new models will be mechanically defective and their purchasers would be expected to sell them in the initial years. The market price would then discount for the expected probability of obtaining a lemon. The "lemon effect" is a resale effect and should not affect the service flow of a "non-lemon" though it would be useful to discount out the "lemons" in making aggregate stock estimates.

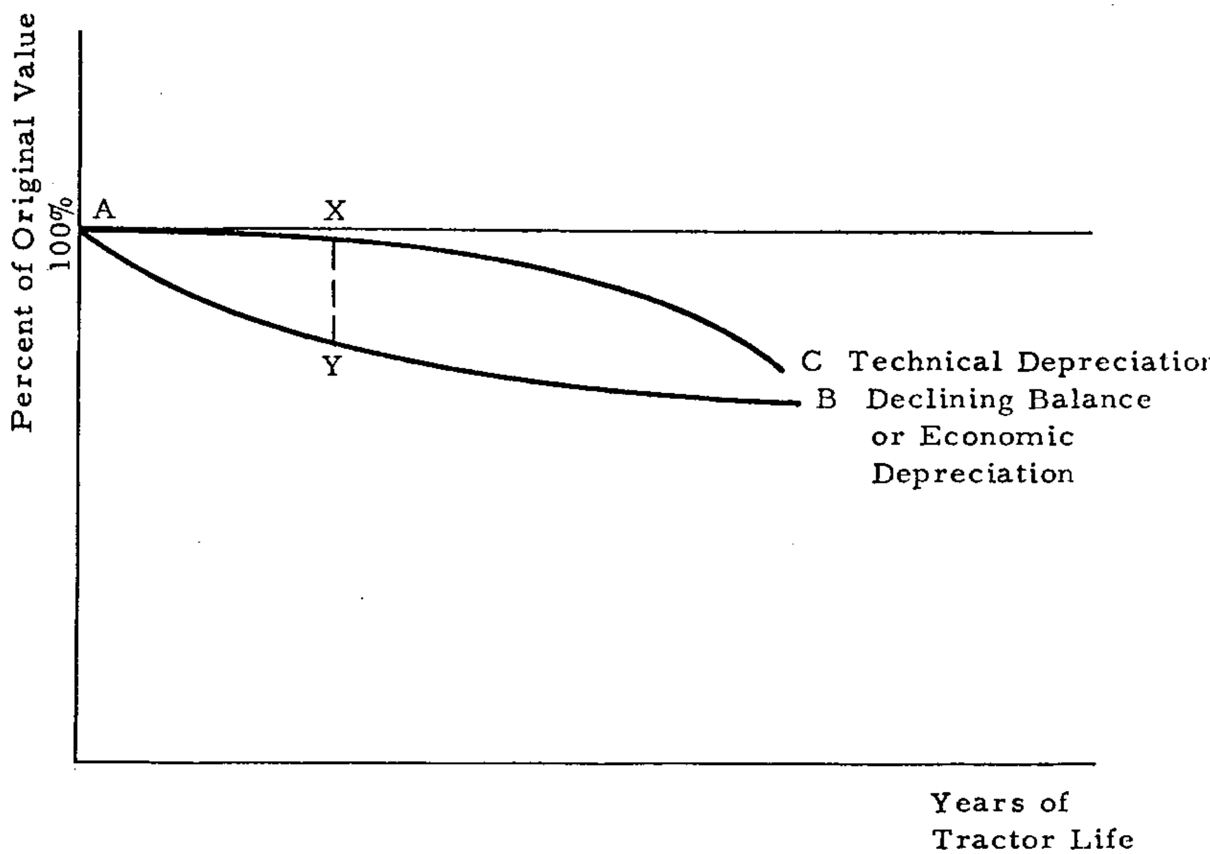

Figure 1. Alternative Treatments of Tractor Depreciation.

closer to the technical depreciation rate over the initial years of life of the tractor stock after which used tractor prices probably reflect the decline in the service flow as repair and other variable costs increase with age. The depreciation method employed here was a 5 percent declining balance rate. This method gives total stock estimates which are consistent with Brazilian Census estimates.[7] This low rate of depreciation prevents the abrupt

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[7] The 1960 Census estimate taken in 1959 reported 61, 345 total tractors and the above depreciation method gave 58, 116 wheel tractors. The 1970 Preliminary Census made in 1970 reported 156, 592 total tractors as compared with the estimate here of 122, 683 wheel tractors. The Census estimate is high because of the inclusion of micro tractors and the very slow depreciation rates implicitly used in the Census. The Census definition included as a whole tractor unit all tractors which were functioning at all. This is an implicit light bulb or "one-horse shay" treatment of depreciation, which substantially overstates the effective tractor units. Used tractors require more service, maintenance, and gasoline per horsepower unit. Hence, a more sophisticated treatment of the on-farm stock is necessary to reflect their service flow rather than the light bulb treatment. The method of declining balance used here will overdepreciate in the initial years thereby understating the effect of the high level of tractor sales in the second half of the sixties.

Estimating the implicit rate of depreciation from the Brazilian data on stocks, imports, and domestic production gives a declining balance depreciation rate of 4.25 percent according to the identity.

$$S_t = S_{t-1}\,(1-g) + M_t + D_t - (\Delta I)_t$$

Where S_t is stock at the beginning of time period "t", g is the declining balance rate of depreciation, M_t is imports, D_t is domestic sales, and $(\Delta I)_t$ is change in inventory holdings, assumed to be equal to zero.

Further work will test the sensitivity of the coefficient results to alternative depreciation rates.

decline in stocks in the initial years resulting from using a higher rate of declining balance. For the older tractors this rate would be expected to understate the decline in service flow.

The final variable is a dummy variable to differentiate between the import and the domestic production periods. The semi-log form has been statistically most successful in previous studies[8] and gave better results than either the linear or the log form in this study. The estimating equation is then:

$$(1) \qquad T_t = \log A + \alpha_1 \log \frac{P_{T_t}}{P_{0_{t-1}}} + \alpha_2 \left(\frac{P_T}{W}\right)_t + \alpha_3 \log \left(\frac{F}{P}\right)_t + \alpha_4 \log S_{t-1} + D_1 + \varepsilon_t$$

where T_t is tractor sales either in numbers or in horsepower; $\left(\frac{P_{T_t}}{P_{0_{t-1}}}\right)$ is the tractor price with respect to the lagged crop output price; $\left(\frac{P_T}{W}\right)_t$ is the tractor price with respect to the agricultural wage rate; $\left(\frac{F}{P}\right)_t$ is the real value of tractor credits; S_{t-1} is the lagged stock; D_1 is the dummy variable taking 0 values in the import period and value of 1 in the domestic production period; and ε_t is the error term. (For more detail on these variables see Appendix A).

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[8]A. J. Rayner and K. Cowling, "Demand for Farm Tractors in the United States and the United Kingdom," op. cit., 898, 903, 904.

One basic assumption of most investment demand studies is that supply is completely elastic at the given price during the observation period or that firms do not readjust the tractor price on the basis of sales during the year. Any price adjustments are assumed to be made at the end of the year. In Brazil tractor prices are actually adjusted several times during the year but primarily for inflation. If manufacturers also take sales during a given year into account, then it would be necessary to use simultaneous equation techniques. As in the other studies it was assumed here that manufacturers do not adjust their prices during the year in response to sales and OLS estimation was employed.

The Results:

In Table 2 the regressions are shown for both 1950-1971 and 1953-1971. There was a modification in exchange rate policies in 1953. Most of the effects of this change should be picked up in the tractor price variables; however, as a cross check the regressions were run including and excluding 1950-1952. Table 2 shows that the real value of tractor financing is highly significant in determining tractor sales. These subsidies overshadow the effect of the relative tractor price on sales. Unlike the American and English studies[4] these relative price

[4]A. J. Rayner and K. Cowling, "Demand for Farm Tractors in the United States and the United Kingdom," op. cit., 896. This article reviews most of the studies cited in footnote 1.

Table 2

Investment Demand for Tractors[a] 1950-1971

No.	Years	Constant	Tractor price relative to the lagged crop price $\frac{P_{T_t}}{P_{C_{t-1}}}$	Tractor price relative to the agricultural wage rate $(\frac{P_T}{W})_t$	The real value of Tractor Financing $(\frac{F}{P})_t$	Lagged tractor stock S_{t-1}	Dummy variable to distinguish between the import and domestic production periods. Intercept Shifter	Standard Error of the Estimate	$\bar{R}^2$	Durbin-Watson Statistic	F-Level	Degrees of Freedom
1.	1950-1971	-154,822 (26,719)			25,369 (6.62)***	-11,477 (5.93)***	-15,135 (4.74)***	2,121	0.74	$1.49^{n.s.}$	21.1	18
2.	1950-1971	-154,863 (28,030)	14.0 (.007)		25,380 (6.08)***	-11,490 (4.48)***	-15,446 (4.27)***	2,183	0.73	$1.49^{n.s.}$	14.9	17
3.	1950-1971	-156,196 (31,119)		14.9 (.09)	25,516 (6.02)***	-11,617 (4.68)***	-15,549 (4.37)***	2,182	0.73	$1.49^{n.s.}$	14.9	17
4.	1950-1971	-166,741 (46,634)	-2,268 (.31)	2,021 (.32)	25,694 (5.85)***	-11,390 (4.29)***	-15,301 (4.09)***	2,243	0.71	$1.47^{n.s.}$	11.3	16
5.	1953-1971	-189,956 (31,785)			25,165 (6.63)***	-7,997 (2.65)***	-17,730 (5.33)***	2,016	0.80	$1.75^{n.s.}$	24.3	15
6.	1953-1971	-188,344 (34,152)	-367 (.17)		25,016 (6.23)***	-7,850 (2.44)**	-17,487 (4.71)***	2,084	0.78	$1.75^{n.s.}$	17.1	14
7.	1953-1971	-188,519 (37,570)		-137 (.08)	25,076 (6.14)***	-7,937 (2.47)**	-17,639 (4.86)***	2,086	0.78	$1.75^{n.s.}$	17.1	14
8.	1953-1971	-197,774 (48,216)	-2,430 (.32)	1,764 (.29)	25,318 (5.91)***	-7,851 (2.35)**	-17,302 (4.44)***	2,156	0.77	$1.71^{n.s.}$	12.8	13
9.	1950-1971 (excluding 1953, '55, '56, '57, '58, and '59)	-153,960 (30,585)			24,661 (5.24)***	-10,705 (4.22)***	-16,401 (4.62)***	2,142	0.67	$1.72^{n.s.}$	10.3	12
10.	1950-1971 (excluding the above years)	-152,945 (32,295)	-411 (.20)		24,418 (4.83)***	-10,392 (3.37)***	-16,109 (4.04)***	2,233	0.62	$1.76^{n.s.}$	7.2	11
11.	1950-1971 (excluding the above years)	-150,002 (36,016)		-405 (.24)	24,238 (4.64)***	-10,322 (3.32)***	-16,078 (4.07)***	2,231	0.62	$1.76^{n.s.}$	7.2	11
12.	1950-1971 (excluding the above years)	-141,835 (68,075)	1,495 (.14)	1,620 (.19)	23,854 (3.92)***	-10,311 (3.17)***	-16,167 (3.86)***	2,338	0.58	$1.75^{n.s.}$	5.2	10

[a] All variables were in log form except the dependent variable. The dependent variable is the number of tractor sales including both imports and domestic production.

(t-values are given in parentheses below the coefficients except for the standard error of the constant)

** significant at 95 percent

*** significant at 99 percent

n.s. At the 5 percent level the Durbin-Watson statistic indicates no serial correlation. When a lagged endogenous variable is one of the independent variables, there is a bias of the Durbin-Watson statistic towards 2. See M. Nerlove and K. F. Wallis, "Use of the Durbin-Watson Statistic in Inappropriate Situations," Econometrica 34 (January 1966), 235-238; and J. Durbin, "Testing for Serial Correlation in Least Squares Regression When Some of the Regressors are Lagged Dependent Variables," Econometrica 38 (May 1970), 410-421. In this situation there are two other tests of auto-correlation.

An alternative test proposed in this Durbin article is the t-statistic of the significance of the difference from zero for h where

$$h = a \sqrt{\frac{n}{1 - n\,v(b_1)}}$$

$a = 1 - 1/2\, d$,
d is the Durbin-Watson statistic,
n is the number of observations,
$v(b_1)$ is the variance of the lagged endogeneous variable.

When the denominator is less than zero, this method doesn't work so this test is often not applicable as in this case. Another test is to run the residuals on all the variables including the lagged residual. A significant coefficient on the lagged residual then indicates a serial correlation problem. The small sample properties of these two tests are still unknown. Note that the estimated coefficients of Tables 2 and 3 will be unbiased, if auto correlation exists, but not efficient.

variables were never significant. However, this is not surprising given the large quantity and favorable terms of tractor loans at a pegged interest rate in an inflationary environment.

Griliches shows that a negative lagged tractor stock indicates that the adjustment rate is greater than the depreciation rate,[10] or the rate of adjustment of investors from actual to desired stocks is larger than the rate of depreciation of the stock.

The sign of the dummy variable for the intercept term is a puzzle. The shift downward of the demand curve may be due to a more limited range of models in the domestic production period and a failure of the price variables to pick up all the effects of preferential exchange rates in the fifties especially the barter or bi-lateral trade (see Appendix B for further discussion of this policy).

The periods 1950-1971 and 1953-1971 gave very similar results. In Colombia, where a government agency controls most tractor distribution, it has been argued that in years of exchange rate scarcity, hence limitations on tractor imports, the government

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[10] In Griliches' model tractor stocks enter in linear form. In the model estimated here the lagged tractor stock in log form gave a better statistical fit than in linear form but both had negative signs. Z. Griliches, "The Demand . . . ," 187, 202, 203. Rayner and Cowling in "Demand . . .," 899, 900 also obtained a negative coefficient for the log of the lagged tractor stock.

pegged the tractor price below the equilibrium price at the restricted supply.[11] Without data on the black market price for tractors it would not be possible to use the years of supply limitations to estimate a demand function. In Brazil the government has not had a significant role in tractor distribution except through its effect on differential exchange rate pricing and has not made much effort to control tractor prices. Hence, supply limitations and a pegged price were not expected in Brazil. Nevertheless, this supply limitation effect was tested for by excluding those years in which tractor imports were very low in the fifties in equations 9-12. No structural shifts were obvious nor do the relative price coefficients become more significant.

Considering domestic production only, the specification of the dependent variable and price variable can be made in horsepower units [12] (Table 3). Once again the price variables were not significant and neither was the lagged stock variable. As in the

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[11] W. R. Thirsk, "The Economics of Colombian Farm Mechanization," unpublished Ph. D. dissertation, Yale University, 1972, 103.

[12] It is reasonable to segment the import markets and the domestic production of tractors as restrictions sharply reduced tractor imports after 1961 limiting them only to heavier horsepower models than were produced domestically. Also the terms and availability of financing were different on imported than on domestically produced models. (see Appendix E)

Table 3

Investment Demand for Tractor Horsepower,[a] 1962-1971

No.	Constant	$\frac{P_{T_+}}{P_{0\,t-1}}$	$\frac{P_T}{W}$	$\frac{F}{P}$	S_{t-1}	Standard Error of the Estimate	$\bar{R}^2$	Durbin-Watson Statistic	F-Level	Degrees of Freedom
1'	-7, 385, 720 (1, 429, 120)			1, 466, 860 (5.60)***		146, 439	0.77	1.68	31.3	8
2'	-9, 349, 889 (2, 963, 122)			1, 273, 173 (3.44)**	197, 859 (0.76)	150, 418	0.76	1.24	15.1	7
3'	-21, 716 (10, 415, 463)	-557, 442 (.94)		1, 362, 293 (3.54)**	-418, 753 (.59)	151, 789	0.75	1.49	10.1	6
4'	2, 573, 342 (12, 595, 015)		-475, 175 (.97)	1, 193, 737 (3.14)**	-410, 595 (.61)	150, 968	0.76	1.49	10.3	6

[a]All variables were in log form except the dependent variable. Note that the tractor price variable is the price per horsepower unit.

(t-values are in parentheses except for the standard error of the constant term)

** significant at 95 percent

*** significant at 99 percent

1953-1971 period the relative price variables had the expected signs. In 3' and 4', the alternative specifications of the full model, the lagged stock variable again had a negative sign though not significant.

Before estimating the elasticity of sales with respect to financing it is useful to ascertain if there is a significant change in the slope of the finance variable between the two periods. Running dummy variables for the intercept and the slope together gave confusing and contradictory results due to the almost perfect correlation between the two dummy variables, (a simple correlation of .99981). To get around this multi-collinearity problem the following modifications of equations #1 and #5 of Table 2 were made.

(2) $$T_+ = \log A + \alpha_1 \log (F/P)_t + \alpha_2 \log S_{t-1} + D_1$$

(3) $$T_+ - (\log A + D_1) = \alpha_1 \log \left(\frac{F}{P}\right)_t + \alpha_2 \log S_{t-1}$$

(4) $$T_+ - (\log A + D_1) = \alpha_1 \log \left(\frac{F}{P}\right)_t + \alpha_3 D_2 \log \left(\frac{F}{P}\right)_t + \alpha_2 \log S_{t-1} + \mathcal{E}_t$$

Then the dummy to test for the significance of a change in slope between periods was introduced and (4) becomes the estimating equation, which is forced through the origin. D_2 is zero in the import period and 1 in the period of domestic production. The test is for the significance of $\alpha_3 D_2$ using the t-statistic. Table 4 indicates that there is no significant

Table 4

Test for a Shift in the Slope of the Finance Variable Between the Import and the Domestic Production Periods

No.	Years	$\frac{F}{P}$	Finance Slope Shifter $\alpha_3 D_2$	S_{t-1}	Standard Error of the Estimate	F-Level	Degrees of Freedom
1.	1950-1971	25,367 (18.7)***	0.66 (.009)	-11,475 (7.95)***	2,065	50,556	19
2.	1953-1971	25,171 (9.04)***	-0.37 (.003)	-8,003 (2.75)**	1,952	72,597	16

(t-values are given in parentheses below the coefficients)

** significant at the 95 percent level
*** significant at the 99 percent level

difference in the slope of the finance coefficient between the two periods. This gives some evidence that the small changes in interest rates and other financial conditions of the subsidized lending between the periods were not significant enough to affect the slope coefficient. Table 5 gives the elasticity estimates for tractor financing.

Table 5

Elasticity of Tractor Sales with Respect to Financing

Years	Elasticity	Data Source
1960-1962[a]	2.55	Total Number of Tractors, 1950-1971
1969-1971[a]	1.64	
1966-1971[b]	2.8-3.5	Domestic Tractor Horsepower, 1962-1971
1969-1971[b]	1.3-1.5	

[a]Equation #1' in Table 2

[b]Equations #1 and #4 in Table 3

In summary tractor financing of the Bank of Brazil has had a large impact on tractor sales. This credit was provided at negative real interest rates and it relegated the price variables to an insignificant role in affecting sales.[13] Subsidized credit swamps the influence of relative prices according to these statistical results. All model specifications and time periods analyzed gave this same result so the conclusions are strengthened.

In the next section recent governmental policy with respect to tractor subsidies will be reviewed and several costs resulting

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[13] In spite of substantial effort to specify the relative price variables there still may have been a specification problem. However, the above explanation for their lack of significance is considered more likely. There is a simple correlation of 0.92 between the horsepower of tractors sold and the real value of Bank of Brazil credits for tractors from 1962-1971. From 1950-1971 the simple correlation is 0.67 between the number of tractor imports and the real value of Bank of Brazil financing. In this earlier period exchange rate subsidies were an important policy instrument promoting mechanization (see Appendix B). There are a few other partially government owned banks making mechanization loans; however, the Bank of Brazil is the most important lender for this purpose. (See Appendix E).

A sample of farmers in one of the best agricultural areas in the state of Sao Paulo indicated that of the 168 tractors employed on the 145 farms interviewed 58 percent were financed completely or partially by this subsidized credit. Moreover, informal credit sources were more important for used and imported models and the importance of formal bank credit was increasing (see Appendix E).

from these factor price distortions will be considered.

B. The Brazilian Tractor Industry and Government Policy

In Brazil's process of import substitution the development of the tractor industry was a natural evolution of the automobile industry, which was begun in 1957. Substantial direct subsidies as well as tariff exemptions and protection were provided for both industries. Backward linkages were insured by requiring that firms purchase 95 percent of their parts by weight from domestic producers.[14] By the time the tractor industry was initiated in 1960 many input suppliers for automobiles were in operation and tractor firms could take advantage of this network.

The Brazilian tractor industry grew rapidly in the period, 1960 to 1964, as credit to farmers at negative real rates was

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[14] This requirement was not immediately imposed as firms were given three years or more to move to the 95 percent domestic parts requirement. J. Bergsman, Brazil, Industrialization and Trade Policies (Oxford University Press: New York; 1970), 120-130; Hugo de Almeida Leme, "A fabricacao de tratores e maquinas agricolas no Brasil," Noticias Automobilisticas (April, 1960), 17-19; "Mecanizacao agricola ganha desenvolvimento no Brasil," O Dirigente Rural 11 (Enero/Fevereiro 1972), 9-18.

I am indebted to several people in the Brazilian tractor industry who generously supplied me with data and some appreciation of industry problems. They should not be implicated by my interpretations. Special thanks are due to Tuire Tiovanen, Ilo Soares Nogueira, and Hugo de Almeida Leme.

steadily provided. The post-Revolution governments devoted more verbal attention to agriculture than previous governments but the primary focus of governmental policy from March 1964 to 1967 was to reduce the inflation. Credit was one of the primary instruments. After the disastrously low tractor sales of 1967 credit for tractor purchases was gradually increased to high levels in 1970 and 1971. Several other policy changes were adopted to stimulate the industry. At the end of 1967 the government removed the industrial products tax (IPI) from tractors and simplified financing procedures. The IPI was estimated by industry sources in 1967 to be 2.3 percent of the tractor purchase price. Also in 1967 the government reduced duties and taxes on machinery imports by agricultural machinery producers. In 1968 the rate of interest on agricultural credit was lowered and the repayment period on machinery loans was extended. The state tax (ICM), composing 10 percent of the tractor purchase price, was removed entirely from tractors and then reimposed on the motors in 1970.[15] Farmers were allowed to depreciate their tractors rapidly and

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[15] Ministerio da Agricultura, Plano Nacional de Mecanizacao Agricola, Planame (Carta de Brasilia; 1967) Anexo 1. One of the factories calculated the importance of IPI and ICM on the purchase price of their basic model in 1967. The ICM provides one of the primary revenue sources for state governments. Rates are kept uniform between states by federal controls.

deduct the purchase costs from their tax base. Moreover, the supply of agricultural credit was expanded for mechanization and other purposes. Credit at subsidized interest rates and long repayment periods was the primary governmental instrument to promote tractor sales in the sixties.

Tables 6 and 7 summarize available data on tractor sales, lending, and terms of the Bank of Brazil tractor financing operations in the sixties. Note that the real interest rate for the entire period was negative because the rate of inflation measured by either agricultural price index exceeds the nominal interest rate. At negative real interest rates an excess demand situation necessitating rationing of the available credit would be expected. There are various types of costs, which would arise from this type of capital subsidy. To illustrate these costs a two sector model is diagrammed in Figure 2. In 2-A there is no governmental role and the equilibrium cost of credit and internal rate of return from projects in both sectors is "r_o." In 2-B the government decides that the cost of credit is too high in sector A so this cost is pegged at r_1 and lending institutions are forced to lend the same amount of credit (0A) as in 2-A. In 2-B there is no efficiency loss necessarily but a transfer of $r_o r_1$ DB from lenders to

Table 6

Tractor Sales and Quantity of Financing, 1960-1971

Year	Four Wheel Tractor Sales--Domestic (excluding micro-tractors)	Number of Credits to Buy Tractors of the Bank of Brazil[a]	Number of Tractors Financed by the Bank of Brazil[a]	Nominal Value of Bank of Brazil Loans for Tractors (Cr. 1,000)[b]	Real Value of Bank of Brazil Loans for Tractors in 1971 Cr (Cr. 1,000)[b]
1960	19				
1961	1,645			2,968	90,200
1962	7,336	6,949		9,262	186,000
1963	9,368	6,956		17,914	205,000
1964	12,032	7,968	9,318	41,146	248,000
1965	8,072	6,715	8,116	50,010	192,000
1966	9,214	10,244	10,859	92,115	256,000
1967	6,470	8,522	9,226	95,191	206,000
1968	9,263	9,872	10,537	142,942	249,000
1969	9,671	9,841		151,943	219,000
1970	14,343	12,751		212,064	255,000
1971	21,732	16,096		348,749	348,749

[a]The number of credits is from the Carteira de Credito Agro-pecuaria e Industrial (CREAI) of the Bank of Brazil. Note that the number of credits is often less than the number of tractors indicating that some farmers had several tractors financed. Besides wheel tractors these loans were for financing of micro-tractors, motorized cultivators, and track tractors. An imported tractor cannot be financed unless there is no "national similar." From 1966-1968 imported tractors were 4.4, 7.1, and 6.5 percent of the tractors financed. Banco de Brasil, Relatorios, various issues.

[b]Data for 1969-1971 also included implements, whereas the data prior to these years did not. Fortunately, there were some overlapping observations so that the two series could be spliced by assuming a constant relationship in the proportion of value in tractors and implements over the period. To obtain the real value of tractor loans the nominal value was deflated with the Getulio Vargas Price Index No. 2.

Source: Appendix E and Banco do Brasil, Relatorios, various issues.

Table 7

The Terms of Tractor Financing, 1960-1971

Year	Interest Rates on Loans for Tractors[a]	Commercial Bank Annual Interest Rates (%)	Bank of Brazil Annual Interest Rate	Wholesale Price Index	Agricultural Wholesale Price Index	Repayment Period on Tractor Loans[b]	Repayment Terms[b]
				Rates of Change (%)			
1960		19.6	9.6				
1961	8	22.3	12.3	50.0	53.3	3-4 years	
1962	9	25.1	13.5	50.3	43.7		Generally 4 yr
1963	11	30.5	14.1	81.9	90.0		1st yr. 15%
1964	11	33.3	18.2	93.3	86.5		2nd yr. 25%
1965	17.25	34.7	22.8	28.3	25.3	4-5 years	3rd yr. 30%
1966	17	34.9	25.5	37.4	42.3		4th yr. 30%
1967	18	34.1	21.7	22.7	21.4		
1968	15	33.7	34.7	24.3	15.2	5 years	1st yr. 10%
1969	15	30.9	--	21.8	31.7		2nd yr. 15%
1970	15	--	--	19.5	20.3		3rd yr. 20%
1971	15	--	--	20.0	24.7		4th yr. 25%
							5th yr. 30%

[a]This total interest rate is divided into various categories by the government, i.e., interest, commission, and correction. Agronomist's costs, the financing tax, and the required insurance costs were not included in the above interest rate as data on these additional costs were not obtained for the entire period. In 1970 the agronomist's charges on agricultural loans could not exceed 2 percent of the principal, the required insurance on machinery items cost 0.75%, and the financing tax was 1%.

[b]In November of 1965 Resolution 8 provided for the above terms to be made available for semi-fixed investments in agriculture, whose loan size was greater than 50 times the minimum wage, at the discretion of the bank manager. In 1968 FUNAGRI loans of the Bank of Brazil were made available at the above terms. In 1970 all semi-fixed investment loans above 50 minimum wages were required to be at these terms.

Sources: Data on rates of inflation were taken from Fundacao Getulio Vargas, "A economia Brailieira, 1971," Conjuntura Economica 26 (Fevereiro 1972) 13, 30, and other sources. Data on commercial and Bank of Brazil interest rates were taken from D. Syvrud, "Estrutura e politica de juros no Brasil-1960/70," Revista Brasileira de Economia 26 (Enero/Marco 1972), 123. Also see L. E. Christoffersen, "Taxas de juros e a estrutura de um sistema de bancos comerciais em condicoes inflacionarias-o caso do Brasil," Revista Brasileira de Economia, 23 (Junho 1969), 5-35; data on the interest rates charged on tractor loans were calculated from ANFAVEA, "A racionalizacao da industria de tratores e fundamental para a tecnificao da nossa agricultura-passo decisivo na retomada do desenvolvimento economico do Pais," Separata de Industria Automotiva, 106 (April 1968). More recent data on interest rates on tractors were obtained from the Banco Central, Manual de Credito Agricola (Rio de Janeiro; May 1970).

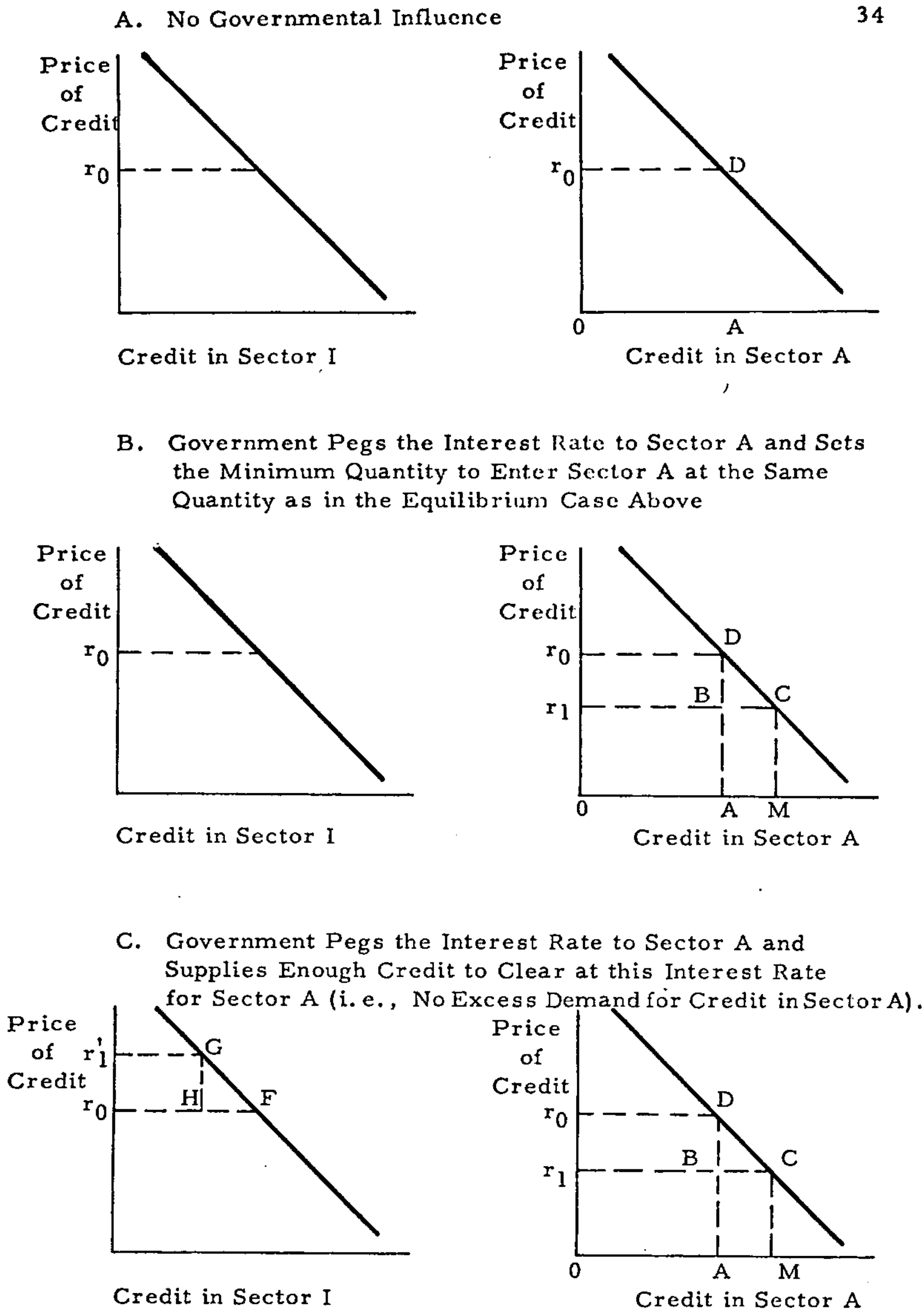

Figure 2. Two Sector Comparative Static Model of the Demand for Credit with and without Governmental Fixing of the Interest Rate.

borrowers. In 1967 Resolution 69 required all banks to lend 10 percent of most classes of deposits to agriculture at rates below the interest rates charged by both private and public banks for other borrowers. If in equilibrium the banking system would lend 10 percent of their deposits to agriculture anyway, then there may be no efficiency loss. Note that in 2-B there is an excess demand for loans by borrowers in sector A at B. In 2-C this excess demand of sector A for loans at r_1 is cleared and in the new equilibrium credit flows into sector A from sector I. There was a rapid expansion of credit for tractors in the late sixties, hence the government through the national and state banks may have been responding to the excess demand for credit at the lower interest rates and pushing the amount of credit towards OM. In this case many investors on the demand curve between D and C would be financed resulting in less financing for those investors along the curve GF. This would result in the classic efficiency loss from the lower rate of return on capital in the favored than in the unfavored sector.[16]

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[16] A. C. Harberger, "Taxation, Resource Allocation, and Welfare," in National Bureau of Economy Research and the Brookings Institution, The Role of Direct and Indirect Taxes in the Federal Revenue System (Princeton University Press: Princeton; 1964).

Now one of the more restrictive implicit assumptions above is removed. In 2-B at interest rate r_1 there was a demand for OM quantity of credit in sector A but the rationing machinery for allocating credit was able to identify potential borrowers and estimate their expected internal rate of return and cut off lending at D. Applicants on the demand curve DC would not be financed. This assumes a sophisticated rationing machinery, which entails a cost to the banking or public sector in identifying borrowers, since the market mechanism will no longer effectively screen investors. Now with the government and private savers in 2-B financing part of the cost of the investment project the private investor is willing to invest in a project whose rate of return is less than the real cost of credit. The rationing problem becomes serious when the nominal cost of credit is set below the inflation rate. Not only would governmental and banking agencies be expected to finance some of the prospective investors along DC, but there are costs associated with this rationing process. These costs may be high if substantial governmental and banking personnel effort goes into defining and administering criteria for rationing this credit.[17]

When transfers from bank depositors to investors are made by ceilings on savings and lending rates and minimum quotas for agricultural lending, it transfers income from savers to investors. Also if excess demand pressure results in an expansion of credit to the favored sector, efficiency losses will result from encouraging investment in which the discounted returns are less than the return in other investments. Theoretically, the government could ascertain the equilibrium quantity of credit, OA, without the subsidy and ration the credit only to those investors whose rate of return is equal to the cost paid by society for their capital investment. In practice it would be difficult for government and banking agencies either to resist the pressures of excess demand at the pegged rate or to effectively screen their clientele.

Hence to the costs of establishing and policing rationing criteria are added the efficiency losses expected to result when

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[17] For agricultural machinery loans the primary published rationing criteria are land title and a minimum land area. See Table E-2. Other types of credit have more sophisticated criteria such as the minimum altitude requirement for financing coffee planting.

To the extent that a "black market" mechanism exists to obtain the rationed credit part of the rent would be obtained by the seller or other party to the rationing scheme except the buyer. In this case the official interest rate understates the real credit costs.

investment is encouraged by underpricing capital services in one sector. Distorted capital prices result in an absolute loss of efficiency in the capital market. This chapter has summarized the types of efficiency losses from capital subsidies and documented their importance in determining tractor sales over time. Cross-sectional analysis of mechanization levels between states and regions in the next chapter provides supplementary information on the determinants of investment in agricultural machinery in Brazil. In the next chapter one effect of these subsidies on the factor proportions choice will be considered by estimating the elasticity of substitution between labor and machinery in Brazilian agriculture.

CHAPTER 3

THE REGIONAL DISTRIBUTION OF BRAZILIAN MECHANIZATION

The concentration of tractors and other heavy agricultural machinery in the South of Brazil has been frequently noted (Tables 8 and 9) and recently the object of special governmental policy.[1] However, there has been no statistical analysis of this regional concentration. Regional data have been collected to undertake this analysis. These regional data are also useful for testing hypotheses about agricultural mechanization such as the impact of variations in labor costs upon the labor-machinery choice. With micro data from a specific region there is generally little variance in labor costs between farms; however, between regions there are substantial differences.

To analyze the regional concentration of Brazilian agricultural mechanization two models will be developed in this chapter. The primary inducement for mechanization would be expected to be the regional differences in labor costs[2]

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[1]"Tratores de rodas, a explosao do crescimento," Transporte Moderno (April, 1972), p. 12.

[2]Both Marx and Ricardo pointed out the relationship between labor costs and mechanization. Cited in A. K. Sen, Choice of Technique, An Aspect of the Theory of Planned Economic Development (Oxford University Press: London; 1962), 61.

Table 8

Location of Agricultural Tractors Between States in Brazil, 1920-1970

Census of:	Sao Paulo	Rio Grande do Sul	Parana	Minas Gerais	Goias[a]	Santa Catarina	Mato Grosso	Rio de Janeiro[b]	Bahia	Pernambuco	Brazil
1920											
Number	401	817	95	153	1	94	1	64	12	36	1,706
% of Total	23.5	47.9	5.6	9.0	--	5.5	--	3.8	0.7	2.1	
1940											
Number	1,410	1,104	65	253	13	71	15	148	43	72	3,390
% of Total	41.7	32.7	1.9	7.5	0.4	2.1	0.4	4.4	1.3	2.1	
1950											
Number	3,819	2,245	280	763	89	41	50	515	82	142	8,372
% of Total	45.6	26.8	3.3	9.1	1.1	0.5	0.6	6.2	1.0	1.7	
1960											
Number	27,176	15,169	5,181	4,772	1,356	1,106	838	1,658	588	1,002	61,324
% of Total	44.3	24.7	8.4	7.8	2.2	1.8	1.4	2.7	0.9	1.6	
1970											
Number	65,731	38,317	17,190	9,245	5,523	5,026	3,925	3,604	1,366	1,328	156,592
% of Total	42.0	24.5	11.0	5.9	3.5	3.2	2.5	2.3	0.9	0.8	

[a] Includes the Federal District

[b] Includes Guanabara

Source: IBGE, Preliminary Agricultural Census Results (Rio de Janeiro; 1972). Includes all tractors used in agriculture.

Table 9

Tractor-Labor Ratios for the Brazilian States and the U. S., 1950 to 1970

State	Tractors per 1,000 Agricultural Workers 1950	1960	1970	United States: Tractors per 1,000 Agricultural Workers Year	
Sao Paulo	2.49	15.7	43.5	1950	360
Rio Grande do Sul	2.10	11.4	26.1	1951	410
Rio de Janeiro	1.65	6.29	13.7	1952	460
Mato Grosso	0.579	4.49	10.3	1953	490
Goias[a]	0.297	2.70	9.57	1954	520
Guanabara	3.51	6.02	8.69	1955	560
Parana	0.532	4.03	8.53	1956	610
Santa Catarina	0.110	1.92	6.49	1957	650
Minas Gerias	0.408	2.28	4.35	1958	670
Espirito Santo	0.212	1.78	3.19	1959	700
Alagoas	0.127	0.901	2.01	1960	720
Rio Grande do Norte	0.072	1.10	1.56	1961	760
Para	0.150	1.04	1.46	1962	780
Sergipe	0.291	0.345	1.35	1963	810
Pernambuco	0.161	0.793	1.15	1964	870
Paraiba	0.143	0.847	1.12	1965	980
Bahia	0.064	0.323	0.618	1966	1,060
Ceara	0.064	0.259	0.532	1967	1,130
Piaui	0.097	0.198	0.321	1968	1,180
Amazonas	0.124	0.162	0.199	1969	1,200
Maranhao	0.044	0.051	0.101	1970	1,205

[a]Includes the Federal District

Source: Brazilian data were taken from IBGE, Preliminary Results of the 1970 Census; the U. S. data were taken from USDA, 1971 Changes in Farm Production and Efficiency, A Summary Report, Statistical Bulletin No. 233 (Economic Research Service: Washington; June 1972) 22, 29. The agricultural labor force includes all workers in agriculture in both countries.

assuming that the costs of capital are equal between regions. As labor costs increase, it becomes more profitable to substitute for labor as long as there are alternative production techniques available. The existence of alternative production techniques is expressed in economic models as an elasticity of substitution greater than zero. A low elasticity of substitution implies a smaller effect from the factor price distortions through the subsidized lending. The simple factor price model then needs to allow for testing of the importance of agricultural labor and machinery costs in influencing mechanization and to estimate the elasticity of substitution between labor and machinery.

The Model:

The two factor CES production function was originally developed to consider factor substitution between capital and labor.[3] The Cobb-Douglas production function was inadequate as it forces the elasticity of substitution between factors to be equal to one and the estimation of this substitution parameter was the primary reason for the development of the CES function. Extension of the CES production function to the multi-factor

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[3]K. J. Arrow, H. B. Chenery, B. S. Minhas, and R. M. Solow, "Capital-Labor Substitution and Economic Efficiency," Review of Economics and Statistics 63 (August 1961), 225-250.

case has been difficult as the simple specification of the CES function forces the elasticity of substitution between all factors to be equal. To avoid this restriction while still retaining a functional form which is relatively simple to estimate Sato and de Janvry have developed a two stage CES function.[4] In this two stage model as adapted here there are two augmented factors -- land and labor. All capital is dichotomized into land and labor substitutes. Then there are three elasticities of substitution which can be estimated. A low elasticity of substitution between the augmented factor bundles and high elasticities of substitution between the primary factor and their capital substitutes would be expected. Or it is easier to substitute between tractors and labor and between fertilizer and land than between land and labor. These elasticities of substitution between the factors and their augmenting substitutes are then of primary concern in considering the substitution relationship of technological change in agriculture.

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[4] K. Sato, "A Two Level Constant Elasticity of Substitution Production Function," Review of Economic Studies 34 (April 1967), 201-208; A. de Janvry, "A Socioeconomic Model of Induced Innovation for Argentine Agricultural Development," Quarterly Journal of Economics, forthcoming.

This two stage CES production function is summarized in equations (1) to (3) below.[5]

(1) $Y = a \left[\alpha A^{-\beta} + (1 - \alpha) L^{-\beta} \right]^{-v/\beta}$

(2) $A = b \left[\gamma C_1^{-\epsilon} + (1 - \gamma) A_1^{-\epsilon} \right]^{-d/\epsilon}$

(3) $L = c \left[\lambda C_2^{-\rho} + (1 - \lambda) L_1^{-\rho} \right]^{-f/\rho}$

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[5] This is a generalization of the factor augmenting CES production function encountered frequently in the literature:

$Y = a \left[\alpha (E_L L)^{-\rho} + (1 - \alpha) (E_K K)^{-\rho} \right]^{-1/\rho}$

where $E_L = b_1 e^{r_1 t}$ and $E_K = b_2 e^{r_2 t}$. L and K are labor and capital respectively and E_L and E_K are labor and capital augmenting technological change. These equations are customarily estimated over time with r_1 and r_2 constant rates of technological change of the two augmenting factors respectively. The above functional form forces a Cobb-Douglas substitution relationship or an elasticity of substitution of one between E_L and L and between E_K and K.

This model is also a two stage model with a Cobb-Douglas substitution relationship between the factor and its augmenting component and a CES relationship between the augmented factors. For examples of the use of this model see P. D. David and T. v. d. Klundert, "Biased Efficiency Growth and Capital-Labor Substitution in the U. S., 1899-1960," American Economic Review 45 (June 1965), 357-395; J. R. Behrman, "Sectoral Elasticities of Substitution Between Capital and Labor in a Developing Economy: Time Series Analysis in the Case of Postwar Chile," Econometrica 40 (March 1972), 311-327; R. Sato, "The Estimation of Biased Technical Progress and the Production Function," International Economic Review (June 1970), 179-201.

The model employed in (1) to (3) above allows for an elasticity of substitution different from one between the factor and its augmenting substitute, does not require constant returns to scale, and makes no assumptions about the process of technological change over time.

Where Y is aggregate agricultural output, A is land and land substitutes, L is labor and labor substitutes, A_1 is land and C_1 is a land substitute bundle, L_1 is labor and C_2 is a labor substitute bundle. The remaining letters are the standard parameters of a CES production function.[6] The primary concern here is with the derived demand equation rather than estimating the parameters of the production function. Differentiating Y with respect to C_2 and L_1 gives the following ratio of marginal products:

$$(4) \quad \frac{\partial Y / \partial L_1}{\partial Y / \partial C_2} = \frac{(1 - \lambda)\, L_1^{-\rho - 1}}{C_2^{-\rho - 1}}$$

where the "λ s" are the factor share parameters of the CES function. The ratio of marginal products can be set equal to factor prices if input markets are in equilibrium and there is perfect competition in input and product markets. Setting (4) equal to the factor price ratio and solving for C_2/L_1 gives:

$$(5) \quad \frac{C_2}{L_1} = \left(\frac{\lambda}{1 - \lambda}\right)^{\frac{1}{1+\rho}} \left(\frac{W}{P_{C_2}}\right)^{\frac{1}{1+\rho}}$$

where W is the agricultural wage rate and P_{C_2} is the rental cost of labor substituting inputs. As in simpler formulations

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[6] For a summary of the economic interpretation of these parameters see M. Brown, On the Theory and Measurement of Technological Change (Cambridge University Press: London; 1968), 43-61.

of the CES production function the ratio of marginal products reduces to a function of the factor shares $(\frac{\lambda}{1-\lambda})$, the elasticity of substitution $(\frac{1}{1+\rho})$, and the two factors C_2 and L_1. Neither the other input prices nor the output price enters into the above factor demand equation so that the assumption of strong separability between factor demand equations is necessary.[7] Using tractors as a proxy for all mechanization and since the elasticity of substitution, σ, is equal to $\frac{1}{1+\rho}$, (5) can also be expressed as the derived demand function for tractors relative to labor:

$$(6) \quad \log \frac{T}{L_1} = \sigma \log \left(\frac{\lambda}{1-\lambda}\right) + \sigma \log \frac{W}{P_t}$$

where T is tractor units and P_t is the rental cost of tractors. Data were not available on tractor rental costs[8] so the estimating equation was modified so that the P_t term enters the constant:

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[7]Strong separability means that only the price of the factor and its substitute determine the demand for each augmented factor class. K. Sato, "A Two-Level Constant Elasticity of Substitution Production Function," op. cit., p. 205.

[8]The tractor rental price (P_t) is equal to the capital cost of tractors (P) times the interest rate (r) plus the depreciation rate (γ) plus the variable costs of tractor use as a percent of capital costs (v). $P_t = P(r + \gamma + v)$. The capital costs and interest rates would be approximately the same between states with the former only varying with the transportation costs. Depreciation may vary to the extent that repair and maintenance services are more adequate in the more industrialized states. Similarly, the variable costs of fuel and repair may vary inversely with the level of industrialization. No data were available on these components of tractor rental cost.
(continued on next page)

$$(7)\quad \log \frac{T}{L_1} = \sigma \left[\log \left(\frac{\lambda}{1-\lambda} \right) - \log P_t \right] + \sigma \log W + \varepsilon_i$$

where ε_i is the error term. Due to the lack of data on P_t the constant term will not give any information on the relative factor shares. However, the primary interest here is in the estimate of the elasticity of substitution (σ) between labor and tractors. This elasticity of substitution will be the coefficient of the wage rate in Table 10.

In most aggregate studies of machinery investment the capital cost rather than the rental price is employed. The rental price is more appropriate but its components are generally not available. Of the components of the capital cost of tractors only the transportation cost would vary between states.

If there is a correlation between the tractor rental cost and the wage rate, a specification bias of σ would result. The bias would be expected to be negative so that the high values of the elasticities of substitution would tend to be further strengthened. Ordinary least squares estimation techniques were employed. With group observations there is a loss of efficiency from the violation of the homoscedascity; however, the OLS estimators are still unbiased. The standard error will be biased so conventional hypothesis testing requires a transformation of the variables. See J. Kmenta, Elements of Econometrics (Macmillan Co.: New York; 1971), 256.

Table 10

Regression Results for the Tractor-Labor Ratios Between Areas As a Function of the Agricultural Wage Rates

Form of Observation	No.	Constant	Wage Rate W	Standard Error of the Estimate	$\bar{R}^2$	Degrees of Freedom
1950 Census: States of Brazil	(1)	-12.10	1.49	0.66	.71	19
		(1.59)	(7.04)*			
1960 Census: States of Brazil	(2)	-0.87	1.89	0.84	.66	19
		(.81)	(6.31)*			
1960 Census: Regions of Sao Paulo	(3)	3.24	0.90	0.72	.18	31
		(1.06)	(2.87)*			

(Both variables were in logarithmic form and the t-values are given below the coefficient estimates in parentheses except for the standard error of the constant.)
*Significant at the 99 percent level.

The results of Table 10 indicate the importance of agricultural wage rates in explaining differences in factor proportions between states. Moreover, the estimates of the elasticity of substitution are substantial enough to suggest a large response in factor substitution to the relative factor prices.

The Expanded Factor Price Model:

The literature on agricultural mechanization suggests several other variables which may influence the factor proportions choice between labor and machinery. Expanding this simple factor price equation to include these variables enables testing of their influence on Brazilian agricultural mechanization.[9] Besides labor costs the mechanization decision may be affected by cropping intensity, the distribution of farm size, the crop mix, and there may be regional differences in the mechanization process.[10] In the rest of this section the rationale for including these other variables will be explained.

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[9] A more serious problem than hetereoscedascity in the simple factor price equation may be the bias and inconsistency from specification error due to the omission of relevant variables. See J. Kmenta, Elements of Econometrics (The Macmillan Company: New York; 1971), 392-395.

[10] Some of these variables were used in a cross sectional study of tractorization in Western Europe. See H. G. Scott and D. J. Smyth, Demand for Farm Machinery-Western Europe, Study No. 9, Royal Commission on Farm Machinery (Queen's Printer: Ottawa; 1970).

A tractor purchaser is hypothesized to be influenced by his cash expenditures in the field such as fertilizer purchase. This variable of expenditures on bio-chemical inputs per hectare is termed here the intensity variable. Once the farmer opts to take the risk[11] associated with higher levels of fertilizer and other cash expenditures, the timing of his critical operations becomes more important. Whether a farmer harvests in two days or a week is less important when yields are low and the only investment in the field is family labor. The higher potential earnings associated with increased fertilizer use are associated with greater risk; however, mechanization offers the prospect of reducing some of the weather risk by enabling the performance of critical operations more rapidly.[12]

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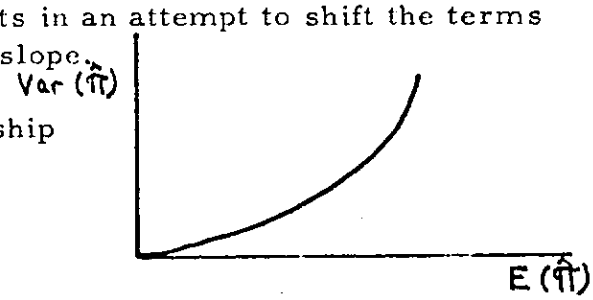
[11] Alain de Janvry, "Optimal Levels of Fertilization Under Risk: The Potential for Corn and Wheat Fertilization Under Alternative Price Policies in Argentina," American Journal of Agricultural Economics 54 (February 1972), 1-10.

[12] According to this hypothesis farmers have a quadratic utility function into which expected profits and the variance of these profits enter. Higher profit levels require more risk as indicated by the trade-off in the figure below. Farmers mechanize and make other risk avoiding investments in an attempt to shift the terms of the trade-off or change its slope.

The Hypothetical Relationship Between Expected Profits and Expected Variance of Profits



The intensity hypothesis is closely related to farm size distribution. On smaller farms an excess of family labor could more easily be used to cope with increased power requirements from more intensive cropping. Hence, the larger the farm the more unlikely that family labor will be in surplus prior to the shift to more intensive cropping.

Moreover, unless the custom rental market functions efficiently, machinery will be a "lumpy" or indivisible input. Tractors, harvesters, and other machines do not come in every horsepower size. Custom operators could reduce this "lumpiness"; however, this may not occur as the period of peak season rental demand for machinery services for a given crop would also be the period of peak season owner demand. A renter then may be able to get machinery services near the peak season demand time but he would not be able to count on obtaining these services unless he were willing to bid the machinery away from the owner at the critical time. Hence, the variance of his expected earnings would still be large and he would be less inclined to crop as large an area or to invest as much in the field as those with an available supply of owned equipment as long as the timing of certain operations is important. (See Appendix E for data to support this inference.) Moreover, there are several developments in Brazilian agricultural policy and in the Brazilian tractor industry, which give external economies in tractor use to large farmers by reducing the price of machinery per horsepower unit for the larger models. Larger farmers have an advantage in obtaining the subsidized credit for machinery loans and there is a continuing tendency in the Brazilian tractor industry to shift to production of the larger models (see Appendices C and E especially Table E-2).

It is useful to consider the power decision of a farmer shifting to more intensive production.[13] Assuming no excess capacity of the power supply prior to this crop shift the farmer can choose some combination of the following five power sources when he shifts to more intensive production,

a) increased number of work animals,

b) increased number of share croppers,

c) increased employment of permanent workers,

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[13] Large farms with extensive operations such as beef cattle or little cash investment in the field would not be expected to mechanize as rapidly as large farms in annual crop production with substantial investment in fertilizer and other bio-chemical inputs. An analysis of the shift of large farmers from beef cattle to wheat-soybeans in Rio Grande do Sul is presented in J. J. de C. Engler, "Alternative Enterprise Combinations Under Various Price Policies on Wheat and Cattle Farms in Southern Brazil," unpublished Ph.D. thesis, Ohio State University, 1971.

d) increased employment of temporary workers,

e) mechanization.

The economics of substitution of machinery for animal power has been considered frequently in the Indian literature.[14] Rao has argued that in India the rising price of land with the increasing demand for more and a higher value of agricultural products in the process of economic growth will raise the opportunity cost of using land for fodder. In his argument mechanical power alleviates a shortage of land as reflected in the higher cost of feeding work animals. In Brazil even in the best farming areas near the large industrial centers there is substantial variation in land quality and a tendency for the lower quality land to be used in pasture. Moreover, fertilizer is a much more effective substitute for land than mechanical power so that a rising land price is a better argument for shifts to more intensive land use through fertilization and specialization in higher valued crops than for mechanization. Hence, the Indian argument of the inducement factor for mechanization being the rising opportunity cost of land in fodder crops does not seem to be relevant for Brazil.

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[14] C. H. Hanumantha Rao, "Farm Mechanization in a Labor Abundant Economy," Economic and Political Weekly 7 (February 1972), 393-400; S. S. Johl, "Mechanization, Labor Use, and Productivity in Agriculture," (Ohio State: Department of Agricultural Economics, 1971), 27 pages.

The choice of employing more share croppers is another method of increasing the power supply. Various regulations to protect the rights of sharecroppers and extend social legislation to rural workers could raise the expected price of sharecroppers or permanent workers at the farm level. The fear of present or future social legislation[15] may discourage the large farm operator

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[15]Although much of the social legislation can be avoided at the farm level due to its complexity or lack of enforcement mechanisms, a large farmer with sharecroppers or permanent workers may have a comparative disadvantage in avoiding these laws. For a thorough discussion of the policy issues involved in agricultural mechanization see K. C. Abercrombie, "Agricultural Mechanization and Employment in Latin America," International Labor Review 55 (July 1972), 11-45; and K. C. Abercrombie, "Preliminary Note on Agricultural Employment Problems in Brazil," mimeo December 1971, 14 pp.

For a historical treatment of the effect of strikes and labor shortages on the production of mechanical technology in industry see N. Rosenberg, "The Direction of Technological Change: Inducement Mechanisms and Focusing Devices," Economic Development and Cultural Change 18 (October 1969), 1-24.

Gotsch argues that labor unrest from the increasing skewness of income distribution in the process of rapid technological change in agricultural development is a contributing factor to the large farmer decision to mechanize rather than expand labor use. The expectation of increased social unrest is an additional expected cost to the landowner. This concept introduces a vicious circle prospect to the income distribution-technological change process expected in agricultural areas where land holdings are initially skewed. C. H. Gotsch, "Technical Change and the Distribution of Income in Rural Areas," American Journal of Agricultural Economics 54 (May 1972), 340.

from employing sharecroppers. There are also several regulations raising the cost of permanent and temporary labor to the farmer.[16]

The choice of power source to the large crop producer narrows down to the choice between d) seasonal or temporary labor and e) mechanization. In the short run he can not rapidly expand his supply of work animals and he needs an increased labor supply to handle these animals. He can justify the employment of a small number of sharecroppers and/or permanent workers; however, he will either be faced with a need to supplement these permanent employees during the peak seasonal demand periods or his permanent labor force will be underemployed during the rest of the year due to the seasonal nature of the demand for labor with annual crops.[17] A farmer can produce crops with a staggered peak season labor demand

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[16] For detail on Brazilian legislation see Fundacao Getulio Vargas, "Encargos sociais do empregador," Conjuntura Economica 26 (April 1972), 59-61.

The landlord can presently reduce the cash minimum wage up to 30 percent by providing payment in kind.

[17] For more detail on seasonal labor requirements based on farm account data from Sao Paulo see Secretaria da Agricultura, Resultados Comparativos da Contabilidade Agricola, 1968-69 (Instituto de Economia Agricola: Sao Paulo; 1970).

In India the introduction of high yielding varieties was accompanied by a substantial increase in seasonal labor expenditures. M. Yudelman, G. Butler, and R. Banerji, Technological Change in Agriculture and Employment in Developing Countries (OECD: Paris; 1971), 76, 84.

in order to more fully utilize his labor; however, his ability to produce an annual crop mix with a constant level of demand for labor is ultimately constrained by the weather especially the seasonal variations in rainfall. In southern Brazil there is a pronounced dry season beginning around May and extending into September-November.

A farmer faced with this choice between hiring supplementary teams of labor to cope with a seasonal labor shortage may prefer to mechanize. He can thereby avoid a higher seasonal, day labor cost[18] plus the uncertainty and management problems

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18 Billings and Singh argue that the primary incentive for mechanization in the Punjab is the sharp seasonal increase in labor demand for the critical operations of planting and harvesting. With more intensive cropping permanent labor is insufficient to cope with these seasonal increases. Moreover, there is a regional effect in areas producing the same crop mix of a substantial increase in day labor costs during the periods of peak demand. This upward shift in seasonal demand for labor could be offset with an effectively functioning system of migratory labor but there has been little interest in this alternative in the literature on agricultural mechanization in the developing countries. See M. H. Billings and A. Singh, "Mechanization and Rural Employment," Economic and Political Weekly 5 (June 27, 1970), A61-A72.

Another study which has emphasized the importance of mechanization in response to a seasonal scarcity of temporary labor is I. Inukai, "Farm Mechanization, Output and Labor Input: A Case Study in Thailand," International Labor Review (May 1970), 453-473. Also see I. R. Wills, "Projections of Effects of Modern Inputs on Agricultural Income and Employment in a Community Development Block, Uttar Pradesh, India," American Journal of Agricultural Economics 54 (August 1972), 458, 459.

associated with the locating, coordinating, and controlling of a temporary labor force several times a year. The larger the crop acreage the more serious the management problem associated with a large seasonal labor force would be (see Appendix A-III). The variable for the concentration of large crop farms could then affect the factor proportions choice because of economies of scale in machinery use, greater difficulty in substituting labor for machinery on a large scale, or other reasons.

The crop mix also is expected to affect the factor proportions choice. Most operations for permanent crops excluding the initial land clearing and preparation are difficult to mechanize. Moreover, once the permanent crop is formed, the basic land preparation activities, in which mechanical power has the greatest advantages over other power sources, will not be required again for a long time. Annual crops then utilize more mechanical power as they require the land preparation activities every year.

Finally, the three variables, intensity of operation, concentration of crop area, and crop mix all pick up some of the effects attributed to the "timeliness" argument for mechanization in U. S. studies.[19] The timeliness concept is that for certain crops or crop combinations, soils and weather regimes, mechanization reduces risks or the probability of crop loss by enabling the performance of a given operation in a shorter time period. Unfortunately, the model here has not sufficiently developed the "timeliness" concept to make a direct empirical test of its relevance to Brazil. The concept is tested indirectly to the extent that variables employed here pick up the components of this timeliness concept.

Since the major Brazilian input and product markets are located in the South, a different relationship between the tractor-labor ratios and the independent variables may exist in the Northeast and the North than in the South. A regional dummy was used to separate these two areas. The demand function to be estimated is:

$$(8)\quad \log \frac{T}{L_1} = \log B + \alpha_1 \log W + \alpha_2 \log \frac{I}{A} + \alpha_3 \log T_e + \alpha_4 \log D + R_e + \mathcal{E}_i$$

where B is a constant, W is the agricultural wage rate, $\frac{I}{A}$ the intensity variable is the expenditures on seeds, plant stock,

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[19] J. B. Hottel, W. R. Grant, and T. Mullins, Equipment Technology and Weather on Rice Farms in the Grand Prairie, Arkansas. Part I: Farm Organization and Risk, Bulletin 734 (Agricultural Experiment Station, University of Arkansas: Fayetteville; December 1968).

fertilizer, and other agricultural chemicals per hectare of crop land, T_e is the crop mix variable, and is equal to the percentage of area in annual crops in the total crop area, D is the percentage of crop area in crop farms with over 100 hectares in crops, R_e is the regional dummy, and $\mathcal{E}_i$ is the error term. (See Appendix A-II for further description and the variables themselves.)

Since the wage rate would be largely determined by the interaction of the farm and the non-farm labor markets and the degree of mechanization was still low in the observation periods (see Appendix D), the agricultural wage rate would be largely exogeneous. The crop mix and intensity of production decisions are assumed to be made prior to and independent of the mechanization decision.[20]

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[20] To the extent that these decisions are made simultaneously hence endogenous to the system the estimated coefficients will be inconsistent. In the case of a serious simultaneity bias it would be necessary to use instrumental variables or a system of simultaneous equations to obtain consistent estimates. Both adjustments require more data than were available. R. J. Wonnacott and T. H. Wonnacott, Econometrics (John Wiley and Sons, Inc., New York: 1970), 152-155.

The Results:

The wage rate coefficient is significantly greater than zero and indicates the statistical relationship between labor costs and the mechanization decision (Table 11). The other variables, intensity, crop mix, and concentration, all have significant coefficients, the expected positive signs, and affect the estimate of the wage rate coefficient. Hence, these variables are consistent with the theoretical justification for including them. The regional dummy for the intercept shifter was weakly significant in 1950 and not significant in 1960. This is an important result because 84 percent of the adjusted tractor units in 1950 and 87 percent of the tractor horsepower in 1960 were in the South of Brazil. The insignificant regional dummy for 1960 then gives some evidence that the variables specified are picking up the factors creating the regional differences in mechanization levels observed in Brazil. Moreover, the significance of the regional dummy in 1950 but not in 1960 is consistent with a diffusion process of technological change in which mechanization was first concentrated in one specific area and then over the decade diffused to the extent that it was encouraged by the conditions indicated with the independent variables.

The statistical results seem to justify the use of the extended factor price model. Higher mechanization levels

Table 11

Regression Results for the Tractor-Labor Ratios as a Function of Wage Rates and Other Variables

Form of Observation	No.	Constant	Wage Rate W	Intensity $\frac{I}{A}$	Crop Mix Te	Concentration D	Regional Dummy Re	Standard Error of Estimate	R^2	F Level	Degrees of Freedom
1950 Census: States of Brazil	(1')	-16.45	1.49	0.31	0.79			0.59	.77	23.0	17
		(3.40)	(5.00)***	(1.99)*	(1.89)*						
	(2')	-17.57	1.58	0.35	0.93	-0.16		0.58	.77	17.9	16
		(3.51)	(5.17)***	(2.22)**	(2.17)**	(1.15)					
	(3')	- 9.34	0.74	0.35	0.29	0.042	0.96	0.53	.81	18.1	15
		(5.10)	(1.50)	(2.45)**	(5.85)***	(2.58)**	(2.07)*				
1960 Census: States of Brazil	(4')	- 4.86	1.52	0.67	1.33			0.69	.77	23.7	17
		(2.51)	(3.80)***	(2.49)**	(2.79)**						
	(5')	- 6.78	1.87	0.45	1.14	0.55		0.58	.84	27.0	16
		(2.22)	(5.20)***	(1.90)*	(2.82)**	(2.81)**					
	(6')	- 4.33	1.32	0.44	0.86	0.53	0.76	0.55	.86	24.9	15
		(2.53)	(2.81)**	(1.95)*	(2.06)*	(2.85)**	(1.73)				
1960 Census: Regions of Sao Paulo	(7')	0.40	1.11		0.52			0.65	.32	8.6	30
		(1.43)	(3.75)***		(2.71)**						
	(8')	0.52	1.06	0.26	0.51			0.65	.33	6.3	29
		(1.42)	(3.58)***	(1.20)	(2.65)**						
	(9')	- 0.16	0.35	0.19	0.62	0.80		0.46	.67	17.4	28
		(1.00)	(1.44)	(1.30)	(4.57)***	(5.57)***					

(t-values in parentheses except for the standard error of the constant)
*significant at the 90 percent level
**significant at the 95 percent level
***significant at the 99 percent level

are associated not only with higher agricultural labor costs but also with increased use of bio-chemical inputs, crop shifts from permanent to annual crops, and concentrations of large crop operators.

The importance of differences in labor costs in influencing mechanization was indicated and is consistent with other work on induced innovation in agriculture.[21] Northeasterners should not be surprised at the lack of mechanization there, given the prevailing very low agricultural wages. Judging by the significance of the other variables the mechanization decision is also influenced by decisions to use other inputs, the crop mix, and the size of crop operations. The policy implications of the significance of the crop farm size are especially important. The statistical results are consistent with the argument that mechanization facilitates larger farmers in producing annual crops more intensively. In the absence of mechanization small and medium size farmers may have an initial comparative advantage in adopting higher levels of bio-chemical inputs on annual crops since these shifts require increased labor use and the smaller the farm the more probable it is that it will have a surplus of family labor.

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[21] Y. Hayami and V. W. Ruttan, op. cit., 133.

It has been shown in Chapter 2 that the capital subsidies have an important effect on the tractor investment decision. In this chapter the importance of wage rates, crop farm size, and other variables on the choice between tractors and labor has been shown. The generally high elasticities of substitution indicate that factor proportions in agriculture are very responsive to relative factor prices (see Appendix A-III). Consequently, the subsidies on the machinery price through the credit mechanism would have had a substantial impact upon employment in agriculture. In the next chapter these employment impacts are considered in more detail.

CHAPTER 4

THE IMPACT OF MECHANIZATION AND MACHINERY SUBSIDIES UPON LABOR ABSORPTION IN BRAZILIAN AGRICULTURE

A. The Impact of Technological Change and Crop Shifts Upon Labor Absorption.

The Problem:

In 1950 almost two-thirds of Brazil's active labor force was employed in agriculture producing a little more than one-fourth of domestic production (Table 12). Consequently, the average product of agriculture was considerably below the other two sectors with per capita income 5,500 Cr. in agriculture, 18,500 Cr. in the secondary sector, and 24,000 in the tertiary sector.[1] Given the lower incomes in agriculture it is not surprising that from 1950-1970 employment in agriculture grew less rapidly than in other sectors[2] and there was substantial migration out of rural areas.

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[1] Fundacao Getulio Vargas, "Evolucao da mao-de-obra brasileira," Conjuntura Economica 10 (June 1956), 85. The secondary sector includes mining, manufacturing, construction, and public utilities. The tertiary sector includes commerce, transport and storage, and other activities.

[2] Republica Federativa do Brasil, I Plano Nacional de Desenvolvimento PND 1972/1974 (Brasilia: November 1971), 64.

Table 12

Production and Employment in the Agricultural Sector of the Brazilian Economy, 1950-1970

	1950	1950-1960	1960	1960-1970	1970
Agriculture:[a]					
Percent of domestic production[b]	26.4		21.0		18.0
Percent of total active labor force	65.5		53.7		44.2
Total agricultural labor force	12,613,849		15,633,985		18,248,999[a]
Adult male agricultural labor force	7,672,000		9,241,857		N.A.
Compound growth rate of domestic production		4.05		4.3	
Compound growth rate of employment: All agriculture		1.7		0.6	
Crops and livestock		2.2		1.6	

[a]Besides crop and livestock production this includes forestry, vegetable extraction, hunting and fishing. In 1950 the other activities besides crop and livestock production only included 2.7 percent of total employment. Considering only crop and livestock production this sector is 62.8 percent of the economically active work force in 1950. The absolute number or workers in agriculture employed the narrower definition of labor in crop and livestock production and was obtained from the Herrmann summary of Census data for 1950 and 1960. The 1970 estimate of the total agricultural labor force would also include these other categories.
[b]Valued at factor costs.

Sources: 1950 employment data were taken from Fundacao Getulio Vargas, "Evolucao da mao-de-obra brasileira," Conjuntura Economica 10 (Junho 1956), 85. In this article corrections were made for the underenumberation of the agricultural labor force in the 1950 census; the data on domestic production were taken from Fundacao Getulio Vargas, "Balanco de uma decada," Conjuntura Economica 24 (Enero 1970), 7; the employment data for 1960 and 1970 were calculated from Fundacao Getulio Vargas, "O censo demografico de 1970," Conjuntura Economica 26 (Fevereiro 1972), 151; employment growth rates were taken from Republica Federativa do Brasil, I Plano Nacional de Desenvolvimento (PND) 1972/1974 (Brasilia: November 1971), 65; and L. F. Herrmann, Changes in Agricultural Production in Brazil, 1947-65, Foreign Agriculture Economic Report No. 79 (Economic Research Service, USDA: Washington, June 1972), 38; and the IBGE, Censo Agricola Preliminar, 1970 (Rio de Janeiro; 1972).

One policy problem of agricultural development in Brazil is how to increase incomes and productivity without releasing a large number of agricultural workers because the other sectors would not be able to absorb them over a short time period. A measure of the appropriateness of the introduction of mechanization in agriculture then is the ability of the non-agricultural sector to absorb labor released from the agricultural sector.[3] Table 13 summarizes some of the principal components of the demand and supply for labor in the non-agricultural sector. Impact on labor absorption of the growth of Brazilian manufacturing is offset by the capital intensity of this sector.[4] Little information is available

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[3]The Hayami-Ruttan criterion for the appropriateness of the introduction of mechanization is when the labor supply is more inelastic than the land supply. These inelasticities would be reflected by changes in relative factor prices over time. In Brazil there are very serious aggregation problems in obtaining a land price index due to extreme variations in land quality between regions so operationally this criterion may not be very helpful.

See Y. Hayami and V. W. Ruttan, Agricultural Development: An International Perspective, (The Johns Hopkins Press: Baltimore; 1971), 132-135.

[4]The value of production in the secondary sector grew at a 9.1 percent compound rate in the fifties and a 6.6 percent rate in the sixties; however, employment in manufacturing increased at a 2.2 and 4.6 percent rate respectively. The data on domestic production were calculated from Fundacao Getulio Vargas, "Balanco de uma decada," Conjuntura Economica 24 (Enero 1970), 7. The employment growth rates were obtained from Republica Federativa do Brasil, I Plano Nacional de Desenvolvimento PND 1972/1974 (Brasilia: November 1971), 64.

Table 13

Factors Affecting Labor Absorption in the Non-Agricultural Sector

	Direction of Relationship
Demand for Labor	
a) Capital Intensity of the Non-Agricultural Sector	-
b) Rate of Growth of the Non-Agricultural Sector	+
Supply of Labor	
c) Unemployment and Under-employment in the Non-Agricultural Sector	-
d) Percent of the Labor Force in Agriculture	-
e) Population Growth Rate	-

Note: This table summarizes the direction of the expected relationship between labor absorbing ability in the non-agricultural sector and several components of this ability.

on unemployment and underemployment in Brazil.[5] The agricultural sector is still a very large sector of the labor force, 44 percent in 1970, and total population growth rates are high, 2.9 percent in the sixties.[6] This review of some of the components of labor supply and demand growth in the non-agricultural sector gives some evidence of a low degree of labor absorption ability in the non-farm sector at the present time.

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[5] If unemployment is measured as not working at all, the rates are extremely low. If underemployment includes all those working part time who would prefer to be working full time the rates are very high. In urban areas the tertiary sector provides part time,low wage employment. F. S. O'Brien and C. L. Salm, "Employment and Underemployment in Brazil," Revista Brasileira de Economia 24 (Outubro/Dezembro 1970), 129-137.

[6] The employment in agriculture as a percent of total employment was estimated from Fundacao Getulio Vargas, "O censo demografico de 1970," Conjuntura Economica 26 (Fevereiro 1972), 151; The population growth rates were taken from Instituto Brasileiro de Estatistica, Sinopse Preliminar do Censo Demografico, VII Recenseamento Geral 1970 (Rio de Janeiro: July 1971).

Given the low incomes in agriculture, policy makers are concerned with increasing the capital-labor ratio in order to increase productivity and incomes. However, the low labor absorption potential outside of agriculture indicates the importance of differentiating the capital input in agriculture between labor absorbing (or land substituting) inputs and labor replacing inputs. Conceptually, agricultural capital inputs can be dichotomized into land substitutes and labor substitutes. In reality few capital inputs fall completely in either of these divisions; however, fertilizer and other biological and chemical inputs excluding weedkillers are primarily land substitutes and machinery is primarily a labor substitute.[7] Mechanization is expected either

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[7] B. F. Johnston and J. Cownie, "The Seed-Fertilizer Revolution and Labor Absorption," American Economic Review 49 (September 1969), 569-583; A. K. Sen, Choice of Technique, An Aspect of the Theory of Planned Economic Development, (Oxford: London; 1962) Appendix A, "Choice of Agricultural Techniques," 90-97; Y. Hayami and V. W. Ruttan, Agricultural Development: An International Perspective (The Johns Hopkins Press: Baltimore;1971), 118-136; M. Yudelman, G. Butler and R. Banerji, Technological Change in Agriculture and Employment in Developing Countries (OECD: Paris, 1971), 69-128. For a qualification to this dichotomy see C. H. Gotsch, "Technical Change and the Distribution of Income in Rural Areas," American Journal of Agricultural Economics 54 (May 1972), 328.

to replace labor or to substitute for a potential increase in labor demand in the case where factor or product shifts increase the demand for both labor and machinery.[8]

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[8] If economies of scale exist in factor use, there will also be a differential effect on farms by size. If it is more difficult to substitute labor for machinery on a large scale than on a small scale as suggested in Chapter 3 and if the use of bio-chemical technology increases labor requirements per hectare, then the initial comparative advantage in utilizing bio-chemical technology would be on smaller farms with an excess capacity of family labor prior to the introduction of bio-chemical technology. Subsidies on machinery by easing the labor or power constraint to the use of bio-chemical inputs on larger farms help return a comparative advantage in the adoption of bio-chemical technology to the larger farms.

The above initial comparative advantage for smaller farmers requires assumptions of equal access to other subsidized inputs including information on the new technology and no cost or price advantages to larger farmers in adopting bio-chemical technology. An extensive policy review of this and related issues is found in M. Yudelman, G. Butler, and R. Banerji, <u>Technological Change in Agriculture and Employment in Developing Countries</u> (Paris: OECD; 1971).

In the analysis here the labor absorption and farm size effects are considered simultaneously. Changes in factor prices may affect both the employment of labor on the large farms and the types of production activities and levels of technology utilized on different farm sizes. In this chapter concern is focused upon the aggregate employment effects rather than the specific process of substitution at the firm level. Whether adjustments would occur through labor for machinery substitution on large farms or through shifts of crops between farms by size in response to different factor costs (or product prices) is not considered at the level of aggregation employed in this section. Further studies of farm adjustments in particular regions are necessary to complement this aggregate analysis.

Agricultural mechanization has two effects on labor productivity, an expansion and a yield effect. According to the identity $\frac{Y}{L} = \frac{Y}{A} \cdot \frac{A}{L}$, where $\frac{Y}{L}$ is labor productivity or crop output per worker, $\frac{Y}{A}$ is aggregate crop yields per hectare and $\frac{A}{L}$ is crop land per worker. Machinery has its primary impact upon the land/labor ratio. Bio-chemical technology has its primary effect upon yields[9] and, as will be shown here, has a negative impact on the land/labor ratio. The expansion effect (A/L) of mechanization results from the increase of cultivated area per worker, which mechanization facilitates. The yield effect of mechanization results from such factors as higher germination rates and less weed problems with mechanized land preparation than with animal power and will be considered in Chapter 5. The inverse of the expansion effect (A/L) can be termed the aggregate labor requirements per hectare for the given crop mix and technology level.[10]

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[9] Y. Hayami and V. W. Ruttan, op. cit., 118.

[10] The effect of mechanical and bio-chemical technologies upon the A/L ratio is also a weak test of the surplus labor concept. If there exists a surplus labor pool in agriculture, then changes in technology may have no effect on the ratio.

The Model:

Power can come from any of three sources, human, animal, or mechanical. The crop area cultivated per worker then depends only upon the power supply available assuming no differences in input use, product mix, or quality of factors.[11] Now several of the more restrictive assumptions can be removed. First, differences in factor use between regions can be allowed for by reintroducing the intensity variable. The utilization of more fertilizer on the same land area increases plant density thereby raising the labor demand for harvesting. Moreover, the cultivation labor requirements increase as the fertilizer stimulates the growth of weeds. Hence, a farm shifting to more intensive land use requires more labor unless mechanization takes place simultaneously thereby substituting for this potential increase of the demand for labor.[12] Secondly, larger

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[11] The expansion function is a physical relationship between the amount of land, which one man can crop, and the power supply, crop mix, and intensity of production. It is not a factor demand equation so input prices do not enter. The expansion function is analogous to a production function as a relationship between physical quantities, i.e., inputs and crop area per worker.

[12] A 40 percent increase in labor expenditures per hectare is reported in India after the adoption of the new seeds and fertilizer. M. Yudelman et al., op. cit., 74; a 50 to 70 percent increase in labor use per acre is reported for a small farmer area in Comilla, Bangladesh after the adoption of a seed-fertilizer-pump package. C. H. Gotsch, "Technical Change and the (continued next page)

areas in annual crops rather than permanent crops are expected to increase labor use per hectare. Finally, there is a specification error[13] resulting from the inability to separate input use in livestock production from crop production in the Census data. This overestimate of the independent and dependent variables from the inclusion of input use in livestock production will give a similar specification problem to that resulting from including irrelevant variables in the estimating equation. One way to handle this specification error is to identify those livestock operations which use substantial labor and introduce a variable for these activities.

Distribution of Income in Rural Areas," American Journal of Agricultural Economics 54 (May 1972), 336. Using linear programming the introduction of new seed-fertilizer-water technology package without increased mechanization results in 35 to 57 percent increase in labor requirements in one block in India, I. R. Wills, "Projections of Effects of Modern Inputs on Agricultural Income and Employment in a Community Development Block, Uttar Pradesh, India," American Journal of Agricultural Economics 54 (August 1972), 456, 457.

[13]The estimators and their variances will be unbiased so the usual significance tests apply. However, the estimates will not be efficient. Another source of inefficiency which invalidates normal significance testing is the heteroscedascity resulting from the use of group means. See J. Kmenta, Elements of Econometrics (Macmillan: New York; 1971), 394-400.

For beef production labor use is extremely low and many farmers have ancillary livestock production in which they don't spend much time. However, milk production requires substantial labor so a variable for milk production per worker is used to adjust for this data problem. The equation to be estimated is:

$$(1)\quad \log (A/L) = \log B + \alpha_1 \log \frac{An}{L} + \alpha_2 \log \frac{T}{L} + \alpha_3 \log \frac{I}{A} + \alpha_4 \log Te + \alpha_5 \log \frac{M}{L} + \varepsilon_i$$

where B is a constant;

$\frac{A}{L}$	is cropland per adult male agricultural worker;
$\frac{An}{L}$	is animal power units per adult, male agricultural worker;
$\frac{T}{L}$	is adjusted tractor numbers (1950) or tractor horsepower (1960) per adult, male agricultural worker;
$\frac{I}{A}$	is expenditures on seeds, plant stock, fertilizer, and other agricultural chemicals per hectare of cropland;
Te	is the percentage of annual crop area in total crop area;
$\frac{M}{L}$	is cows milked (M_1) and milk production (M_2) per adult, male agricultural worker;
ε_i	is the error term.

(See Appendix A-III for the variables and further detail.)

One basic assumption is that cropland per worker will be determined by the decisions on power and other inputs. To the extent that all input use including crop area will be decided simultaneously, there will be a simultaneous equation bias. Given the abundant land area in many regions of Brazil it is reasonable to consider crop area per worker as determined by decisions on other inputs and crop mix.

The Results:

For the 1950 and 1960 All States functions, both power variables were significant (Table 14). In 1950 there was little bio-chemical input use in Brazil and this variable was not significant but the sign was as expected. Neither the crop mix nor the milk production variables were significant in 1950. In 1960 the intensity variable became highly significant as by 1960 there was more use of fertilizer and other purchased inputs.

Much more of the variance in cropland per worker ratios was explained with 1960 data for the regions of Sao Paulo. By 1960 the use of both mechanical inputs and fertilizer had increased substantially especially in Sao Paulo, the primary agricultural and industrial state of Brazil. Moreover, variables such as crop area are expected to be more homogenous in the state than for the country so this function would have less

Table 14

The Impact of Different Technologies, Crop Mix, and Milk Production Upon Crop Area per Worker

Form of Observation	No.	Constant	Animal Power $\frac{An}{L}$	Tractor Power $\frac{T}{L}$	Intensity of Production $\frac{I}{A}$	Crop Mix Te	Milk Production $\frac{M_1}{L}$	$\frac{M_2}{L}$	$\bar{R}^2$	F	Degrees of Freedom
1950 Census: All States of Brazil	(1)	1.0715	0.2429 (3.17)**	0.1420 (2.48)**					.42	8.03**	18
	(2)	1.5824	0.2388 (3.27)**	0.2344 (3.02)**	-0.1394 (1.68)				.48	6.83**	17
1960 Census: All States of Brazil	(3)	0.6110	0.1961 (2.37)*	0.1146 (2.27)*					.48	10.2**	18
	(4)	0.6797	0.0796 (1.12)	0.3262 (4.72)**	-0.3666 (.369)**				.70	16.1**	17
1960 Census: Regions of Sao Paulo	(5)	1.4313	0.3642 (3.19)**	0.3378 (6.32)**	-0.3202 (4.88)**	-0.3287 (4.57)**	-0.1776 (3.36)**		.73	18.0**	27
	(6)	1.5842	0.3483 (3.31)**	0.3371 (6.49)**	-0.2773 (4.30)**	-0.3507 (4.95)**		-0.1501 (3.69)**	.74	19.4**	27

(t-values are given in parentheses below the coefficients. All variables are in log form)
*significant at 95 percent
**significant at 99 percent
Source: 1950 and 1960 Agricultural Censuses. See Appendix A-III for detailed variable description and the data.

specification bias from omitting qualitative components in the variables. The assumption of no qualitative differences between states for either the land or labor variable is a heroic assumption; however, no data were available to adjust for these expected qualitative differences. For the regions of Sao Paulo all variables had the expected sign and were significant at the 99 percent level. The negative sign of the intensity variable indicates that area per worker was decreased with an increase in the utilization of bio-chemical inputs. Thus the above equations clearly demonstrated that bio-chemical and mechanical technologies had the expected opposite effects on labor requirements per hectare.[14] Larger areas in annual crops also resulted in higher labor requirements per hectare as was hypothesized. Regions with more milk production utilized substantial labor thus decreasing the observed cropland per worker. These milk production variables were significant for Sao Paulo but they were never significant in the All States functions for either 1950 or 1960.

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[14]These results are consistent with a number of studies summarized in M. Yudelman et al., op. cit., 69-89 and with the estimates of labor use with different technologies in Ministerio de Agricultura, Govierno de Colombia, "Consideraciones Sobre el Papel de la Maquinaria en la Agricultura Colombiana," mimeo, 32.

It is not clear from the analysis of the expansion effect how much of the migration to urban areas or of the decline of the relative importance of agriculture in total employment can be attributed to agricultural mechanization. In the next section of this chapter the impact of one of the capital subsidies upon labor absorption in Sao Paulo agriculture will be estimated.

B. The Impact of Tractor Subsidies Upon Labor Absorption in Sao Paulo Agriculture.

The Problem:

The capacity of agricultural growth in a rapidly developing area to generate employment can be separated conceptually into stages of migration and potential migration. As industrialization proceeds in Sao Paulo or Porto Alegre, migrants from the rural areas of Sao Paulo state or Rio Grande do Sul go into the urban areas with the expectation of obtaining high-wage employment in manufacturing or other sectors.[15] Industrialization generates an increasing demand

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[15] The implicit migration model is a variation of the model developed by M. Todoro, "A Model of Labor Migration and Urban Unemployment in Less Developed Countries," American Economic Review 59 (March 1969), 138-148. In this model migration is a function of the wage differential between the two regions or sectors adjusted for the probability of obtaining higher wage employment as seen by the migrant. The distance and the costs of finding employment may also enter into the migration decision. (continued next page)

for agricultural products and the rural workers in the state of Sao Paulo are replaced by some combination of rural in-migrants from other areas and machinery. Migration is sensitive to the wage differentials between states[16] and the statistical association of labor costs and mechanization levels has been shown in Chapter 3.

A decreased rural labor supply and an increased demand for agricultural products in the industrialization process results in an increased demand for agricultural labor in Sao Paulo and Rio Grande do Sul agriculture. Farmers can respond to this demand by mechanizing or the government can facilitate in-migration from outside the state as it did in the 19th century for coffee producers. Both adjustments take time as machinery

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From 1950-1969 the agricultural population in Sao Paulo decreased from 43.2 to 18.6 percent of total population and in Rio Grande do Sul there was an absolute loss of population in the state over the period 1950-1970 (see Tables15 and 16) and Secretaria da Agricultura, Desenvolvimento da Agricultura Paulista (Instituto de Economia Agricola: Sao Paulo; 1972), 109-114.

[16] G. S. Sahota, "An Economic Analysis of Internal Migration in Brazil," Journal of Political Economy 76 (March-April 1968), 218-245.

is adapted[17] to Brazilian agriculture or migration takes place. In recent years the government has chosen to subsidize machinery and discourage migration from the Northeast to Sao Paulo. Thus, one effect of machinery subsidies is the reduced ability of the most rapidly developing area, the South, to absorb labor from the other areas.

The Model:

What is the magnitude of the effect of the subsidized tractor price upon labor absorption in Sao Paulo agriculture? To answer this question the cross-sectionally estimated equations of Chapters 3 and 4-A are differentiated with respect to time and the tractor price is substituted back into the first equation (Equation No. 9 of Table 1(in Chapter 3. and Equation No. 5 of Table 14 in Chapter 4):

$$(2) \quad \frac{\dot{T}}{L} = \alpha_1 \frac{\dot{W}}{P_t} + \alpha_2 \frac{\dot{I}}{A} + \alpha_3 \dot{T}_e + \alpha_4 \dot{C}$$

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17 This adaptation of mechanical inputs to local conditions has been termed "induced innovation." Private firms make model modifications in response to particular conditions or requirements of the local environment. For example, in 1972 several firms produced narrow tractor models, which would fit between the rows of coffee trees to spray for rust. Governmental agencies performed a role in encouraging the development of these models.

For further elaboration of the concept of "induced innovation" see Y. Hayami and V. W. Ruttan, op. cit., 118-136.

$$(3) \quad \dot{A} - \dot{L} = \beta_1 \frac{\dot{An}}{L} + \beta_2 \frac{\dot{T}}{L} + \beta_3 \frac{\dot{I}}{A} + \beta_4 \dot{Te} + \beta_5 \frac{\dot{M}}{L}$$

where all the variables are now expressed as proportional rates of change with respect to time. Table 15 summarizes those growth rates for the principal variables for Sao Paulo in the sixties.

The Results:

If there had been no increase in the wage rate relative to the tractor price over time,[18] then the labor force exponential growth rate in

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[18] As long as wages were greater in Sao Paulo than in other states, in-migration would be expected to keep real wages from increasing. Schuh points out that real agricultural wages in Sao Paulo have been constant since World War II except for a jump in the 1964-65 crop year due to the implementation of minimum wage legislation in Sao Paulo agriculture. See G. E. Schuh, "Patterns of Equity Under Agricultural Development in Latin America," in A. G. Bell and E. O. Heady (ed.), Externalities in the Transformation of Agriculture: The Distribution of Benefits and Costs from Development (Iowa State University Press: Ames; forthcoming), 53-58. The data were taken from Secretaria da Agricultura, Desenvolvimento da Agricultura Paulista (Instituto da Economia Agricola: Sao Paulo; 1972), 118, 119.

Table 15

Rates of Change of Mechanization, Real Wages, Bio-Chemical Input Use, and Crop Area in Sao Paulo, 1960-1970

$\frac{\dot{T}}{L}$	10.73%
$\frac{\dot{W}}{P_t}$	5.38
$\frac{\dot{I}}{A}$	8.40
$\dot{T}e$	1.73
$\dot{A}$	0.28

Sources:

$\frac{\dot{T}}{L}$ was from Table 9 in Chapter 3

$\frac{\dot{W}}{P_t}$ was from Table A-5 in Appendix A-I and only includes the years 1962-1970

$\frac{\dot{I}}{A}$ only includes 1962-1969 and was total chemical fertilizer utilization per hectare of cultivable land including temporary and permanent crops and idle land

$\frac{\dot{I}}{A}$, $\dot{T}e$, and $\dot{A}$ were estimated from Secretaria da Agricultura, Desenvolvimento da Agricultura Paulista (Instituto de Economia Agricola: Sao Paulo; 1972), 98, 135.

Sao Paulo agriculture would have increased 0.63 percent annually from 1960-1970.[19] Male,adult labor in agricultural employment in Sao Paulo would have increased by 75,771 more than it did over the decade. Using this same variation in machinery prices approximately 18 percent of the increase in the tractor-labor ratio from 1960 to 1970 is associated with the subsidized capital price.[20] Hence, mechanization of Sao Paulo agriculture is not only related to the distortion of the credit price for tractors. Much of Sao Paulo mechanization would have occurred even without this factor price distortion according to the model.

Since the male, adult agricultural labor force in Sao Paulo agriculture was 1.2 million in 1960 and from 1957-1969 the total agricultural population of Sao Paulo decreased by 875,000, this estimate of the effect of capital subsidies upon

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[19] If $\frac{\dot{W}}{P_t} = 0$, then $\frac{\dot{T}}{L}$ is decreased by a 1.88 percent rate of growth over the period. Holding area and the other variables constant in (2) then $-\Delta L = \beta_2(\Delta \frac{\dot{T}}{L})$. This assumes that the same area would have been cultivated in Sao Paulo with more labor. The use of a Taylor Series expansion in equation (2) allows variation of the interest rate but gave erratic results.

[20] From 1960 to 1970 the tractor-labor ratio increased at a 10.73 percent exponential growth rate. $\alpha_1 \frac{\dot{W}}{P_t}$ was equal to 1.88 or 17.5 percent of the change in the tractor--labor ratio during the sixties. If $\frac{\dot{W}}{P_t} = 0$, then the tractor-labor ratio only increases at a 8.85 percent rate of growth over the decade (see equation (2) in this section).

labor absorption in Sao Paulo appears relatively small.[21] However, it is consistent with the low elasticities of substitution between machinery and labor estimated for Sao Paulo agriculture. In areas with concentrations of large crop farms, such as most of the state of Sao Paulo, it may be more difficult to substitute temporary labor for machinery. Moreover, until the present machinery stock depreciates, the factor proportions choice may not respond significantly to changes in factor prices. Since capital subsidies are used pervasively in Brazilian agricultural policy such as to encourage coffee removal and later replanting in the seventies, the cumulative effect of these subsidies may be substantially larger than the tractor subsidy alone. In the following section another way of approaching labor absorption will be examined.

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[21] Secretaria da Agricultura, Desenvolvimento da Agricultura Paulista, 110, 111. (Also see Tables 16 and A-12). If one adult male per family of 5.5 worked in agriculture, and entire families left agriculture, then approximately 159,000 adult males left Sao Paulo agriculture from 1957-1969. If the appropriate number of adult male workers is 1.5 per family, then approximately 239,000 adult males left.

Table 16

Interstate Migration: Number and Rates of Migration, 1950-1970

	Number of Migrants 1950-1960	Rates[a] of Migration 1950-1960 (Percent)	Number of Migrants 1960-1970	Rates[a] of Migration 1960-1970 (Percent)
Sao Paulo	712,706	7.80	993,428	7.66
Rio Grande do Sul	-162,532	-3.90	-339,909	-6.24
Rio de Janeiro	195,842	8.53	201,315	5.92
Mato Grosso	131,859	23.59	268,517	27.38
Goias[b]	259,310	21.34	449,076	21.42
Guanabara	372,816	15.68	372,181	11.25
Parana	912,855	43.58	790,169	18.39
Santa Catarina	-63,441	-4.07	-49,237	-2.29
Minas Gerais	-593,386	-7.62	-1,273,746	-12.79
Espirito Santo	44,612	4.66	-227,833	-16.06
Alagoas	-182,636	-16.71	-92,917	-7.31
Rio Grande do Norte	-133,723	-13.82	26,171	2.26
Para	8,638	0.74	89,410	5.52
Sergipe	-99,123	-15.38	-88,313	-11.62
Pernambuco	-372,565	-10.97	-203,231	-4.91
Paraiba	-256,418	-14.97	-204,418	-10.13
Bahia	-506,165	-10.47	-366,763	-6.12
Ceara	-330,739	-12.27	-82,859	-2.48
Piaui	-157,655	-15.08	-18,858	-1.49
Amazonas	1,261	0.24	-17,983	-2.40
Maranhao	212,231	13.40	-220,542	-8.85

[a] Calculated by the global survival method with rates equal to migrants over base population.

[b] Includes the Federal district.

Source: D. H. Graham and S. B. de Hollanda Filho, Migration, Regional and Urban Growth and Development in Brazil: A Selective Analysis of the Historical Record: 1872-1970, Vol. I (Instituto de Pesquisas Economicas, USP: Sao Paulo, 1971), 80.

Table 17

Annual Rate of Increase in Agricultural Employment from 1950 to 1960

	1950[a]	1960	Annual Rate of Increase
	(1,000)		(%)
Sao Paulo	1,708	1,727	0.1
Rio Grande do Sul	1,136	1,334	1.6
Rio de Janeiro	337	224	-3.2
Mato Grosso	126	187	4.1
Goias[b]	399	502	2.4
Guanabara	20	20	0
Parana	611	1,285	7.7
Santa Catarina	433	575	2.9
Minas Gerais[c]	2,108	2,272	0.8
Espirito Santo	288	285	-0.1
Alagoas	301	363	1.8
Rio Grande do Norte	256	299	1.6
Para	230	335	3.9
Sergipe	162	249	4.3
Pernambuco	947	1,263	2.9
Paraiba	483	553	1.4
Bahia	1,495	1,820	2.0
Ceara	675	801	1.8
Piaui	302	358	1.8
Amazonas	84	167	7.1
Maranhao	491	952	6.8
Brazil	12,614	15,634	2.2

[a]Corrected for the underenumeration of the 1950 Census.

[b]Includes the Federal District

[c]Includes Serra dos Aimores

Source: L. F. Herrmann, Changes in Agricultural Production in Brazil, 1947-1965, For. Ag. Econ. Report No. 79 (ERS, USDA; June 1972), 36.

C. Regional Crop Specialization and Labor Absorption.

The Problem:

Machinery subsidies also may affect the comparative advantage of various regions. In the absence of machinery subsidies and ignoring transportation costs areas with abundant labor, hence low wages relative to other factors, would specialize in the production of labor intensive commodities.[22] For products with high elasticities of substitution a subsidy on the capital price may transfer the comparative advantage by making it more profitable to produce it in an area with a high labor price but with a capital intensive technology.

If regional crop shifts occur in the absence of mechanization in response to the same factors associated with mechanization, then another alternative to machinery subsidies is available. It was shown in Chapter 3 that mechanization levels between states are statistically associated with differences in labor costs. In this section a test is made of the crop shifts of three labor intensive, commercial crops between states with different labor costs. The hypothesis is that crops with high labor costs and

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[22]Production decisions are also influenced by demand conditions as well as supply costs. A sufficiently large trading area without barriers is assumed here to enable product specialization and trade.

with operations, which can't easily be mechanized, will move out of the high labor cost area, Sao Paulo in this case. The assumption of a lack of sufficient factor mobility including labor migration to equalize these differentials in initial factor prices is necessary. The three crops,which satisfy the above criteria,are coffee, cotton, and cane. All three crops require substantial labor to harvest and this operation is still difficult or expensive to mechanize in Brazil. Harvesting coffee by machine is very difficult and reduces the quality of the harvest. Machine harvesting of cotton requires the development of varieties adapted for mechanization and more sophisticated processing equipment in the gins. Sugar cane harvesting by machine generally reduces yields so labor costs must be very high to induce this type of substitution.

The primary product shifts from 1950-1970 in Sao Paulo agriculture were to those high value crops, which are difficult to process and store and expensive to transport. In the last twenty years Sao Paulo production of milk, eggs, fruits, and vegetables has increased at very rapid rates. The production of subsistence crops especially beans, rice, and manioc has been declining as has meat production.[23] With increasing land values these subsistence activities and also land extensive activities such as beef cattle production have not been sufficiently profitable to stay in the state of Sao Paulo with its rising land values.

The movement of crops out of the state for export back to the urban market of Sao Paulo or into international trade has been facilitated by the improvement of interstate transportation and in the ports. Prior to this public investment these high value commercial crops, cotton, coffee, and cane, would concentrate in the state of Sao Paulo due to the proximity to the major domestic market of Sao Paulo and the modern port of Santos and the high transportation costs to these centers from outside the state. In the period 1950 to 1970 the construction of roads and port improvements extended the potential export marketing area for commercial crops from Sao Paulo south into Parana, northwest into Goias and Mato Grosso, and north into Minas Gerais.

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[23]This summary of crop shifts over time in Sao Paulo is based upon area and production data in Secretaria da Agricultura, Desenvolvimento da Agricultura Paulista (Instituto de Economia Agricola: Sao Paulo; 1972), 282-314.

I am indebted to Martin Katzman for help with the regional economic analysis above. He shouldn't be implicated by any remaining errors, however.

The Crop Shift Test:

To test for the hypothesized crop shifts of the labor intensive cash crops, cotton, coffee, and sugar, out of Sao Paulo a ratio from regional economics can be adapted. The concentration of a particular crop is its relative importance in the particular state normalized by the relative importance of all crops in that state or,

$$C = \frac{\frac{\text{Area of Crop A in State B}}{\text{Area of Crop A in the Country}}}{\frac{\text{Area of all Crops in State B}}{\text{Area of All Crops in the Country}}}$$

A ratio or C value greater than one implies that the given crop is concentrated in the particular state relative to other crops and conversely. The C values of the labor intensive, cash crops are hypothesized to decline in Sao Paulo from 1950 to 1970 and to increase in the surrounding states.

The Results:

Table 18 presents the results of this ratio calculation for the greater Sao Paulo area for three periods, 1949-1951, 1959-1961, and 1968-1970. Over this period the total Brazilian crop area increased from 17, 556, 278 to 25, 105, 362 from 1949-51 to 1959-61 and to 34, 090, 399 hectares in 1968-1970. The relative importance of Sao Paulo in crop production fell from

Table 18

Concentration Ratios for Several Labor Intensive, Cash Crops and Subsistence Crops.

	Year	Labor Intensive Cash Crops			Subsistence Crops				% of Total Brazilian Crop-Land in this State
		Cotton	Coffee	Cane	Manioc	Beans	Rice	Potatoes	
Sao Paulo:	1949-1951	1.67	1.93	0.65	0.64	0.51	1.20	1.20	27.0
	1959-1961	1.08	1.81	1.35	0.28	0.55	0.99	1.24	20.3
	1968-1970	0.84	2.05	2.03	0.35	0.45	1.04	1.35	14.7
Parana:	1949-1951	0.31	1.21	0.15	0.24	1.94	0.53	2.07	8.3
	1959-1961	0.44	2.41	0.15	0.17	1.22	0.58	1.49	12.6
	1968-1970	0.65	3.02	0.15	0.29	1.33	0.59	1.37	14.7
Goias:	1949-1951	0.30	0.35	1.07	1.24	1.13	3.60	0.15	2.0
	1959-1961	0.19	0.44	0.76	0.96	0.90	4.03	0.08	3.4
	1968-1970	0.18	0.10	0.37	0.70	0.87	4.10	0.03	5.0
Mato Grosso:	1949-1951	0.19	0.25	1.11	1.87	1.61	2.60	0.28	0.7
	1959-1961	0.23	0.33	0.56	1.36	1.39	3.58	---	1.5
	1968-1970	0.69	0.25	0.37	0.83	1.00	3.19	---	1.7
Minas Gerais:	1949-1951	0.13	1.31	1.00	0.52	1.46	1.56	0.46	16.6
	1959-1961	0.30	1.23	0.89	0.50	1.35	1.32	0.75	14.9
	1968-1970	0.32	0.98	1.15	0.53	1.23	1.58	1.07	11.4

Source: IBGE, Annuario Estatistico (Rio de Janeiro; 1952, 1962, and 1971 issues).

27 percent of Brazilian crop area in 1949-51 to 14.7 percent in 1968-70.[24] The total area expansion in Brazil over this period is impressive reflecting the settlement of substantial new areas over the last twenty years with a doubling of crop area. The relative importance in Brazilian crop area of the frontier states including Parana, Mato Grosso and Goias increased rapidly.

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[24] From 1950 to 1970 total crop area in Sao Paulo increased from 4,627,400 to 5,522,000 hectares. Secretaria da Agricultura, Desenvolvimento da Agricultura Paulista (Instituto de Economia Agricola: Sao Paulo; 1972), 98. It cannot be argued that higher yields in Sao Paulo enabled the state to maintain its output share in spite of less rapid area expansion. Herrmann showed that over the period 1947-1965 absolute yields were not higher in Sao Paulo but were lower for most crops there than in the frontier states of Parana, Goias, and Mato Grosso. In spite of higher fertilizer use in Sao Paulo, the advantage of natural fertility in newly opened areas resulted in higher aggregate yields. See L. F. Herrmann, Changes in Agricultural Production in Brazil, 1947-1965, For. Ag. Econ. Report No. 79(ERS, USDA; Superintendent of Documents: Washington, D. C.; June 1972), 32.

Since 1965 the acceleration of fertilizer use in Sao Paulo would have been expected to close this yield gap. Of the sixteen crops studied in Sao Paulo over the period, 1948 through 1971, only five, cotton, potatoes, manioc, bananas, and tea had substantial average aggregate yield increases. Another six, cane, tomatoes, soybeans, corn, peanuts and onions had small yield increases. Five crops, including two of the most important cash crops, coffee and oranges, had no yield increases or yield declines. This last category also included rice, beans, and castorseed. Secretaria da Agricultura, op. cit., 285-307.

The test for crop shifts works well for cotton as the proportionate share of cotton steadily falls in Sao Paulo over the period while increasing in Parana, Mato Grosso, and Minas Gerais. The test works moderately well for coffee as the ratio fluctuates but stays almost constant over the period for Sao Paulo but increases rapidly in Parana. In the fifties and early sixties Parana's share of Brazilian coffee production increased from 8 to 35 percent.[25] Soil quality undoubtedly also influenced this shift.

The test doesn't work at all for sugar but rather indicates an increasing concentration of sugar production in Sao Paulo. There are several components to the explanation for this puzzle. First, production of refined sugar has been controlled by the government with the quota of Sao Paulo gradually increasing over the period 1950-1971. The quota is accompanied by a sufficiently high price support to encourage rapid expansion of production up to the quota ceiling. It isn't reasonable to predict regional crop shifts by considering only costs. The relative profitability

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[25] The in-migration into rural Parana is strongly associated with the rapid rise of coffee production in the fifties. Exhaustion of the soil in Sao Paulo rather than differences in labor costs is the prevalent explanation for this shift. See L. F. Herrmann, Changes in Agricultural Production in Brazil, 1947-65, Foreign Agricultural Economic Report No. 79 (ERS, USDA: Washington, D. C.; June 1972), 29.

of alternative enterprises and enterprise combinations would be a better indicator if the data were available. Secondly, in the surrounding states the decreased importance of sugar may reflect sugar's declining importance as a subsistence crop. Sugar can also be grown for local use as "rapadura," "caldo de cana," "cachaca,"[26] and as a forage. As agricultural development proceeds specialization increases so that farmers produce fewer subsistence crops.[27] In those areas in which sugar was grown

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[26] "Rapadura" is unrefined sugar, "caldo de cana" is the undistilled liquid product, and "cachaca" is the distilled product.

[27] See S. Hymer and S. Resnick, "A Model of an Agrarian Economy with Non-agricultural Activities," American Economic Review 59 (September 1969), 493-506.

Besides failing for sugar the results of the concentration ratio are surprising for Goias as none of the expected shifts occur there. For a more complete discussion of crop shifts in Goias overtime see P. I. Mandell, "The Development of the Southern Goias Brasilia Region: Agricultural Development in a Land Rich Economy," unpublished Ph. D. dissertation, Columbia University, 1969, 391 ff. His explanation is that the construction and rapid growth of Brasilia has led to an extremely rapid rate of demand growth for foodstuffs. Previous production of sugar and cotton had been for home consumption. With the increasing demand for footstuffs less effort was devoted to production of these "z-goods."

for subsistence purposes the shift to commercial production would require a quota and the construction of milling capacity.

There is strong support for the original hypothesis that cotton would shift out of Sao Paulo over the period. Coffee shifts into Parana and stays constant in Sao Paulo so there is partial support for the coffee case. Sugar becomes more concentrated in Sao Paulo due to several phenomena which the test did not include. For none of the crops was this a definitive analysis of the reasons for the crop shift. Nevertheless, there is qualified support for the original hypothesis that regional crop shifts would occur in response to variations in labor costs. It would be appropriate for further research to approach this question from the opposite perspective and consider some of the more important regional crop shifts in Brazil. For example, how much of the shift of the production center of sugar cane from the Northeast to the South of Brazil can be attributed to the subsidies on the machinery price enabling the South to offset the initial comparative advantage of the lower cost labor in the Northeast.

In summary of Chapter 4 it was shown in 4-A that capital inputs in agriculture can be dichotomized into those increasing and decreasing labor utilization per hectare. In 4-B the absolute impact on labor absorption in Sao Paulo agriculture from the subsidies on credit for tractor financing was estimated. Approximately 76,000 more male, adult agricultural workers could have been utilized in Sao Paulo agriculture in the absence of the subsidy during the sixties. In 4-C cotton and to a lesser extent coffee production shifts between regions in the South appear to be responsive to variations in labor costs between regions.

In the previous chapters attention has been concentrated primarily upon the effect of factor price distortions upon mechanization and labor use and the substitution effect of machinery for labor. To the extent that mechanization raises yields it also substitutes for land. Moreover, there may be other factors inducing mechanization in particular areas. In the next chapter some of these issues will be considered with farm level data from Mato Grosso.

CHAPTER 5

THE INTERNAL RATE OF RETURN TO MECHANIZED LAND PREPARATION ON SMALL FARMS IN MATO GROSSO

Mechanization is occurring at rapid rates in Brazil especially in the frontier states of Mato Grosso and Goias (see Chapter 3, Tables 8 and 9). Mechanization on large crop farms is not surprising as the labor costs of obtaining, controlling, and coordinating large seasonal labor forces several times a year may encourage the substitution of machinery for labor especially at the subsidized machinery prices prevailing in Brazil (see Chapter 3). On smaller crop farms the existence of surplus family labor and the lumpiness of machinery inputs would be expected to discourage mechanization. Since small farmers generally don't receive the direct benefits of the subsidies on credit for financing tractors (see Appendix E), their reasons for mechanizing should be more independent of these factor price distortions. Nevertheless, the frontier is different from the older agricultural areas since it is easier to expand crop area into uncleared areas or pasture than in older areas which have a higher cropping intensity. For two samples of small farmers the reasons for mechanizing, the private rate of return to mechanized land preparation, and the substantial differences in mechanization levels between the two samples[1] are the primary concerns of this chapter.

A. Terenos Results.

Of the 66 small farmers in Terenos with an average crop area of 10.9 hectares only four used animal power for land preparation. The rest used custom rental or their landlord's machinery. In Terenos farmers stated that mechanized land preparation was necessary due to the difficulty of working the "cerrado"[2] soil after the long dry season. The planting season is in October-December after five to six months of dry season. To use animal power at all it is necessary to wait for the first rains. One advantage of mechanical land preparation is that the soil can be broken in anticipation of the first rains

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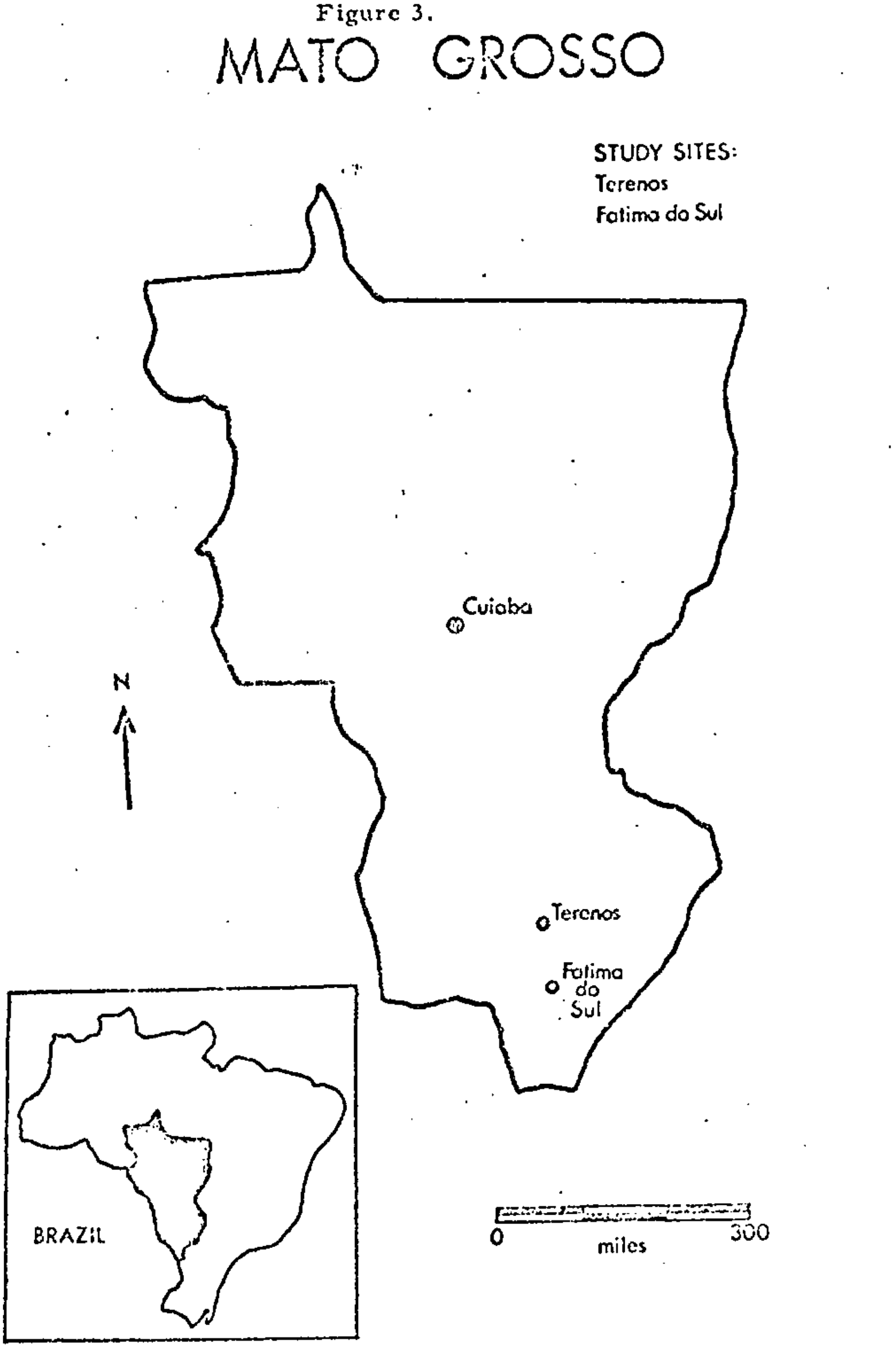
[1]I am indebted to Frederick Bein for the use of his data from the 1971/72 crop season. The sampling technique was cluster sampling from the two colonization projects.

[2]"Cerrado" refers to a broad category of soils found in Brazil characterized by low natural fertility especially phosphorous and organic material deficiency, high aluminum levels, and difficult to work after repeated cultivation. The interaction of a long dry season with occasional hard rains makes these soils difficult to break at planting time.

Figure 3.



This map was provided by Frederick Bein, Geography Department, University of Florida.

and water absorption will be improved.[3] This ability to anticipate the first rains and plant shortly thereafter may reduce the risk incurred by late planting for the user of animal power. For example, the cotton production cycle is timed so that the cotton bolls are exposed during the dry season. Too much rain at this time would lower the value of the bolls. However, late planting could result in the cotton having insufficient moisture during a critical point of plant development.

Before using animal power it is necessary to cut or burn down the weeds and remove some of the plant roots and clods. Both operations can be avoided by using mechanical power. Moreover, Terenos' farmers claim that animals with the implements used locally do not plough deeply enough for cotton even though for rice it is sufficient but germination is reduced by the failure to break the soil adequately. Furthermore, farmers reported that mechanized land preparation reduces the weed problem by turning over and preparing the soil better, especially the disking so that fewer cultivations are required.

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[3]Erosion will also be increased and the benefits from increased water retention have to be weighed against the losses from erosion. Those that prepare the soil in anticipation of the first rains need a second disking to eradicate the weeds, which will spring up after the rains. After this disking, planting can take place.

This turning and disking is considered to be equal to another cultivation. Finally, farmers report a risk component to using animals for land preparation. The difficult land preparation activities occur at the weakest point for the animal stock, immediately after the long dry season. Supplementary feeding is not generally given to work animals during the dry season and an overworked, weakened animal could die.

The most striking comparison between mechanical and animal power is the reduction in time required for the basic land preparation operations with mechanical power. Land preparation activities required an average of 5 animal and man-days per hectare or 5 hours of machinery and man-time.[4] The costs of animal power were lower than those of mechanical power for land preparation due to the low value of labor and animal rental cost. Mechanical power only becomes advantageous per hectare when the cost savings from one less cultivation and/or

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[4] Oxen were generally worked only half days after the dry season. Similar time savings were also possible from mechanized cultivation but this was not done by any of the farmers in the sample including the two owning tractors. Tractor owners had heavier tractors, which were better for breaking the soil but more awkward for other operations.

the yield advantage[5] of mechanized land preparation were also considered.

Now these effects are combined to estimate the internal rate of return to hiring custom rental services for land preparation. In this analysis the reduced risks are not considered nor is the expansion effect of enabling crop area expansion per worker. The nominal rate of return for mechanized land preparation is then:[6]

$$\frac{C_1 + C_2 + Y - K}{K}$$

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[5]Substantially lower yields were observed for the animal power users in Terenos with 3 of the 4 having crop failures and the other below average rice yields. However, the sample is too small and it is unlikely that these disastrous yields can be attributed to the failure to use mechanical power. The yield advantage of mechanical power in Table 19 was based upon the calculations in Appendix F. Three yield differentials of 10, 15, and 20 percent were employed.

[6]Adjusting for time passed between operations this becomes:

$$C_1 + \frac{C_2}{(1 + r)^{0.17}} + \frac{Y}{(1 + r)^{0.5}} = K$$

where r is the internal rate of return. The left hand term includes the discounted benefits of mechanized land preparation and the right hand term the cost of custom rental. The discounting is based on the following pattern of activities. The cultivation occurs one and a half to two months after planting and the sale is approximately 6 months after planting. There were substantial variations in the time of sale between observations. Although rice production only takes 3 to 4 months depending upon the variety, many farmers in Terenos keep their rice covered in the field and wait for the recovery after the post-harvest price collapse. It is also easier to get labor for threshing after the harvest season.

The simplification of the rate of return calculation used in Table 19 assumes that all costs and returns occur at the same time.

where:

C_1 is the cost savings from reduced labor and animal time in land preparation;

C_2 is the cost savings due to the decreased number of cultivations;

Y is the value of the yield difference from mechanization; and

K is the cost of custom rental.

Table 19 indicates that the rate of return per hectare to using custom rental for land preparation is positive except for the case in which there are no savings in cultivation costs and a yield differential of 10 percent. Ninety-four percent of the farmers interviewed in Terenos used mechanized land preparation; nevertheless, they still used animal power and hand labor for cultivation. Moreover, no one used fertilizer in the area so land preparation was the major cash outlay in the crop operation. Table 19 illustrates that even though production costs go up with mechanized land preparation, gross income goes up even faster from the yield effect so that the returns per hectare to mechanized land preparation are positive even with higher per unit production costs.[7]

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[7] Production cost analysis includes the economic costs in the numerator but only the physical yields in the denominator. The value of the yield increase may be sufficiently great to offset the increased production cost from shifting to mechanical power thereby justifying the investment even though the per unit production costs (continued next page)

Table 19

Rates of Return per Hectare to Mechanized Land Preparation of Upland Rice in Terenos, 1971/72 Crop Year

	Animal Power	Mechanical Power
Time Requirements to Prepare One Hectare[a]		
Ploughing	5 days	3 hours
Disking or Breaking		2 hours
Cost of Land Preparation per Hectare[b]	58.60 Cr	77 Cr
Value of the Yield Advantage of Mechanized Land Preparation[c]		
10 percent		72 Cr.
15 percent		108
20 percent		144
Cost of Additional Cultivations[d]	35 Cr.	
Nominal Rate of Return to Mechanized Land Preparation	**Yield Effect[f] (% increase)**	**(Percent)**
Without the Cost Savings of an Additional Cultivation: Yield Advantage of	10%	-33%
	15%	16
	20%	63

Table 19 (continued)

With the Cost Saving of an Additional Cultivation: Yield Advantage of	10%	15%
	15%	62
	20%	109
Production Cost of Land Preparation[e]		
Animal Power		2.42 Cr/sack
Mechanical Power: Yield Increase of	10%	2.89
	15%	2.77
	20%	2.65

[a]Furrowing is sometimes also done.

[b]For mechanical power an average of the custom rental price was obtained with 22 observations. The cost of the animal power was calculated as the summation of labor, animal, and implement cost. Labor was priced at the minimum wage with animal and implement costs calculated in the same manner as in Appendix F including interest. Data for Mato Grosso labor and other costs were provided by IPEAO, Campo Grande, Mato Grosso. The formula for interest and depreciation used was $(r + d)\ C$. For details on this calculation for the daily costs of animal power see Table 20 after this section.

[c]For rice production at mean yields and price received. See Table 21.

[d]See Table 22 for details on this calculation.

[e]The production cost effect of various technologies is calculated by taking the production cost of that particular operation per hectare and dividing by the yields. Average yields from Table 21 were used. The effect of reduced cultivation costs was not considered here.

[f]These yield effects were taken from the estimates in Appendix F. The yield effect varied from 9 to 20 percent depending upon the crop.

Besides the increased yields mechanized land preparation can make it possible to increase crop land cultivated. The average crop area of the four producers using animal power was 6.5 hectares while for mechanized crop producers it was 11.2 hectares.

B. Fatima do Sul Results.

In the Fatima do Sul sample of 49 only 16.3 percent used mechanical power for land preparation. This group also consists of small farmers in a colony founded in 1943 in an area of fertile soil ("terra roxa"). Besides having better soil than Terenos there is a wider diversity of crops grown including peanuts, cotton, rice, and soybeans as the principal annuals.

Summary:

One explanation for the difference between the two areas in the mechanization of land preparation is the substantial difference in the cost of custom rental. The average cost of mechanized land preparation with custom rental was Cr $190 per hectare or more than double the custom rental price of mechanized land preparation in Terenos. Another explanation is the difference in land quality

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increase. (See Appendix F for a comparative production cost analysis of animal and mechanical power in Sao Paulo agriculture.) One assumption above is that the individual farmer is a price taker so that increased production does not affect price received. In considering the aggregate effects of mechanization this assumption would have to be modified.

between the two areas. In uncleared areas of better soil on the frontier it is more difficult to mechanize than in areas of poorer soil. "Mata" or "terra roxa" has more dense original growth than "cerrado" or "campo limpo." The original clearing process in good soil generally entails waiting for the large stumps to rot, up to twenty years. In the interim, pasture can be planted or crops with land preparation between the stumps utilizing animal power. The capital investment in labor time, dynamite, or the use of bulldozers was high to remove the large stumps in good soils. The estimated cost of stump removal was Cr $500 per hectare in good soil or an approximate 50 percent increase in the purchase price of the land.[8] For the smaller farmers the capital cost of stump removal may be an impo tant barrier to engaging

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[8]The estimate was made by Frederick Bein based upon his field interviews of the 1971/72 crop season. I am also indebted to Rick Bein for this explanation of the difference in mechanization levels between the two areas.

In areas of rapid mechanization such as the wheat-soybean planting in the greater Dourados area of Mato Grosso in the last three years the in-migrants have either purchased already cleared and destumped good land or more commonly uncleared, "campo limpo," which is the lower quality land distinguished by its paucity of original vegetation. The apparent reason for this preference for the poorer soils is to avoid the capital costs of land clearing on the high quality, densely vegetated soils.

custom rental services. Furthermore, the yield advantage of mechanization on better soil in Fatima do Sul may be less due to the better texture hence increased facility of animal power implements in breaking the soil.

At least on some soils there is a substantial rate of return to mechanized land preparation. More research needs to be done on the yield effect of mechanization on different soil types. In areas of "cerrado" soils mechanization both extends crop area per worker and increases yields. Since there is substantial "cerrado" area in Brazil, mechanization is expected to continue at rapid rates especially in the South and Central West and to facilitate the settlement and more intensive use of "cerrado" areas. The yield increasing effect of mechanization is based upon the estimates of Appendix F. If these estimates are correct and the farmers interviewed in Terenos presented various reasons why mechanization increases yields on "cerrado" soils; then, mechanization cannot be neatly categorized as a labor substitute but also substitutes for land by increasing yields. If labor released from agriculture has a social cost greater than its private cost due to externalities from migration or a decreased labor productivity in the non-agricultural sector it is useful to consider alternative policies to increase yields.[9] Moreover, subsidies on machinery may make it more profitable to expand extensive use of marginal land rather than more intensive use of better land both on the frontier and in other regions of Brazil.

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[9] One alternative method to increase yields would be to subsidize "bio-chemical" inputs. See G. W. Smith, "Brazilian Agricultural Policy, 1950-1967," in H. S. Ellis (ed.), The Economy of Brazil (University of California Press: Berkeley; 1969), 226-238, for an analysis of the costs and returns to the Brazilian fertilizer subsidies.

Table 20

Daily Costs of Animal Power for Land Preparation, 1971/1972 Crop Year in Mato Grosso

Labor Cost -- including minimum wage and other employee costs paid by the employer	7.53
Animal Cost	2.72
Plough Cost	1.47
Total Daily Costs	11.72 Cr.

Calculation of Animal Daily Costs:

Value of new animal	Cr. 700
Expected work life	15 years
Annual use	180 days

1. Depreciation (straight line) $\frac{700}{15 \cdot 180}$ = 0.26

2. Feed
   (a) Corn 2kg/day · 0.40 Cr/kg = .80

   (b) Pasture
   Rental of artificial pasture
   $\frac{11 \text{ Cr./cow/month} \cdot 12 \text{ months}}{180}$ = .73

   (c) Labor costs of feeding and handlings = .35

3. Interest costs .58

Total Daily Costs 2.72 Cr.

Source: Data provided by IPEAO, Campo Grande, Mato Grosso. IPEAO is the federally supported agricultural experiment station of Mato Grosso.

Table 21

Data Employed to Calculate the Yield Advantage of Mechanized Land Preparation, Terenos, 1971/72 Crop Year

Number	Crop Area of Farm	Price Received for Rice per Sack (1971/72 crop year)	Yields	Gross Income per Hectare
1	20 ha.	30 Cr. /sack	15 sacks/ha	450
2	7	27	35	945
3	20	27	30	810
4	30	31.8	30	954
5	3	37.2	23	856
6	8	30	20	600
7	40	36	35	1,260
8	30	37.2	33	1,223
9	12	37.2	16	592
10	5	37.2	16	595
11	30	36	24	864
12	6	42	39	1,638
13	6	42	50	2,100
14	1/2	for own consumption	6	No sale
15	15	39	15	585
16	10	36	20	720
17	8	39	35	1,365
18	12	39.6	16	634
19	10	40.8	20.4	832
20	6	38.4	6.3	242
	Average	36 Cr.	24.2 Sacks/ha	909 Cr.

Table 21 (continued)

10% yield increase[a]	36 Cr · 2 sacks	=	72 Cr.
15% yield increase[a]	36 Cr · 3 sacks	=	108 Cr.
20% yield increase[a]	36 Cr · 4 sacks	=	144 Cr.

Source: Data collected by Frederick Bein in Terenos, 1971/72 Crop Year. A sack is 60 kg.

[a] It wasn't possible to separate the effect of mechanization on the average yields above. This average was reduced to 20 sacks to estimate the yield affect.

Table 22

Cost of One Weeding or Cultivation in Terenos Upland Rice Production, 1971/72 Crop Year

One animal-man day · 10.82	=	10.82
3.2 man days with a hoe · 7.53	=	24.10
Total Daily Costs		Cr. 34.92
Animal daily cost	=	2.72
Man daily cost	=	7.53
Cultivator daily cost	=	0.57
Animal-man daily cost		Cr. 10.82

Note that this above estimate prices family labor at the minimum wage. Hence, for a small farmer this would be expected to overstate the opportunity cost of his family and his own labor. The cultivation process is generally done with animal power and then followed by laborers with hoes. There were four observations of time spent cultivating with three of the observations using animal power for land preparation. These three used more animal-man days in cultivating than those using mechanized land preparation.

CHAPTER 6

THE POLICY IMPLICATIONS OF BRAZILIAN AGRICULTURAL MECHANIZATION

In this chapter the empirical findings of this study are integrated with the results of other studies as they relate to the on-going policy debate on mechanization in Brazilian agriculture. The appropriateness of the policy of machinery subsidies revolves around the case for and against agricultural mechanization at the present stage of Brazilian economic development. There are various advantages of mechanized production, which have been discussed. Machinery enables the replacement of a seasonal labor force for the critical seasonal operations, which require rapid completion to reduce weather risk (Chapter 3). In these critical seasons temporary labor costs increase in areas of specialized production. Moreover, on larger crop farms there may be additional costs associated with obtaining and managing a large seasonal labor force. On larger farms, which have adopted high levels of bio-chemical inputs and have larger marketed surplus than smaller farms, reduced production costs can lead to greater agricultural exports. Presently, Brazilian export prospects for soybeans, feed grains, and meat and meat products appear to be very favorable.[1]

Moreover, machinery can increase yields in the power demanding,land preparation operation. Hence, machinery serves as a substitute for land as well as for labor. In areas with substantial potential land area to be developed mechanization also raises farmer income by enabling the expansion of crop area per worker. The two effects of increased yields through improved land preparation and crop area expansion help explain the extremely rapid growth of mechanization on the Brazilian frontier (see Chapter 5). Finally, Brazil now has a domestic tractor and other agricultural implements industry, which have had employment and multiplier effects on the economy.

The costs of Brazilian mechanization have also been discussed in various places. The cumulative effect of

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[1] C. V. Doellinger and H. de Barros Castro Faria, Exportacao de productos primarios nao-tradicionais (milho, soja, carnes, productos de madeira, derivadas de cacau, e alimentos processados (IPEA, INPES: Rio de Janeiro; 1971).

mechanization in Brazilian agriculture has been to release labor or in the case of simultaneous factor and product shifts not to absorb as much labor as could have been absorbed with less mechanization. It was estimated that Sao Paulo agriculture could have absorbed 76,000 more adult male workers from 1960 to 1970 in the absence of subsidies on the tractor price (see Chapter 4B).

Mechanization may also result in a further skewness of income distribution within agriculture.[2] By alleviating a seasonal power shortage for larger crop farmers mechanization enables them to capture more of the gains from bio-chemical technological change than would otherwise be the case. For the large farmer moving into annual crops with his peak seasonal demands for power, the costs of seasonal labor may be a constraining factor to his crop shifts, which mechanization can relieve especially at the subsidized prices for machinery (Chapters 2 and 3). The distribution of income between farms by size may be more equitable with a slower rate of growth

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[2]There have been several articles documenting the increasing skewness of Brazilian income distribution over time. A. Fishlow, "Brazilian Size Distribution of Income," American Economic Review, Papers and Proceedings (May 1972); R. Hoffmann and J. C. Duarte, "A distribuicao da renda no Brasil," Revista de Administracao de Empresas 12 (Junho de 1972), 46-67.

of mechanization on larger farms as these farmers would then not be encouraged to shift as rapidly into intensive, annual crop production.[3]

A slower mechanization process in agriculture would enable more in-migration into the rapidly developing industrial-agricultural states such as Sao Paulo and Rio Grande do Sul. This in-migration could relieve some of the population pressure of the Northeast and other less rapidly developing areas. To the extent that migration is selective of the younger and more aggressive elements of the labor force the population exporting area will lose some of the better part of its labor force. Moreover, the importing area will have social costs imposed upon it

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[3] A continuing study of the process of technological change in the wheat-soybean area of Rio Grande do Sul provides evidence that changes in input and product price policy would result in a less skewed income distribution between farms by size. Singh and Ahn argue that the marginal efficiency of capital is lower on larger farms than on smaller farms hence increasing the interest rate would decrease the demand for capital goods more rapidly on large farms than on small farms. Reduction in the high price support for wheat and a reduced supply of the subsidized credit with simulation reduces the rate of output growth on large farms and increases the rate on small farms. I. J. Singh and C. Y. Ahn, "Employment and Capital-Labor Substitution in South Brazilian Agriculture," Economics and Sociology Occasional Paper No. 72 (Ohio State University: Columbus; March 1972); C. Y. Ahn and I. J. Singh, "Distribution of Farm Incomes Under Alternative Policy Regimes: A Dynamic Analysis of Recent Developments in Southern Brazil, (1960-1970)," Economics and Sociology Occasional Paper No. 89 (Ohio State University: Columbus; August 1972); C. Y. Ahn, "A Recursive Programming Model of Regional Agricultural Development in Southern Brazil (1960-1970): An Application of Farm Size Decomposition," unpublished Ph. D. dissertation, Ohio State University, 1972.

if the migration process between regions does not function efficiently. Presently, Brazilian policy makers are very concerned with the extremely rapid growth rates of the major urban industrial areas and have been attempting to discourage migration from the Northeast to the South.[4]

The policy choice on subsidizing mechanization then depends upon the weights given to the various positive and adverse consequences of mechanization as well as developments in the non-agricultural sector. There does seem to be several intermediate choices with regard to machinery policy. Brazilian mechanization has been very similar to the U. S. mechanization process with the production of heavy machinery purchased primarily by larger farmers (see Appendices C and E). Measures could be taken to encourage

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[4] The illiteracy rates of the in-migrants into Sao Paulo has been extremely high. It was 96 percent in 1952 and 79 percent in 1968. Illiterate, unskilled in-migrants have difficulty being assimilated in the high wage, high skill industrial jobs of Sao Paulo. The agricultural sector has been the primary recipient of these in-migrants. There is an increasingly popular belief in Sao Paulo that these in-migrants can only be absorbed in the most menial employment and that Sao Paulo is being forced to bear the social costs from underinvestment in human capital in other regions of Brazil. For the migration data see Secretaria da Agricultura, <u>Desenvolvimento da Agricultura Paulista</u>, 113, 114.

the selective development of agricultural machinery to be utilized on medium and even small farms and some of the rationed credit could be provided to these farms.

The efficiency and other losses from capital subsidies could be reduced by raising the interest rates thereby allowing the market rather than the governmental and banking bureaucracies to allocate the credit for mechanization and other agricultural activities. The various types of efficiency gains and cost savings to the various bureaucracies may be substantial (see Chapter 2-B). The effect of higher capital costs on the rate of the capital formation would have to be considered.

Removing the distortions on factor prices especially the underpriced capital input would not stop the agricultural mechanization process in Brazil. Less than 20 percent of the increase in the tractor-labor ratio in Sao Paulo was associated with the factor price distortion studied (see Chapter 4-B). However, raising the capital price would bring factor prices more in line with their real opportunity costs to society and dampen the rate of growth of mechanization and labor displacement. In the short run little substitution response of labor for machinery on farms already mechanized would be expected. In the long run a shift of larger farms out of intensive cropping to more extensive activities, such as beef cattle[5] or other activities with a constant level of labor demand during the year such as milk production would be expected.

Moreover, machinery subsidies may facilitate the shift of the comparative advantage of labor intensive commodities such as sugar cane to mechanized production in other areas. There are gains through the reduction of production costs due to the crop shift of cane from the Northeast to the better agricultural areas of the South; however, the labor reduction

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[5] Engler found a return from wheat-soybeans to beef cattle as the price support for wheat was reduced to the world price but an inelastic response to variations in the interest rate. Singh and Ahn employing the same data source but with different assumptions and a recursive programming model found a very elastic response to higher capital costs on larger farms. See the papers cited in footnote 3 and J. J. de C. Engler, "Alternative Enterprise Combinations Under Various Price Policies on Wheat and Cattle Farms in Southern Brazil," unpublished Ph. D. dissertation, Ohio State University, 1971.

and income distribution consequences of this shift are substantial.[6]

A more selective and gradual process of agricultural mechanization would enable the attainment of several goals besides output increase. The recent history of Brazilian agricultural development illustrates the ability to expand agricultural output at a high rate when demand increases.[7]

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[6] Cane Production Costs, Labor Use, and Labor Costs

	Average Cost of Cane Production Per Ton	Man-Days Per Hectare	Labor Costs Per Hectare
Sao Paulo	3,341	37.4	631
Pernambuco	4,541	98.2	997

Note that most of Sao Paulo production was mechanized and most of Pernambuco production was not. "Pesquisa sobre condicoes e custos de producao de Lavoura Canavieira," Revista Brasileira de Economia (Dezembro 1965), 37-40.

[7] J. H. Sanders, "The Performance of the Brazilian Agricultural Sector from 1950 to 1971: Demand or Supply Constraints?" mimeo, 1973, 18 pages; L. F. Herrmann, Changes in Agricultural Production in Brazil, 1947-65 (ERS, USDA: Washington; June 1972), 12-19, 49-52.

Schuh has come to a similar conclusion and pointed out that agriculture has performed reasonably well in spite of numerous policies discriminating against agriculture especially exchange rate policies discouraging agricultural exports. G. E. Schuh, "A agricultura e o desenvolvimento do Brasil," Revista Brasileira de Economia, 27 (Out./Dez. 1972), 169-207.

Nicholls has observed that output expansion has been keeping up with demand growth maintaining real food prices constant. He attributes these supply shifts primarily to expansion of land area. See W. N. Nicholls, "A agricultura e o desenvolvimento economico do Brasil," Revista Brasileira de Economia 26 (Out./Dez. 1972), 170.

Hence, Brazilian policy makers may be able to pursue multiple objectives in agricultural development and be more concerned with the employment and income distribution consequences of various policy alternatives. Both strategies to increase area cultivated and to expand the use of bio-chemical inputs could increase agricultural employment more than subsidies on machinery. Moreover, both types of strategies could result in a less skewed income distribution than policies to encourage heavy mechanization.

Finally, one test of the appropriateness of mechanization to the particular stage of development is the existence of excess demand for labor in the non-agricultural sector. In evaluating some of the components of excess demand it appears that the ability of the non-agricultural sector to absorb large numbers of rural migrants was not very great at the present time. An increased governmental interest in differentiating between labor absorbing and labor releasing technologies and product shifts in agriculture may be necessary to reduce the social costs of the very high rural-urban migration rates until the ability of the non-agricultural sector to absorb labor can be improved. No one is denying the advantages of mechanization in increasing farmer income by expanding crop area and increasing yields on some types of soils. The difficult problem for Brazilian policy makers is the timing and the type of mechanization to be encouraged at different stages of development.

APPENDIX A

THE DATA EMPLOYED IN CHAPTERS 2-4

A-I. The Data and Variable Descriptions for Chapter 2

Table A-1

The Demand for Tractors: 1950-1971 (Only Wheel Tractors-Excluding Micro Tractors)

Year	Total Tractor Sales Imports and Domestic Sales (No.)[a] T	Tractor Price Relative to Lagged Output Price[b] $P_{T_t}/P_{o_{t-1}}$	Tractor Price Relative to the Agri. Wage Rate[c] $(P_T/W)_t$	Real Value of Tractor Financing[d] $(F/P)_t$ 1971 Cr $ (1000)	Tractor Stock[e] S_t	Dummy Variable[f] D_1	Adjustment to test for the significance of the shift of the slope of the finance variable[g]: T - Log B-D (equation #1 in Table 2)	T - Log B-D (equation #5 in Table 2)
1949					6,589			
1950	8,375	23.4	1,625	31,400	14,637	0	163,197	
1951	10,967	25.1	1,593	50,000	24,872	0	165,789	
1952	7,363	23.8	1,441	64,500	30,992	0	162,185	
1953	2,154	39.9	2,405	56,900	31,596	0	156,976	192,110
1954	12,258	53.3	3,163	73,800	42,274	0	167,080	202,214
1955	5,345	66.1	3,667	71,000	45,505	0	160,167	195,301
1956	4,117	63.3	3,889	71,000	47,347	0	158,939	194,073
1957	6,810	58.0	3,526	86,200	51,790	0	161,632	196,766
1958	7,135	52.3	3,329	79,000	56,336	0	161,957	197,091
1959	4,597	99.2	6,097	70,200	58,116	0	159,419	194,553
1960	12,721	80.7	5,955	96,500	67,931	0	167,543	202,677
1961	8,027	70.2	4,444	90,200	72,561	0	162,849	197,983
1962	9,050	104.8	5,819	186,000	77,983	1	179,307	216,736
1963	10,698	123.5	7,739	205,000	84,782	1	180,955	218,384
1964	13,373	161.6	8,009	248,000	93,916	1	183,630	221,059
1965	8,446	124.2	6,176	192,000	97,666	1	178,703	216,132

Table A-1--continued

Year	Total Tractor Sales Imports and Domestic Sales (No.)[a] T	Tractor Price Relative to Lagged Output Price[b] $P_{T_t}/P_{o_{t-1}}$	Tractor Price Relative to the Agri. Wage Rate[c] $(P_T/W)_t$	Real Value of Tractor Financing[d] $(F/P)_t$ 1971 Cr $ (1000)	Tractor Stock[e] S_t	Dummy Variable[f] D_1	Adjustment to test for the significance of the shift of the slope of the finance variable[g]: T - Log B-D (equation #1 in Table 2)	T - Log B-D (equation #5 in Table 2)
1966	9,853	109.1	5,341	256,000	102,636	1	180,110	217,539
1967	6,812	100.5	5,412	206,000	104,316	1	177,069	214,498
1968	10,253	96.8	4,520	249,000	109,353	1	180,510	217,939
1969	10,094	92.1	4,848	219,000	113,979	1	180,531	217,780
1970	14,402	79.5	3,527	255,000	122,683	1	184,660	222,089
1971	21,782[p]	72.1	3,001	348,749		1	192,039	229,468

[p]based upon an estimate of 1971 imports. See Table B-1 in Appendix B.

[a]The tractor sales variable was constructed by summing imports and domestic sales. Import data were taken from Table B-1. Micro and track tractors were not included. It was assumed that the governmental classification of wheel tractors from 1950-1961 only included agricultural uses and their classification from 1962-1970 of agricultural tractors only included wheel tractors. See the footnotes to Table B-1.

[b]For the tractor price the data from Table B-1 were used with horsepower of the basic model held constant. The agricultural output price is a Laspeyres weighted index with a base year of 1971 for the primary mechanized crops in Brazil including wheat, soybeans, cane, cotton, rice, corn and peanuts. Farmers are expected to observe last season's output price and the present machinery price in deciding upon purchasing a tractor.

[c]The agricultural wage rate was the daily wage of a "volante" in Sao Paulo. "Volante" is the Brazilian term for a day or temporary worker. See Table A-7 for more details on agricultural wages.

Table A-1--continued

[d]The values of nominal credit for all crop producers were obtained from the Banco de Brasil, Relatorios, various issues. Mechanization loans are also made by some other banks primarily the Banco do Estado do Sao Paulo. The Bank of Brazil is the primary machinery financer for all machinery financing (see Appendix E). For some years over the period 1950-1971 the Bank of Brazil did not separate tractor lending from other machinery lending so an estimate of tractor financing was made. For further detail on the assumptions employed to make these estimates see Table A-8. The nominal value of tractor credits was deflated with the index of Brazilian domestic prices constructed from the Getulio Vargas Institute Series No. 2.

[e]The tractor stock variable was based upon the estimate of tractors excluding micro-tractors with the 1950 Census as the base estimate. The 1950 Census was done in 1949. The age of this tractor stock was estimated using the import data of the forties below. Then the declining balance method of treating depreciation and the import and domestic sales data were used to obtain an estimate of the tractor stock excluding micro-tractors. A five percent rate of declining balance depreciation was used. See Chapter 2-A for further detail.

Year	No. of Imports of Tractors and Accessories	Weight of that Year	Estimate of the Tractor Imports
1942	836	1.8	128
1943	971	2.1	149
1944	1,739	3.8	270
1945	2,544	5.6	398
1946	5,460	12.0	852
1947	8,010	17.6	1,249
1948	8,161	17.9	1,271
1949	17,917	39.3	2,790

[f]This dummy variable reflects the difference between the import period and the period of domestic production.

[g]A new dependent variable was constructed from equations #1 and #5 of Table 2 of Chapter 2 to test for a different slope on the finance variable between the two periods, before and after the commencement of the Brazilian tractor industry. This was necessary because of the almost perfect correlation between the two dummy variables.

Table A-2

Correlation Matrix for Tractor Demand, 1950-1971
(Equations 1-4 in Table 2, Chapter 2)

	T	log $\frac{P_T}{Po_{t-1}}$	log $\frac{P_T}{W}$	log $\frac{F}{P}$	log S_{t-1}
log $\frac{P_T}{Po_{t-1}}$	.21				
log $\frac{P_T}{W}$	.08	.96			
log $\frac{F}{P}$	.57	.79	.63		
log S_{t-1}	.34	.86	.75	.90	
D_o	.49	.70	.55	.93	.73

Table A-3

Correlation Matrix for Tractor Demand, 1953-1971
(Equations 5-8 in Table 2, Chapter 2)

	T	log $\frac{P_T}{P_{o_{t-1}}}$	log $\frac{P_T}{W}$	log $\frac{F}{P}$	log S_{t-1}
log $\frac{P_T}{P_{o_{t-1}}}$	.29				
log $\frac{P_T}{W}$	.07	.91			
log $\frac{F}{P}$	.69	.69	.40		
log S_{t-1}	.57	.69	.43	.93	
D_o	.51	.73	.45	.96	.87

Table A-4

Correlation Matrix for Tractor Demand, 1950-1971, Excluding the Years 1953, 1955 - 1959
(Equations 9-12 in Table 2, Chapter 2)

	T	$\log \frac{P_T}{P_{o_{t-1}}}$	$\log \frac{P_T}{W}$	$\log \frac{F}{P}$	$\log S_{t-1}$
$\log \frac{P_T}{P_{o_{t-1}}}$	.14				
$\log \frac{P_T}{W}$	.01	.97			
$\log \frac{F}{P}$	.40	.85	.70		
$\log S_{t-1}$	.29	.87	.76	.94	
D_o	.21	.78	.63	.92	.78

Table A-5

Variables for the Regression of Brazilian Domestic Tractor Sales in Horsepower, 1962-1971

Year	Total HP of 4 Wheel Tractor Sales (excl. micro tractors) T_{H_t}	Tractor Price Per Horsepower Relative to Lagged Crop Output Price $P_T/(P_o)_{t-1}$	Tractor Price Per Horsepower Relative to the Agricultural Wage Rate $(P_T/W)_t$	Real Value of Bank of Brazil Loans for Tractors (Million 1971 Cr $) $(F/P)_t$	Horsepower of the Total Wheel Tractor Stock S_{H_t}
1961					2,692,893
1962	352,128	2.90	159.8	186	3,059,494
1963	435,612	2.95	184.7	205	3,457,841
1964	604,006	2.95	146.1	248	4,005,622
1965	431,852	2.25	112.0	192	4,269,731
1966	490,185	1.94	94.8	256	4,602,022
1967	359,085	1.85	99.6	206	4,765,206
1968	559,485	2.11	98.6	249	5,185,431
1969	602,503	1.60	84.2	219	5,570,962
1970	889,226	1.47	65.0	255	6,187,680
1971	1,356,077	1.37	56.9	349	7,239,373

Description of Variables in Table A-5

T_H: Horsepower of the Brazilian produced tractors sold. Sales data for 4-wheel tractors, excluding micro-tractors, were obtained from industry sources as was the average horsepower of models produced. Since there is little inventory holding (see Table E-4), the horsepower of sales was assumed to be equal to the average horsepower of tractors produced.

P_T: Price per tractor horsepower. This variable was obtained by taking the median purchase price of one representative factory and dividing it by the weighted (by sales) horsepower of their basic model. The variable thus reflects the shift to heavier horsepower tractors over time as well as the influence of various government policy shifts on the tractor price. See Appendix C and Chapter 2-B.

$(P_o)_{t-1}$: Output price lagged one period. Farmers buying a tractor can observe the present price of the tractor but have to use the previous harvest price as the future harvest price is unknown at the time of purchase. The primary mechanized crops are wheat, soybeans, cane, cotton, corn, and rice. The weights were constructed with a Lespreyes Index with 1971 as the base year. A price expectations variable was used for both the entire period and the domestic production period but it gave poor results so it was not included in this analysis.

W: The daily wages for "volantes" or temporary workers in Sao Paulo were used. See Table A-7.

F_P: Real value of tractor credits financed by the Bank of Brazil. This was obtained by deflating the nominal value of tractor credits with the standard index of Brazilian domestic prices, the Getulio Vargas Foundation Index No. 2. There are a few other partially government owned banks making mechanization loans but the Bank of Brazil is the dominant institution (see Appendix E). Due to capital erosion over the long time period allowed for repayment and the low ceiling on interest rates only banks with governmental stockholders would be expected to make agricultural machinery loans and these banks would make only as many agricultural machinery loans as they were ordered to make. It is assumed that within the constraints of government policy directives, the partially state owned banks would maximize profits and that there are many more profitable, shorter term lending activities other than agricultural machinery.

S_H: The average horsepower of the Sao Paulo stock was used to estimate the average horsepower of total Brazilian stock. In the 1959 Census Sao Paulo had 44.3 percent of Brazilian tractors and this Census data was used for the base estimate. For 1960 and 1961 the horsepower of imports was assumed to be equal to the horsepower of the United States tractor sales, as the United States was an important supplier of Brazilian tractor imports in most years. For imports after 1961 the horsepower was assumed to be equal to the Brazilian largest tractor model plus ten horsepower to reflect the prohibitions on tractor imports of models with "national similars" and the tendency to import heavier tractors. A declining balance treatment of depreciation was employed at the annual rate of five percent. At the beginning of 1960 the estimated horsepower of the Sao Paulo stock of 27, 176 tractors was 31.5 C.V. giving an estimate of total Brazilian horsepower of the effective stock of 1, 830, 654. (C. V. is the Portuguese abbreviation for horsepower.)

Table A-6

Correlation Matrix for Domestic Tractor Sales in Horse Power, 1962-1971 (Table 3 in Chapter 2)

	T_H	$\log \frac{P_{T_H}}{P_{o_{t-1}}}$	$\log \frac{P_{T_H}}{W}$	$\log \frac{F}{P}$
$\log \frac{P_{T_H}}{P_{o_{t-1}}}$	-0.67			
$\log \frac{P_{T_H}}{W}$	-0.75	0.97		
$\log \frac{F}{P}$	0.89	-0.60	-0.70	
$\log S_{t-1}$	0.70	-0.95	-0.96	0.69

Table A-7

Agricultural Wage Rates in Sao Paulo, 1950-1971

Year	Resident Agricultural Worker-Monthly Wage[a] (Cr)	Minimum Monthly Wage[b] (Cr)	Farm Resident Wage Over Minimum Wage (%)	"Volante"[c] Daily Wage (Cr)
1950	0.66	0.36	183	0.024
1951	0.81	0.36	225	0.027
1952	0.93	1.19	78	0.034
1953	0.99	1.19	83	0.037
1954	1.14	1.74	66	0.049
1955	1.41	2.30	61	0.060
1956	1.65	2.88	57	0.063
1957	1.89	3.70	51	0.076
1958	2.10	3.70	57	0.082
1959	2.61	5.90	44	0.103
1960	3.42	6.79	50	0.110
1961	4.68	10.38	45	0.171
1962	7.08	13.21	54	0.254
1963	12.30	21.00	59	0.398
1964	31.38	40.25	78	0.814
1965	51.87	62.00	84	1.547
1966	66.48	81.00	82	2.071
1967	83.97	101.50	83	2.538
1968	105.90	125.50	84	3.700
1969	123.00	147.20	84	4.081
1970	154.05	176.80	87	5.511
1971	193.35	213.05	91	7.071

Table A-7--continued

[a]This resident wage does not include the value of perquisites. Credit against the total minimum wage can be given for the perquisites provided to permanent rural workers including the use of a house, a garden plot, and sometimes part of the produce. Perquisites can be provided up to a 30 percent reduction of the minimum wage.

[b]There are regional differences in this minimum wage but the highest value was selected as this included most of the state of Sao Paulo.

[c]"Volantes" are day laborers who are generally contracted by the truck load to do specific jobs such as cultivating or harvesting. The comparison of "volante" and resident labor wages depends upon the assumption about days worked per month by resident workers.

Source: Secretaria da Agricultura, Desenvolvimento da Agricultura Paulista (Instituto de Economia Agricola: Sao Paulo, 1972), 119; Secretaria da Agricultura, Prognostico, Ano Agricola, 1972/73 (Instituto de Economia Agricola: Sao Paulo, 1972), 6-26.

Table A-8

Bank of Brazil Loans for Agricultural Machinery

Year	Machinery Financing for Crops and Livestock[a] (1,000 Cr)	Machinery Financing for Crops (1,000 Cr)	Crop Mechanization Loans as a % of Total Lending (%)	Tractor Financing for Crops and Livestock[b] (1,000 Cr)	Tractor Financing as a % of Total Agricultural Machinery Lending (%)
1949	(59)	52		(45)	
1950	(163)	144		(124)	
1951	(303)	267		(230)	
1952	(436)	385		(331)	
1953	(412)	390		(336)	
1954	(729)	643		(553)	
1955	(817)	721		(620)	
1956	(979)	864		(738)	
1957	(1,352)	1,193		(1,026)	
1958	(1,404)	1,239		(1,066)	
1959	(1,720)	1,518		(1,306)	
1960	(3,052)	2,694		(2,317)	
1961	3,645	3,582	98.3	2,968	81.4
1962	10,919	10,096	92.5	9,262	84.8
1963	20,958	19,706	94.0	17,914	85.5
1964	48,387	45,020	93.0	41,146	85.0
1965	64,763	58,075	89.7	50,010	77.2
1966	130,544	105,087	80.5	92,115	70.6
1967	159,396	128,521	80.6	95,191	59.7
1968	226,028	181,785	80.4	142,942	63.2

Table A-8--continued

Year	Machinery Financing for Crops and Livestock[a] (1,000 Cr)	Machinery Financing for Crops (1,000 Cr)	Crop Mechanization Loans as a % of Total Lending (%)	Tractor Financing for Crops and Livestock[b] (1,000 Cr)	Tractor Financing as a % of Total Agricultural Machinery Lending (%)
1969	304,500	253,920	83.4	151,943[c]	49.9
1970	457,811	397,453	86.8	212,064[c]	46.3
1971	678,626	621,704	91.6	348,749[c]	51.4

[a]To estimate machinery financing for crops and livestock from 1949-1960 the same proportional relationship between machinery financing for crops and for livestock was assumed to exist from 1949-1960 as from 1961-1971.

[b]It was assumed that tractors were the same percentage of total agricultural machinery financing from 1949-1960 as they were from 1961-1968. After 1968 more expensive equipment such as combines reduced the relative importance of tractor financing in total agricultural machinery financing.

[c]From 1969 to 1971 implements and tractors were included as one category in the Relatorios. It was possible to separate out implements by assuming that the same relationship existed between implements and tractors as existed for the years with overlapping data 1967 and 1968. In these years tractors were ninety-seven percent of the category of tractors and implements by value of financing.

Source: Prior to 1961 the Relatorios list machinery financing under the category "Maquinas e utensilios agricolas" but there are separate categories for motorized vehicles and work animals, others, and investment financing for farm improvements. Also prior to 1960 only machinery lending for crop production was included. Banco do Brasil, Relatorios e Boletim, various issues.

Table A-9

Average Horsepower of Tractors Sold in the United States and Great Britain, 1948-1965

Year	United States	Great Britain
1947	25.8	----
1948	27.1	24.1
1949	28.3	24.4
1950	29.0	24.2
1951	29.0	27.7
1952	31.2	29.8
1953	34.6	30.8
1954	38.7	31.1
1955	40.6	31.6
1956	39.6	32.3
1957	43.2	36.0
1958	45.7	35.8
1959	46.2	39.6
1960	50.5	40.4
1961	53.8	42.1
1962	56.0	43.5
1963	58.0	44.8
1964	59.3	45.1
1965	63.1	49.5

Sources: The United States data were calculated and provided by Mr. Paul E. Strickler, USDA, from reports of the Farm and Industrial Equipment Institute. This data reports all tractors shipped or sold hence it would include inventories; the Great Britain data are from A. J. Rayner, An Econometric Analysis of the Demand for Farm Tractors, Bulletin No. 113 (University of Manchester: Manchester; October, 1966), 97.

Table A-10

Brazil's Largest Domestically Produced Tractor

Year	Model	Horsepower
1960	Ford Br 8	56
1961	Ford Br 8	56
1962	CBT 1020	77
1963	CBT 1020	77
1964	CBT 1020	77
1965	CBT 1020	77
1966	CBT 1020	77
1967	CBT 1090	90
1968	CBT 1090	90
1969	CBT 1090	90
1970	CBT 1090	90
1971	CBT 1090	90

Source: Table C-6

A-II. Description of Variables for the 1950 and 1960 States and the 1960 Regions of Sao Paulo: Chapter 3

In the 1950 Census tractors are differentiated between those over and under 10 C. V. ("cavalho vapor" or horsepower in Portuguese) or between micro-tractors and wheel tractors. It was assumed that micro-tractors had one-fourth the horsepower of other tractors. The total agricultural labor force was composed of four components in 1950, owner-operators including renters and administrators, permanent labor, temporary labor, and sharecroppers. In 1950 the four categories of agricultural labor included females and minors working in agriculture; however, most of the field work would be done by males fifteen and over. The seasonal labor utilized in the permanent crop operations such as coffee picking would also include minors and women; however, including all the labor engaged seasonally would substantially overstate the size of the regular agricultural labor force. Hence, minors and women were excluded from the labor force variable. Moreover, the mechanization process was expected to first replace the regular adult male labor force since the harvesting operations which use the largest amounts of minors and women, are generally more difficult to mechanize.

Agricultural wage data were not presented in the Census; however, total expenditures on agricultural labor or the wage bill were available by state. This brought us to a dilemma. The available wage data were presented on an annual basis. Including all women and children employed seasonally would result in an underestimate of annual wages per agricultural worker. It would also bias the comparison of wage rates between states as important producers of coffee and other permanent crops such as cocoa would have a greater downward bias than the states without these large seasonal requirements. Only men and women over fourteen were included here in the total agricultural labor force to divide the wage bill and obtain an estimate of annual wages. The overestimate resulting from including these women in the regular work force would be expected to be offset by the underestimate resulting from excluding all minors. The Census wage bill included the estimated value of perquisites but it did not include the returns to labor of the owner-operator or the sharecropper's payments hence these components of the labor force were not included in the calculation of the annual agricultural wage. The estimated annual wage here would be an estimate of the returns to sharecroppers in equilibrium.

In Table A-11 the results of the calculations of the annual agricultural earnings are presented in column 4. Column 5 gives the per capita income estimates for 1950. The two columns are remarkably consistent. The coefficient of correlation is 0.958.

The distribution variable (D) was the percentage of crop area harvested in the state in farms with over 100 hectares in crop area. Census data gave the frequency distribution of farms by crop acreage in various classifications. Assuming that the number in each cell was normally distributed around the mean of the cell it was possible to calculate the area cultivated in farms with 100 or more cultivated hectares. For over 1,000 hectares a mean of 1,200 was used. One hundred hectares in crop area was considered too large a crop area to depend upon draft animal and human power. The crop mix variable (T_e) was the percentage of total crop area in annual crops. The intensity variable ($\frac{I}{A}$) was the expenditure per hectare of cropland on fertilizers, seeds, plant stock, insecticide, and fungicide.

The only difference between the variable definitions for Brazil and for Sao Paulo was that the 1960 Agricultural Census of All States and for Sao Paulo gave more data on tractor horse-power hence the dependent variable was measured in C.V. per 1,000 agricultural workers. The other variables employed the same definitions. In 1960 an adult worker was defined as fourteen and over whereas in 1950 it was fifteen and over.

Table A-11

Variables for the Tractor Demand Analysis Between States, 1950 Census Data

	Adjusted Tractor Series (no) T	Male, Adult Agricultural Labor Force (no) L	Tractors Per 1,000 Agricultural Workers T/L	Farm Worker Annual Earnings in Agriculture (Cr.) W	Annual Per Capita Income (Cr.)	Percent of Crop Area in Farms with 100 or More Ha. in Crops (%) C	Percent of Crop Area in Annual Crops (%) Te	Expenditures on Fertilizer, Seed, Plant Stock and Insecticide Per Hectare of Cropland (Cr /ha.) I/A	Regional Dummy Re
Brasil[a]	7,417	6,688,904	1.11	2,240	4,100	15.68	76.9	68.2	
North									
Amazonas	9	46,473	0.19	2,300	3,200	7.53	56.2	15.8	0
Para	31	124,916	0.25	1,540	2,400	4.36	78.9	9.9	0
Northeast									
Maranhao	15	198,701	0.075	430	1,400	2.48	95.7	6.3	0
Piaui	19	118,867	0.16	580	1,200	0.91	96.0	8.9	0
Ceara	29	344,708	0.084	720	1,900	7.58	93.9	9.8	0
Rio Grande do Norte	14	159,315	0.088	1,170	2,200	30.68	96.7	9.5	0
Paraiba	57	290,111	0.20	1,000	2,000	17.58	96.5	13.7	0
Pernambuco	123	505,575	0.24	1,560	2,500	17.49	90.7	77.9	0
Alagoas	32	171,671	0.19	1,150	1,800	14.35	89.4	77.3	0
East									
Sergipe	42	98,371	0.43	1,350	2,000	15.97	83.0	70.2	0
Bahia	76	676,076	0.11	1,320	2,000	9.79	61.6	21.3	0
Minas Gerais	664	1,241,108	0.47	1,570	3,100	14.28	76.9	34.3	0

Table A-11--continued

	Adjusted Tractor Series (no) T	Male, Adult Agricultural Labor Force (no) L	Tractors Per 1,000 Agricultural Workers T/L	Farm Worker Annual Earnings in Agriculture (Cr.) W	Annual Per Capita Income (Cr.)	Percent of Crop Area in Farms with 100 or More Ha. in Crops (%) C	Percent of Crop Area in Annual Crops (%) Te	Expenditures on Fertilizer, Seed, Plant Stock and Insecticide Per Hectare of Cropland (Cr/ha.) I/A	Regional Dummy Re
Espirito Santo	51	153,311	0.33	2,660	3,200	9.10	38.8	15.9	0
Rio de Janeiro	401	199,178	2.01	3,580	4,200	26.87	68.4	57.0	1
Federal Distrit (Guanabara)	42	13,662	3.07	7,530	13,700	4.60	15.0	346.0	1
South									
Sao Paulo	3,344	1,002,874	3.33	4,920	7,800	29.71	63.3	159.5	1
Parana	248	299,326	0.83	3,240	4,800	11.36	64.0	35.2	1
Santa Catarina	37	188,688	0.20	1,550	3,500	0.59	95.3	18.4	1
Rio Grande do Sul	2,066	602,041	3.43	2,650	4,600	7.24	95.2	100.4	1
Center West									
Mato Grosso	46	51,174	0.90	2,950	3,000	8.86	86.2	12.9	1
Goias	82	165,850	0.49	1,700	2,300	6.52	88.7	5.7	1

[a]Due to the exclusion of the territories the columns do not sum. Acre was also excluded due to the almost complete lack of tractors.

Source: IBGE, Brasil-Censo Agricola, VI Recenseamento Geral do Brasil-1950 (Rio de Janeiro, 1956); Annual per capita incomes were taken from FGV and IBGE, 25 Anos de Economia Brasileira (Comissao Mista Brasil-Estados Unidos: Rio de Janeiro; 1965), p.260.

Table A-12

Variables for the Tractor Demand Function Between States in Brazil, 1960 Census Data

State	Tractor Horse-power (CV) T_H	Male, Adult Labor Force in Agricul. (no) L	$\frac{CV}{1000\ L}$ T/L	Annual Earnings in Agric. per Farm Worker (Cr. 1000) W	Percent of Crop Area in Farms with 100 or More Ha. in Crops (%) C	Percent of Crop Area in Annual Crops (%) Tc	Bio-chemical Expenditures Per Hectare (Cr. 1000) I/A	Pooling Dummy	Regional Dummy Re
Brasil	2,012,816	9,241,857	217.8	16.422	21.5	72.8	0.674		
North									
Amazonas	736	90,168	8.2	17.730	2.8	74.4	0.166	0	0
Para	8,188	183,067	44.7	13.936	11.6	76.5	0.445	0	0
Northeast									
Maranhao	1,058	506,079	4.7	4.448	17.3	96.6	0.056	0	0
Piaui	1,890	204,436	9.2	6.487	13.9	95.4	0.171	0	0
Ceara	5,678	523,794	10.8	5.189	21.6	63.5	0.124	0	0
Rio Grande do Norte	7,734	132,299	42.4	9.894	33.7	65.1	0.159	0	0
Paraiba	11,554	320,624	36.0	10.544	28.5	81.2	0.191	0	0
Pernambuco	32,284	686,307	47.0	9.822	30.7	79.7	0.554	0	0
Alagoas	9,300	198,580	46.8	9.886	33.7	89.4	0.545	0	0
East									
Sergipe	2,966	142,198	20.9	7.537	21.6	73.4	0.412	0	0
Bahia	14,886	937,863	15.9	10.711	15.5	60.3	0.256	0	0
Minas Gerais	154,674	1,377,239	112.3	12.551	17.5	76.1	0.453	0	0
Espirito Santo	14,904	183,799	81.1	17.678	11.3	41.5	0.244	0	0
Rio de Janeiro	45,336	186,595	243.0	28.350	24.8	68.3	0.676	0	1
Guanabara	3,116	15,142	205.8	50.615	6.1	16.9	4.250	0	1

Table A-12--continued

State	Tractor Horse-power (CV) T_H	Male, Adult Labor Force in Agricul. (no) L	$\frac{CV}{1000\ L}$ T_H/L	Annual Earnings in Agric. per Farm Worker (Cr. 1000) W	Percent of Crop Area in Farms with 100 or More Ha. in Crops (%) C	Percent of Crop Area in Annual Crops (%) Te	Bio-chemical Expenditures Per Hectare (Cr. 1000) I/A	Pooling Dummy	Regional Dummy Re
South									
Sao Paulo	856,102	1,165,715	734.4	30.704	34.0	64.7	1.597	0	1
Parana	156,076	763,514	204.4	29.113	20.9	51.8	0.575	0	1
Santa Catarina	37,552	276,485	135.8	17.732	2.6	93.3	0.415	0	1
Rio Grande do Sul	573,754	746,263	768.8	23.889	18.4	95.0	1.149	0	1
Center West									
Mato Grosso	27,772	120,598	230.3	25.796	17.7	83.2	0.395	0	1
Goias[a]	45,652	306,049	149.2	17.154	18.3	87.6	0.237	0	1

[a]Including the federal district in Goias.

Source; IBGE, Brasil-Censo Agricola, VII Recensamento Geral do Brasil-1960 (Rio de Janeiro: 1970).

Table A-13

Variables for the Tractor Demand Function Between Regions in Sao Paulo, 1960 Census Data

	Tractor Horse-power at the Drawbar (CV) T_H	Male Adult Labor Force in Agriculture (no.) L	(CV/1000L) T_H/L	Annual Earnings in Agric. per Farm Worker (Cr. $1000) W	Percent of Crop Area in Farms with 100 or More Ha. in Crops (%) C	Percent of Crop Area in Annual Crops Te	Bio-chemical Expenditures Per Hectare (Cr. $1000) I/A	Pooling Dummy
Sao Paulo	856,102	1,165,715	734.4	30.704	34.0	64.7	1.597	
Zona do:								
Lit. de Sao Sabastiao	1,104	2,287	482.7	37.537	22.8	28.8	1.133	1
Medio Paraiba	19,810	27,507	720.2	28.645	29.2	74.7	3.083	1
Alto Paraiba	1,428	14,000	102.0	22.562	5.3	91.1	0.614	1
Mantiquiera	404	3,734	108.2	29.890	13.6	88.4	3.290	1
Lit. de Santos	392	3,086	127.0	37.367	36.0	3.1	2.269	1
Baixada do Ribeira	3,034	23,327	130.1	33.076	13.5	46.2	0.710	1
Sao Jose do Rio Pardo	13,006	28,226	460.8	23.990	46.5	57.6	2.326	1
Braganca	25,870	42,471	609.1	21.835	28.9	59.7	2.221	1
Sao Paulo	69,844	56,347	1,239.5	43.872	33.8	69.1	5.652	1
Paranapiacaba	27,104	26,651	1,032.5	24.138	10.5	94.8	4.875	1
Alto Ribeira	846	12,668	66.8	4.547	3.8	97.4	1.200	1
Pirassununga	38,472	47,496	810.0	14.535	43.3	79.5	1.913	1
Rio Claro	36,282	23,114	1,569.7	33.097	49.8	73.1	1.853	1
Piracicaba	39,700	37,669	1,053.9	33.709	44.2	91.1	1.037	1
Campos Gerais	26,912	35,576	756.5	22.504	18.5	94.7	1.233	1

Table A-13--continued

	Tractor Horse-power at the Drawbar (CV) T_H	Male Adult Labor Force in Agriculture (no.) L	(CV/1000L) T_H/L	Annual Earnings in Agric. per Farm Worker (Cr. $1000) W	Percent of Crop Area in Farms with 100 or More Ha. in Crops (%) C	Percent of Crop Area in Annual Crops Te	Bio-chemical Expenditures Per Hectare (Cr. $1000) I/A	Pooling Dummy
Itaporanga	4,546	11,357	400.3	25.267	14.0	85.3	0.470	1
Franca	14,418	22,504	640.7	36.555	38.3	60.5	1.303	1
Ribeirao Preto	44,490	50,967	872.9	33.355	67.2	69.8	1.415	1
Araraquara	37,280	30,834	1,209.1	38.787	45.7	72.9	2.199	1
Sao Carlos e Jau	28,556	33,249	858.9	39.186	61.5	58.2	1.385	1
Botucatu	22,156	28,628	773.9	32.214	54.8	50.6	1.421	1
Piraju	6,788	15,043	451.2	35.603	52.1	27.5	0.848	1
Barretos	88,696	55,679	1,593.0	37.501	49.7	79.2	1.257	1
Rio Preto	36,162	65,478	552.3	22.725	27.1	53.3	0.898	1
Catanduva	29,886	50,120	596.3	26.731	41.4	45.9	1.048	1
Bauru	35,018	49,861	702.3	34.309	47.5	37.6	1.081	1
Aracatuba	37,334	51,690	722.3	34.101	21.9	54.9	1.350	1
Marilia	64,182	113,771	564.1	32.968	27.1	49.2	1.664	1
Assis	39,472	55,485	711.4	28.186	26.2	63.3	0.989	1
Pres. Prud.	23,784	50,241	473.4	35.708	10.2	91.7	1.993	1
Pereira Barreto	24,112	60,563	398.1	28.598	22.4	65.4	0.983	1
Andradina	8,522	27,418	310.8	28.380	20.5	51.1	1.865	1
Pres. Venceslau	6,492	8,668	749.0	40.667	38.7	96.8	1.952	1

Source: IBGE, Sao Paulo, Censo Agricola, VII Recenseamento Geral do Brasil, 1960 (Rio de Janeiro; 1970).

Table A-14

Correlation Matrix for the 1950 All States Tractor-Labor Ratios

	log T/L	log W	log I/A	log Te	log D
log W	.85				
log I/A	.71	.66			
log Te	-.44	-.68	-.51		
log D′	.25	.32	.34	-.03	
Re	.77	.69	.36	-.23	-.07

Table A-15

Correlation Matrix for the 1960 All States Tractor-Labor Ratios

	log T_{ii}/L	log W	log I/A	log Te	log D
log W	.82				
log I/A	.77	.78			
log Te	-.21	-.51	-.52		
log D	.13	-.25	-.02	.20	
Re	.81	.79	.61	-.19	-.13

Table A-16

Correlation Matrix for the 1960 Sao Paulo Regions Tractor-Labor Ratios

	log T_H/ L	log W	log I/A	log Te
log W	.46			
log I/A	.25	.12		
log Te	.26	-.26	.02	
log D	.68	.56	.12	-.26

A-III. Pooled Regression of All States and Sao Paulo for 1960: Chapter 3

The equations for All States and Sao Paulo in 1960 gave different results for the wage rate coefficient and several other variables. By pooling these two sets of observations and constraining their coefficient estimates to be equal the significance of their difference can be tested. The pooling model is:

1) $$\log \frac{T_H}{L} = \log B + D_o + \alpha_1 \log W + \alpha_2 D_1 \log W + \alpha_3 \log \frac{I}{A} + \alpha_4 \log T_e + \alpha_5 \log D + \varepsilon_i$$

where D_o is a dummy used as an intercept shifter as there is no reason to expect the Sao Paulo and All States tractor demand equations to have the same intercept. D_1 is a dummy employed to allow the wage rate coefficient slope to vary for the two sets of observations. Equations (5') and (9') from Table 11 are significantly different even when the intercept is allowed to shift. When both the intercept and the wage rate coefficient are allowed to shift between the two sets of observations, the slopes of the three other variables are not significantly different (Table A-17).[1]

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[1]The test is $$\frac{\dfrac{A - B - C}{k}}{\dfrac{B+C}{N_1+N_2-2k}}$$

where A, B, and C are the error sums of squares for the pooled regression or constrained equation and the two unrestricted equations, 5' and 9' from Table 11 in Chapter 3; k is the number of constraints on the equations: N_1 and N_2 are the number of observations in 5' and 9' respectively. See G. C. Chow, "Tests of Equality Between Sets of Coefficients in Two Linear Regressions," Econometrica (July 1960), 591-605.

Table A-17

Pooled Regression Results For The 1960 Census All States and Sao Paulo Regions: Tractor-Labor Ratios As A Function of Wage Rates And Other Variables

No.	Constant	Dummy for Intercept Shifter Do	Wage Rate W	Dummy for Slope Shifter of Wage Rate $\alpha_2 D_1$	Intensity $\frac{I}{A}$	Crop Mix Te	Concentration D	Standard Error of Estimate	$\bar{R}^2$	F Level	Degree of Freedom	F-test[a] for the significance of the difference between Equations (5') and (9') of Table 11, Chapter 3
(1")	-3.01 (1.10)		1.30 (6.28)***		0.62 (5.12)***	0.70 (4.26)***	0.53 (4.41)***	0.61	0.84	69.1	49	5.46***
(2")	-2.48 (1.12)	-0.43 (1.82)*	1.25 (6.13)***		0.50 (3.70)***	0.68 (4.24)***	0.48 (4.02)***	0.59	0.84	58.5	48	4.54***
(3")	-0.44 (1.05)	-5.33 (4.73)***	0.45 (1.78)*	1.55 (4.42)***	0.26 (2.02)**	0.68 (4.95)***	0.71 (6.24)***	0.51	0.89	70.8	47	0.59[n.s.]

(t-values in paranthese except for the standard error of the intercept)

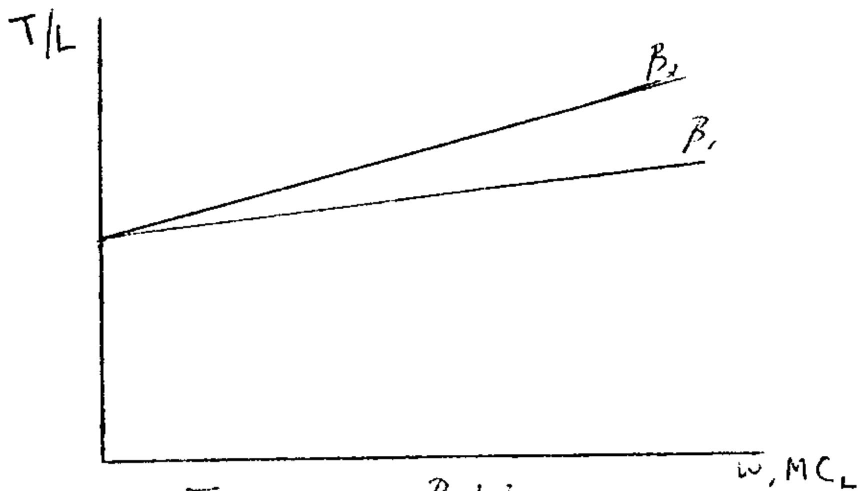
* significant at the 90 percent level
** significant at the 95 percent level
*** significant at the 99 percent level

a. The number of degrees of freedom of the test was 5/44.

This leaves us with a puzzle of why the wage rate coefficient is significantly lower in Sao Paulo than in the entire country. One hypothesis for this difference is that there could be a measurement problem of failing to include the additional marginal cost of labor to the large employer resulting from the costs of finding, coordinating and controlling a large seasonal labor force. Moreover, there is an uncertainty component that the large crop farmer will either not be able to find labor at all at the critical time or that the labor price will be higher than expected. If this explanation is correct, the slope B_1 rather than B_2 is being estimated due to the concentration of large crop farms in Sao Paulo (see Tables A-11 and A-12).

Figure A-1

Tractor-Labor
Ratios and Labor Costs in Regions with Different
Crop Farm Sizes



$$\frac{T}{L} = \alpha_1 + \beta_1 w$$

$$\frac{T}{L} = \alpha_2 + \beta_2 (MC_L)$$

where MC_L is the marginal cost of labor.

An alternative explanation is that the costs of a seasonal labor force may not be higher but that the large farmer prefers to avoid the bother of labor intensive production or that labor intensive production enters his utility function in a negative way.

Table A-18

Correlation Matrix for the 1960 Pooled Regression of Tractor-Labor Ratios Combining Sao Paulo and All States Observations

	log T_W/L	Do	log W	$\alpha_j D_1$	log I/A	log Te
Do	-.70					
log W	.80	-.57				
$\alpha_j D_1$	-.53	.96	-.36			
log I/A	.79	-.69	.71	-.53		
log Te	-.06	.15	-.35	.08	-.23	
log D	.49	-.35	.31	-.38	.27	-.17

A-IV. The Census Data Employed in Chapter 4

A/L was cropland per adult, male agricultural worker. The animal power variable (An/L) was difficult to specify as many animals can be used for land preparation. These same animals are also used for other operations. In 1950 animal power was defined as burros, mules, and donkeys. In the 1960 All States function animal power was defined as horses, mules, and oxen. In the 1960 Sao Paulo Regions function the animal power variable was defined as oxen and mules. In all three cases the animal units were divided by the number of adult, male agricultural workers. Since it wasn't possible to separate out the power and other uses in any of the animal categories, the specification of the proxy for animal power was determined statistically as that variable giving the most significant and consistent estimates. T/L or tractor utilization per worker in the 1950 Census was defined as tractor numbers with micro-tractors weighted as one-fourth. In 1960 T/L was tractor horsepower divided by the number of male, adult agricultural workers. In the Census of 1960 tractors were stratified by horsepower category and the mean of each stratum was used to estimate the total horsepower in that stratum as follows:

Strata	Expected Mean
Less than 10 C.V.	6 C.V.
10-30	20
30-50	40
More than 50	60

I/A or bio-chemical input use was defined as expenditures in cruzeiros per hectare of crop land on fertilizers, seeds, plant stock, insecticide, and fungicide. The crop mix variable was the percentage of the total crop area in annual crops with sugarcane defined as an annual crop. There were two milk production variables:

M_1/L was cows milked per agricultural worker; and

M_2/L was milk production per agricultural worker.

Table A-19

The Expansion Function, 1950 Census Data, for the States of Brazil

	A/L	An/L	T/L	I/A	Te	M_1/L	M_2/L
North:							
Amazonas	1.144	0.0104	0.19×10^{-3}	15.8	56.2	0.272	1.057
Para	1.295	0.0141	0.25×10^{-3}	9.9	78.9	0.284	0.503
Northeast:							
Maranhao	1.654	0.181	0.075×10^{-3}	6.3	95.7	0.332	0.377
Piaui	1.894	0.312	0.160×10^{-3}	8.9	96.0	1.023	1.236
Ceara	2.399	0.267	0.084×10^{-3}	9.8	93.9	0.480	1.422
R. Grande do Norte	2.785	0.142	0.088×10^{-3}	9.5	96.7	0.422	2.034
Paraiba	2.277	0.144	0.20×10^{-3}	13.7	96.5	0.335	1.465
Pernambuco	1.976	0.124	0.240×10^{-3}	77.9	90.7	0.257	1.469
Alagoas	1.642	0.118	0.190×10^{-3}	77.3	89.4	0.197	0.862
East:							
Sergipe	1.378	0.182	0.430×10^{-3}	70.2	83.0	0.417	1.582
Bahia	2.030	0.329	0.110×10^{-3}	21.3	61.6	0.702	1.930
Minas Gerais	2.367	0.163	0.470×10^{-3}	34.3	76.9	1.468	7.048
Espirito Santo	3.835	0.249	0.33×10^{-3}	15.9	38.8	0.450	2.367
Rio de Janeiro	2.954	0.136	2.01×10^{-3}	57.0	68.4	0.748	5.845
Federal District (Guanabara	1.593	0.0494	3.07×10^{-3}	346.0	15.0	0.193	2.689

Table A-19--continued

	A/L	An/L	T/L	I/A	Te	M_1/L	M_2/L
South:							
Sao Paulo	4.245	0.370	3.33×10^{-3}	159.5	63.3	0.826	5.132
Parana	4.538	0.147	0.83×10^{-3}	35.2	64.0	0.313	1.886
Santa Catarina	3.549	0.106	0.20×10^{-3}	18.4	95.3	1.008	8.448
R. Grande do Sul	4.157	0.120	3.43×10^{-3}	100.4	95.2	1.017	7.455
Center West:							
Mato Grosso	2.801	0.180	0.90×10^{-3}	12.9	86.2	3.225	7.522
Goias	2.803	0.204	0.49×10^{-3}	5.7	88.7	2.856	6.287
Brazil	2.855	0.207	1.11×10^{-3}	68.2	76.9	0.850	4.113

Source: IBGE, Brasil-Censo Agricola, VI Recenseamento Geral do Brasil-1950 (Rio de Janeiro; 1956).

A/L: hectares of cropland per agricultural worker
An/L: number of work animals per agricultural worker
T/L: weighted tractor units per agricultural worker
I/A: cruzeiros of expenditures on bio-chemical inputs per hectare of cropland
T_e: percent of cropland in annual crops
M_1/L: cows per agricultural worker
M_2/L: 100 kg of milk production per agricultural worker

Table A-20

The Expansion Function, 1960 Census Data, for the States of Brazil

Regions	A/L	An/L	T_w/L	I/A	Te	M_1/L	M_2/L
Brazil	3.107	0.746	0.218	0.674	72.8	2.170	4.002
Amazonas	1.056	0.022	0.008	0.166	74.4	0.590	0.958
Para	1.609	0.298	0.045	0.445	76.5	1.659	0.778
Maranhao	1.770	0.508	0.002	0.056	96.6	0.972	0.314
Piaui	2.269	0.514	0.009	0.171	95.4	1.991	1.063
Ceara	2.988	0.358	0.011	0.124	63.5	0.982	1.222
Rio Grande do Norte	3.409	0.404	0.042	0.159	65.1	0.875	1.485
Paraiba	3.158	0.329	0.036	0.191	81.2	0.854	1.393
Pernambuco	2.036	0.299	0.047	0.554	79.7	0.477	1.146
Alagoas	2.165	0.473	0.047	0.545	89.4	0.664	1.251
Sergipe	1.259	0.672	0.021	0.412	73.4	1.054	1.795
Bahia	2.306	0.706	0.016	0.256	60.3	1.780	1.749
Minas Gerais	2.613	1.030	0.112	0.453	76.1	3.083	7.929
Espirito Santo	4.013	0.584	0.081	0.244	41.5	1.227	3.328
Rio de Janeiro	3.202	0.764	0.243	0.676	68.3	2.038	8.955
Guanabara	1.553	0.190	0.206	4.250	16.9	0.509	3.536
Sao Paulo	4.090	0.666	0.734	1.597	64.7	1.998	5.801

Table A-20--continued

Regions	A/L	An/L	T/L	I/A	Te	M_1/L	M_2/L
Parana	4.507	0.493	0.204	0.575	51.8	0.869	1.568
Santa Catarina	3.593	1.057	0.136	0.415	93.3	1.458	7.957
Rio Grande do Sul	4.971	1.597	0.769	1.149	95.0	4.111	8.107
Mato Grosso	3.099	2.045	0.230	0.395	83.2	19.446	4.487
Goias[a]	3.242	1.433	0.149	0.237	87.6	5.678	6.315

[a]Includes the Federal District of Brasilia.

Source: IBGE, Brasil-Censo Agricola, VII Recenseamento Geral do Brasil-1960 (Rio de Janeiro; 1970).

A/L: hectares of cropland per agricultural worker
An/L: number of work animals per agricultural worker
T/L: tractor horsepower per agricultural worker
I/A: 1,000 cruzeiros of expenditures on bio-chemical inputs per hectare of cropland
T_e: percent of cropland in annual crops
M_1/L: cows per agricultural worker
M_2/L: 100 kg of milk production per agricultural worker

Table A-21

The Expansion Function for the Regions of Sao Paulo, Census Data of 1960

	A/L	An_1/L	T_H/L	I/A	Te	M_1/L	M_2/L
Sao Paulo	4.090	0.3865	0.7344	1.597	64.7	0.8061	5.802
Litoral de Sao Sebastiao	3.452	0.0734	0.4827	1.133	28.8	0.1241	1.002
Medio Paraiba	1.823	0.4721	0.7202	3.083	74.7	3.0278	34.485
Alto Paraiba	1.881	0.5334	0.1020	0.614	91.1	3.1570	29.523
Manti-queira	1.580	0.3596	0.1082	3.290	88.4	1.0289	7.517
Litoral de Santos	4.953	0.0609	0.1270	2.269	3.1	0.0482	0.537
Baixada do Ribeira	2.539	0.0714	0.1301	0.710	46.2	0.0629	0.195
Sao Jose do Rio Pardo	3.133	0.4977	0.4608	2.326	57.6	1.3059	12.017
Braganca	2.708	0.3199	0.6091	2.221	59.7	0.6501	5.632
Sao Paulo	2.713	0.3628	1.2395	5.652	69.1	0.5825	6.687
Paranapia-caba	2.491	0.3751	1.0325	4.875	94.8	0.1644	1.035
Alto Ribeira	1.776	0.1105	0.0668	1.200	97.4	0.0339	0.151
Pirassun-unga	2.664	0.2996	0.8100	1.913	79.5	1.0131	10.176

Table A-21--continued

	A/L	An_1/L	T_H/L	I/A	Te	M_1/L	M_2/L
Rio Claro	5.311	0.4850	1.5697	1.853	73.1	0.7546	6.470
Piracicaba	5.096	0.6153	1.0539	1.037	91.1	0.5853	3.963
Campos Gerais	4.376	0.5193	0.7565	1.233	94.7	0.7881	5.569
Itaporanga	5.085	0.6447	0.4003	0.470	85.3	0.4300	2.701
Franca	4.688	0.4607	0.6407	1.303	60.5	1.3590	7.551
Ribeirao Preto	4.532	0.3702	0.8729	1.415	69.8	1.1067	10.362
Araraquara	5.091	0.3386	1.2901	2.199	72.9	0.8301	6.510
Sao Carlos e Jau	4.756	0.4263	0.8589	1.385	58.2	0.8270	6.419
Botucatu	4.305	0.4101	0.7739	1.421	50.6	0.8398	5.183
Piraju	4.663	0.3232	0.4512	0.848	27.5	0.3518	1.955
Barretos	6.534	0.4129	1.5930	1.257	79.2	1.1618	7.413
Rio Preto	4.100	0.3380	0.5523	0.898	53.3	1.1762	5.724
Catanduva	4.643	0.3880	0.5963	1.048	45.9	0.8690	4.142
Bauru	4.557	0.4020	0.7023	1.081	37.6	0.6960	3.922
Aracatuba	4.027	0.3635	0.7223	1.350	54.9	0.7380	2.791
Marilia	4.185	0.3313	0.5641	1.664	49.2	0.3772	1.733
Assis	4.668	0.4279	0.7114	0.989	63.3	0.8679	4.352
Presidente Prudente	4.634	0.5678	0.4734	1.993	91.7	0.3491	1.446
Pereira Barreto	3.820	0.2986	0.3981	0.983	65.4	0.5446	2.416
Andradina	3.944	0.2511	0.3108	1.865	51.1	0.4254	2.560
Presidente Wenceslau	5.876	0.4670	0.7490	1.952	96.8	0.3464	1.816

Source: IBGE, Sao Paulo, Censo Agricola, VII Recenseamento Geral do Brasil, 1960 (Rio de Janeiro; 1970)

NOTE: The units of the variables in this table were the same as those in Table A-20.

Table A-22

Correlation Matrix for the 1950 All States Expansion Function

	log A/L	log An/L	log T/L	log I/A	log Te	log M_1/L
log An/L	.54					
log T/L	.42	-.01				
log I/A	.09	-.03	.71			
log Te	.09	.25	-.44	-.51		
log M_1/L	.45	.43	.23	-.28	.32	
log M_2/L	.67	.31	.61	.27	-.06	.73

Table A-23

Correlation Matrix for the 1960 All States Expansion Function

	log A/L	log An/L	log T/L	log I/A	log Te
log An/L	.63				
log T/L	.62	.47			
log I/A	.13	.13	.78		
log Te	-.09	.28	-.22	-.52	
log M_2/L	.55	.55	.83	.57	-.11

Table A-24

Correlation Matrix for the 1960 Sao Paulo Regions Expansion Function

	log A/L	log An/L	log T/L	log I/A	log Te	log M_1/L
log An/L	.23					
log T/L	.56	.53				
log I/A	-.29	.03	.25			
log Te	-.21	.63	.26	.02		
log M_1/L	.04	.77	.44	.01	.42	
log M_2/L	-.03	.70	.44	.14	.33	.96

APPENDIX B

TRACTOR IMPORTS AND GOVERNMENT POLICY

Tractor Imports and Government Policy

Brazilian commercial policy with respect to tractor imports can be divided into three periods, 1947-1952, 1953-1961, and 1961 to the present.[1] At the end of the Second World War Brazil had a large foreign exchange reserve and an overvalued exchange rate. These exchange reserves were quickly exhausted from 1945 to 1947 as imports became available after the war. From 1947 to 1953 a licensing system was employed in order to maintain the overvalued exchange rate with five categories in which agricultural equipment were considered "super essential." Imports depended not only upon their ranking but also upon the balance of payments position, which in turn was primarily determined by export earnings at this time.

In the early fifties Brazilian exports boomed due to two factors; (a) the increased world demand for Brazilian agricultural and raw material exports resulting from the Korean War and (b) the increased coffee price after the expiration of the Inter-American coffee agreement in 1948 (see Table B-4). Nevertheless, imports continued at such high levels that Brazil had

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[1] I am not implying that Brazil had a specific tractor policy but that various exchange rate and commercial policies affected the growth of the Brazilian tractor stock. This section draws heavily upon J. Bergsman, Brazil, Industrialization and Trade Policies (Oxford University Press: London; 1970), Ch. 3, "Post-War Commercial Policy," 27-54.

exhausted foreign reserves by the beginning of 1952. It took a year to reverse the expansion policy of the import licensing agency. Both the general import index and the tractor imports reflect this import boom in 1951 and 1952 and the subsequent crunch in 1953.[2]

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[2]D. L. Huddle, "Balanco de pagamentos e controle de cambios no Brasil: eficacia, ben-estar e desenvolvimento economico," Revista Brasileira de Economia, 18 (June, 1964), 6, 7, 13, 28 ff.

Huddle criticizes this licensing system as being ad hoc hence not stimulating development and resulting in the growth of firms specializing in obtaining licenses for imports at preferential rates.

Table B-1

Tractor Imports, Prices, and Financing, 1950-1971

Year	Total Value of Imports Index (1954 = 100) (1)	Wheel Tractors Excluding Micro Tractors[a] (No.) (2)	Tractors for Agricultural Use[a] (No.) (3)	Micro Tractors[b] (No.) (4)	Track Tractors (No.) (5)	Tractors for Non-Specified Use[c] (No.) (6)	Total Tractors (No.) (col. 2-6) (7)	Track Tractors[d] as a % of Total Tractors (%) (8)	Tractor Price[c] (Cr$) (9)	Price of Tractors Relative to the Agricultural Wage $\frac{Pt}{W}$ (10)	Real Value of Tractor Financing of the Bank of Brazil in 1971 Cr. (million Cr$) (11)
1950	63	8,375							39	1,625	31.4
1951	95	10,967							43	1,593	50.0
1952	92	7,363							49	1,441	64.5
1953	70	2,154			1,135		3,289		89	2,405	56.9
1954	100	12,258			2,744		15,002		155	3,163	73.8
1955	89	5,345		39	569		5,953	9.6	220	3,667	71.0
1956	84	4,117		21	612		4,750	12.9	245	3,889	71.0
1957	104	6,810		46	1,299		8,155	15.9	268	3,526	86.2
1958	102	7,135		46	1,095		8,276	13.2	273	3,329	79.0
1959	113	4,597		2	377		4,976	7.6	628	6,097	70.2
1960	114	12,702		425	1,338		14,465	9.2	655	5,955	96.5
1961	106	6,382		732	990		8,104	12.2	760	4,444	90.2
1962			1,714	1,309		1,085	4,108	26.4	1,478	5,819	186
1963			1,330	1,083		794	3,207	24.8	3,030	7,739	205
1964			1,341	442		632	2,415	26.2	6,519	8,009	248
1965			374	183		864	1,421	60.8	9,555	6,176	192
1966			639	20		1,820	2,479	73.4	11,061	5,341	256
1967			342	5		1,013	1,360	74.5	13,735	5,412	206

Table B-1--continued

Year	Total Value of Imports Index (1954 = 100) (1)	Wheel Tractors Excluding Micro Tractors[a] (No.) (2)	Tractors for Agricultural Use[a] (No.) (3)	Micro Tractors[b] (No.) (4)	Track Tractors (No.) (5)	Tractors for Non-Specified Use[c] (No.) (6)	Total Tractors (No.) (col. 2-6) (7)	Track Tractors[d] as a % of Total Tractors (%) (8)	Tractor Price[e] (Cr$) (9)	Price of Tractors Relative to the Agricultural Wage Pt (10)	Real Value of Tractor Financing of the Bank of Brazil in 1971 Cr. (million Cr$) (11)
1968			990	4		2,317	3,311	70.0	16,724	4,520	249
1969			423	11		2,180	2,614	83.4	19,785	4,848	219
1970			60[E]	38		3,268	3,366	97.1	19,436	3,527	255
1971			50[E]						21,223	3,001	349

[a]From 1955 to 1961 the data are differentiated between wheel, track, and micro tractors. After 1961 the data are listed as agricultural tractors, tractors for non-specified use, and micro tractors.

[b]From 1960 to 1968 these data were obtained from the airgrams of the United States State Department. From 1955 to 1959 these data were calculated as a residual. For 1969 and 1970 they were obtained from CACEX of the Bank of Brazil.

[c]Non-specified use excludes agricultural use.

[d]Note that after 1961 this column becomes non-agricultural tractors as a percent of total tractors.

[e]This is the purchase price of the Fordson 42 horsepower tractor, which was calculated from data presented in Desenvolvimento for 1953-1961. For 1950-1952 the Fordson price was extrapolated using the agricultural machinery price index of the above source. For 1962-1971 this is the purchase price of the Massey-Ferguson 50X, which has a 44.5 horsepower motor. The price is in new cruzeiros which are equal to 1,000 old cruzeiros.

Table B-1--continued

[E]Estimate.

Sources: Data on tractor imports were obtained from various sources including CACEX, which is the foreign trade division of the Bank of Brazil, the Ministerio de Fazenda, airgrams on agricultural mechanization of the U.S. Department of State, and Secretaria da Agricultura, I Simposio sobre Fabricacao do Trator e Implementos Agricolas no Brasil (Sao Paulo; November, 1955), 128.

Help in obtaining this data is gratefully acknowledged to Dr. Philip Warnken and Mr. Lee Bettis; data on tractor prices were calculated from the Secretaria da Agricultura, Desenvolvimento da Agricultura Paulista (Instituto de Economia Agricola: Sao Paulo, 1972), 86, 92, 295. The import index is from N. H. Leff, "Import Constraints and Development: Causes of the Recent Decline of Brazilian Economic Growth," Review of Economics and Statistics, 49 (November 1967), 494-502. For detail on the construction of the agricultural wage rate and the real value of tractor credits see Appendix A.

In 1953 Brazil implemented a multiple exchange auction system. This system did not include all exchange transactions (around fifty percent in 1954) but it was designed to eliminate some of the worst abuses of the gains from rationing foreign exchange at an over-valued rate.[3] From 1953 to 1961 tractors and other agricultural capital goods were again given favorable exchange rate and tariff treatment. Data for this period are available to estimate the size of this subsidy on agricultural machinery. There are two ways of illustrating this preferential treatment. First, the purchasing power of cruzeiros for agricultural capital goods can be compared with that for other imports. If it takes thirty cruzeiros to buy one dollar for importing capital goods and sixty cruzeiros to buy one dollar for other imports, than the ratio of the two indicates the favorable treatment of agricultural capital goods. Over the period 1954 to 1961 on the average it was possible to purchase 1.3 and 2.2 times as many dollars for importing agricultural capital goods as for the general category of imports with and without protection. (See Table B-2) Note that from 1961 to 1962 there was a shift in exchange rate treatment so that agricultural capital goods were

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[3]See A. Kafka, "The Brazilian Exchange Auction System," Review of Economics and Statistics (August 1956), 310 ff. The system was revised in 1957, reducing the number of exchange rates from five to two and imposing "ad valorem" tariffs. This change doesn't affect the above analysis so it will be ignored. For further detail see J. Bergsman, op cit., 32 ff. There was a substantial gain in Federal revenue from this system. Kafka estimates that in 1954 one-third of Federal revenue was derived from these auctions. See Kafka, 314.

treated less favorably than the general category of imports excluding tariffs. Tariffs were also imposed on all tractor models similar to those produced domestically so that after 1961 the agricultural capital goods category only includes heavy tractors and other capital goods not produced domestically.

Another way of evaluating exchange rates is to estimate their effect upon the tractor price. The difference between an equilibrium free exchange rate[4] and the exchange rate for agricultural capital goods is then an estimate of the value of the transfer from other importers to the importers of the given subsidized import per dollar. Then the impact of this subsidy can be estimated for its effect upon the tractor price (see footnote a to Table B-2 for details on this calculation).

From 1954 to 1961 there were substantial annual variations in the effect of the exchange rate subsidy on tractor price with an average for the period of a seventeen to eighteen percent reduction.[5]

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[4]J. Bergsman, op. cit., 43-45. The quasi-free exchange rate continues the tax on coffee but drops all other subsidies and taxes.

[5]This agrees closely with Bergsman's estimates for the exchange rate subsidy on the general category of capital goods of eleven percent from 1954 to 1956 and nineteen percent from 1958 to 1964. J. Bergsman, op. cit., 53.

Also see N. H. Leff, "Export Stagnation and Autarkic Development in Brazil, 1947-1962," Quarterly Journal of Economics, 81 (May 1967), 286-302 and N. H. Leff, "Import Constraints and Development: Causes of the Recent Decline of Brazilian Economic Growth," Review of Economics and Statistics, 49 (November 1967), 494-502.

Table B-2

Average Exchange Rates for All Imports, Agricultural Capital Goods, the Estimated Quasi Free Rate, and the Effect of Favorable Exchange Rate Treatment Upon Tractor Prices

Year (1)	Nominal Import Rate (Cr/$) (2)	Import Rate Including Protection (Cr/$) (3)	Effective Exchange Rate for Importing Agricul. Capital Goods (Cr/$) (4)	Purchasing Power Advantage of Importing Ag. Capital Goods Over Unprotected Imports (Col. 2/4) (5)	Purchasing Power Advantage of Importing Ag. Capital Goods Over Protected Imports (Col. 3/4) (6)	Estimated Quasi-Free Exchange Rate (7)	Value of Exchange Rate Subsidy on Agric. Capital Goods Per Dollar (Col. 7-4) (Cr.) (8)	Value of Exchange Rate Subsidy on Agricul. Capital Goods Per Tractor[a] (Cr.) (9)	Percent Purchase Price Reduction of Tractors due to the Subsidy on the Exchange Rate[b] (10)	Nominal Value of Transfer to Tractor Purchasers[c] (Col. 9 x no. of Wheel Tractor Imports) (1,000 Cr.) (11)	Real Value of the Transfer-Deflated with an Index of the Nominal Exchange Rate for Imports[d] (1961 = 100) (1,000 Cr.) (12)
1953			19.0								
1954	41.80	62.30	31.2	1.34	2.00	38	7	27,800	-17.9%	341,000	2,190,000
1955	63.80	91.90	46.4	1.38	1.98	57	11	41,700	-18.9	223,000	937,000
1956	73.80	173.00	63.0	1.17	2.75	71	8	24,900	-10.2	103,000	375,000
1957	65.60	173.00	56.8	1.15	3.05	81	24	90,400	-33.7	616,000	2,510,000
1958	149.00	173.00	96.0	1.55	1.80	95	-1	-2,270	0.83	-16,200	-29,100
1959	202.00	291.00	152.3	1.33	1.91	160	8	26,400	-4.2	121,000	160,000
1960	223.00	321.00	177.5	1.26	1.81	210	32	94,500	-14.4	1,200,000	1,440,000
1961	268.00	611.00	234.8	1.14	2.60	350	115	298,000	-39.2	1,900,000	1,900,000
1962	390.00	1040.00	419.8	0.93	2.48	550	130				
1963	575.00	1670.00	660.2	0.87	2.53	830	170				
1964	1284.00	3000.00	1125.2	1.14	2.67	1700	575				
1965	1899.00	3930.00	2103.6	0.90	1.86	2500	391				

Table B-2--continued

[a]The retail tractor price was converted to the wholesale price by assuming a twenty percent retail margin. This wholesale price in new cruzeiros was converted to old cruzeiros by multiplying by 1,000. Then the cruzeiro price was converted to dollars at the preferential exchange rate for importing capital goods (column 4 of Table B-2). This gives a dollar value of tractors at the preferential rate. The value or price of the subsidy per dollar is equal to the difference between the preferential exchange rate and the free exchange rate. In this case the quasi-free exchange rate was employed. In this quasi-free rate Bergsman estimates the exchange rate with the continuation of the coffee export tax. Column 8 of Table B-2 gives the value of the subsidy per dollar. Then multiplying:

$$\frac{\text{Subsidy in Cruzeiros}}{\text{Per Dollar}} \cdot \frac{\text{Wholesale Cost in Dollars}}{\text{Tractor}} = \frac{\text{Subsidy}}{\text{Tractor}}$$

, which is given in Column 9.

[b]The subsidy divided by the retail price of the tractor is equal to the percentage price reduction due to the subsidy.

[c]The value of the subsidy in cruzeiros per tractor (column 9) is multiplied by the number of wheel tractor imports in order to obtain the total cruzeiro value of the exchange rate subsidy on wheel tractor imports.

[d]The total nominal value of the subsidy is deflated with the index constructed from the nominal exchange rate for imports. This nominal rate is column 2 of Table B-2.

Sources: The general import rates with and without protection and the estimated quasi-free exchange rate were taken from J. Bergsman, Brazil: Industrialization and Trade Policies (Oxford University Press: London; 1971), 38, 45. The effective exchange rates for agricultural capital goods were estimated by G. W. Smith, "Brazilian Agricultural Policy, 1950-1967," in H. S. Ellis (ed.), The Economy of Brazil (University of California Press: Berkeley; 1969), 229.

In spite of the subsidy on tractor prices tractor imports were generally low from 1953 until 1960. From 1953 to 1960 tractor imports fluctuate with the import index. A declining coffee price after 1954 while other exports were stagnating led to a reduction in all imports.[6] (See Tables B-3 and B-4) Even with large private and public capital inflows in the late fifties[7], total import capacity continued its decline until a recovery in 1960 (see Table B-3). Tractor imports continued to be very low from 1955 to 1960. Another reason for low tractor imports were other governmental priorities. In the late fifties most governmental attention was devoted to Brasilia and import substituting industrialization.

One method of maintaing an overvalued import exchange rate without draining foreign reserves was to channel imports to countries with which a trade surplus existed. This bilateral type of commercial policy in which exports are in effect bartered for the desired imports was very important prior to the

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[6] Fundacao Getulio Vargas, "Balanco de pagamentos-1947 a 1971," Conjuntura Economica, 26 (Rio de Janeiro: November 1972), 83.

[7] See Bergsman, op. cit., 73, 76 for data on these capital flows. Also see E. N. Baklanoff, "Foreign Private Investment and Industrialization in Brazil," in E. N. Baklanoff (ed.) New Perspectives of Brazil (Vanderbilt University Press: Nashville, 1966), 101-136. Also Fundacao Getulio Vargas, "Balanco de pagamentos," op. cit., 87.

multiple exchange rate system in 1953 and continued into the 1960's.[8]

One effect of this barter approach to trade was the multiplicity of brands. According to one industrial source the Brazilian tractor stock in 1959 was composed of up to 150 different models.[9] The resulting parts and maintenance problems were formidable resulting in a rapid depreciation rate. This problem of maintenance and parts stimulated farmer support for a domestic industry. Without this multiplicity of brands farmers would not be expected to support an import substitution policy, which in the short run at least would result in a higher priced agricultural machine. (See Table B-1)

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[8]Note that in 1954 the auction exchange rate system only covered fifty percent of exchange rate dealings. Kafka emphasizes that bi-lateral trading arrangements at special rates and conditions continued to be important during the auction exchange rate period. See Kafka, op. cit, 318-319. In the early sixties a licensing requirement and a cash deposit for agricultural machinery imports were required for eighty percent of the value of the import but these conditions were waived for countries with which Brazil had a trade surplus. Unclassified Airgram A-1215, U.S. Department of State, "Agricultural Machinery: Production and Trade," (American Embassy: Rio de Janeiro; March 1963), 4.

[9]"Mecanizacao agricola ganha desenvolvimento no Brasil," O Dirigente Rural, (Janeiro/Fevereiro 1970), 9. Parts shortages were chronic and could require delays of up to four months for imports. Only the animal implement business was booming in the field of agricultural implements. Another source cites 200 different brands. See Hugo de Almeida Leme, "A fabricacao de tratores e maquinas agricolas no Brasil," Noticias Automobilisticas, No. 305 (April 1960), 17-19.

The spurt of tractor imports in 1960 and 1961 appears to reflect a speculative hedge against the probability of a higher priced, protected, domestically produced tractor.[10] Protection for the domestic industry was officially begun on July 1, 1960, with the removal of all favorable tariff and exchange rate treatment on tractor imports, which were produced domestically. This was made possible by the Brazilian "Law of Similars" which as applied in the fifties and sixties provided for special licensing requirements and high tariffs for importation of products which were produced domestically. In the sixties the import policy was reversed from preferential treatment of imports to tariffs and tight restrictions limiting imports. After 1961 tractor imports fell drastically and the relative importance of tractors for non-agricultural uses, increased substantially. (See Table B-1) In 1962 tractors for non-agricultural use were 26.4 percent of total imports while by 1970 non-agricultural tractors were ninety-seven percent of total imports. It was still possible to import larger horsepower, agricultural tractors than those produced in Brazil but by 1970 agricultural tractor imports had fallen to sixty as compared with 1,714 in 1962.

Besides exchange rate subsidies and the low prices associated with barter transactions there were also subsidized

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[10] Besides the higher costs of a new industry with the requirement of the purchase of ninety-five percent of domestic parts by weight, another component of the higher tractor prices in real terms was the termination of the favorable exchange rate treatment with the commencement of the domestic industry. See Fundacao Getulio Vargas, "Balanco de uma decada," Conjuntura Economica, 24 (Rio de Janeiro; 1970), 12.

loans from international agencies for tractor purchases in the fifties. In 1952 the Export-Import Bank of the United States provided $18 million for financing tractor imports through the National Development Bank. From the import data it is clear that tractor imports jumped up in 1954. An estimated 10,250 tractors were imported with this financing.[11]

From 1953-1959 there were erratic fluctuations but generally low levels of tractor imports resulting primarily from the decreased capacity to import after 1954. The tractor price was still subsidized through favorable exchange rate treatment but importation was generally low until the speculative buying of 1960 and 1961. After 1961 the effect of government exchange rate and tariff policy to protect the domestic tractor industry is clearly seen.

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[11] Secretaria da Agricultura de Sao Paulo, "Informacoes sobre mecanizacao da lavoura no Brasil, especialmente tratores," mimeo (Sao Paulo; 1955).

Table B-3

Indices of Brazil's Capacity to Import, 1950-1961 (1948=100)

Year	Quantum of Exports	Export Prices	Coffee Prices	Capacity to Import[a]
1950	78	152	208	152
1951	82	186	231	159
1952	64	178	236	108
1953	75	169	250	130
1954	75	197	310	177
1955	82	155	220	149
1956	83	150	218	141
1957	77	147	211	127
1958	74	134	190	119
1959	86	109	150	119
1960	90	107	151	131
1961	102	108	149	148

[a]Equal to the foreign exchange received from exports-imports plus the algebraic sum of the net balance of service account and net capital inflow. Baklanoff attempts to combine the current or trade account and the capital account in order to measure the capacity of Brazil to purchase imports. Leff has argued that economic growth was dependent upon imports of certain capital goods and other imports such as raw materials not available in Brazil. This index then attempts to show the relative capacity to import in various periods. See N. H. Leff, "Import Constraints and Development: Causes of the Recent Decline of Brazilian Economic Growth," op. cit. and Fundacao Getulio Vargas, "Balanco de pagamentos-1947 a 1971," op. cit., 83 – 87.

Source: SUMOC, "Relatorio do exercicio de 1961," 25, cited in E. N. Baklanoff, "Foreign Private Investment and Industrialization in Brazil," in E. H. Baklanoff (ed.), New Perspectives of Brazil (Nashville: Vanderbilt University Press, 1966), pp. 105, 106.

Table B-4

The Volume and Value of Brazilian Coffee Exports, 1947-1972

Crop Year	Sacks sold (thousand)	Value in U.S. dollars (million)	Average Price in U.S. dollars per sack
1947-48	16,125	451	27.97
1948-49	17,745	504	28.39
1949-50	16,935	701	41.42
1950-51	16,593	1,052	63.38
1951-52	16,333	1,057	64.69
1952-53	14,968	1,007	67.27
1953-54	14,325	1,113	77.71
1954-55	10,796	826	76.56
1955-56	16,970	995	58.65
1956-57	14,907	923	61.94
1957-58	13,552	786	57.99
1958-59	14,840	684	46.09
1959-60	17,938	753	41.97
1960-61	16,114	685	42.49
1961-62	17,412	706	40.55
1962-63	16,873	644	38.16
1963-64	18,869	807	42.78
1964-65	12,419	664	53.43
1965-66	16,521	815	49.33
1966-67	16,421	717	43.67
1967-68	18,964	788	41.53
1968-69	19,090	792	41.50
1969-70	19,135	948	49.54
1970-71	16,037	821	51.22
1971-72	20,042	963	48.03

Source: Fundacao Getulio Vargas, "25 anos da politica do cafe --alguns aspectos," Conjuntura Economica, 26 (Novembro 1972), 33. A sack is 60 kg.

APPENDIX C

THE SHIFT TO HEAVIER HORSEPOWER TRACTORS IN THE BRAZILIAN TRACTOR INDUSTRY

The Shift to Heavier Horsepower Tractors in the Brazilian Tractor Industry

The importance of governmental subsidies in influencing tractor sales, primarily through credit, has been considered in Chapter 2. A related problem is the appropriateness of the type of mechanical technology to the Brazilian economy. This section considers model shifts and characteristics of the Brazilian tractor industry and attempts to explain why the Brazilian tractor industry with a slight lag appears to be imitating industrial developments in the United States.

Tables C-1 and C-2 summarize the development of the Brazilian tractor industry in its first eleven years. Both tables reflect a gradual shift to heavier horsepower tractors. Light tractor production ceased in 1970 and medium tractors, 40-60 horsepower, fell from a high of eighty percent of total production in 1964 to thirty-two percent in 1971. Table C-2 indicates that with a lag Brazilian average tractor horsepower shows the same upward trend as in the United States.

There are several possible explanations for this shift from light tractors. Heavier horsepower tractors do have lower variable costs in the power demanding, soil preparation activities. However, earlier tractor models of lower horsepower were able to prepare the soil and were sold in England and the United States in the forties. In 1947 the average horsepower of

Table C-1

Brazilian Domestic Tractor Production, 1960-1971

Year	Wheel Tractors: Light Tractors: Up to 40 Horse-power	Medium Tractors: 40 to 60 Horse-power	Heavy Tractors: 60 HP and above	Micro Tractors	Motor-ized Culti-vators	Track Tractors
1960	---	37	---	---	---	---
1961	25	1,654	---	---	751	---
1962	1,984	5,459	143	---	1,240	---
1963	3,990	5,449	469	---	1,110	---
1964	1,329	9,178	1,030	---	1,765	---
1965	241	6,363	1,517	280	2,403	
1966	96	7,171	1,802	291	3,336	13
1967	56	4,478	1,667	72	2,500	73
1968	39	4,903	4,626	148	2,463	106
1969	22	3,879	5,599	335	1,946	91
1970	---	4,919	9,131	409	2,065	186
1971	---	7,079	14,801	376	2,180	750

Source:
Calculated from ANFAVEA,"A racionalizacao da industria de tratores e fundamental para a tecnificao da nossa agricultura - passo decisivo na retomada do desenvolvimento economico do Pais," Separata de Industria Automotiva, No. 106 (April 1968) and other industry data. See Table C-6.

Table C-2

Average Horsepower Per Four Wheel Tractor (excluding Micro Tractors) in Brazil, the U.S., and Great Britain

Year	Brazil[a]	United States[b]	Great Britain[b]
1960	54.1	50.5	40.4
1961	52.9	53.8	42.1
1962	48.0	56.0	43.5
1963	46.5	58.0	44.8
1964	50.2	59.3	45.1
1965	53.5	63.1	49.5
1966	53.2	65.9	
1967	55.5	68.2	
1968	60.4	69.5	
1969	62.3	72.8	
1970	62.3	72.4	
1971	63.1	76.9	

a. In Brazil these average horsepower data are from production. Since there is little inventory holding in the industry, there would be little difference between the horsepower of sales and production (See Table E-4).

b. Wheel tractor sales.

Source: For Brazil calculated from ANFAVEA, "A racionalizacao da industria de tratores e fundamental para a tecnificao da nossa agricultura--passo decisivo na retomada do desenvolvimento economico do Pais," Separata de Industria Automotiva, No. 106 (April 1968), and other industry data.

See Table C-6 for the Brazilian data used to calculate average horsepower. U.S. data were provided by Paul E. Strickler, Agricultural Economist, Production Resources Branch, Farm Production Economics Division, Economic Research Service, U.S. Department of Agriculture, July 1971; Data on farm tractors for the United Kingdom were taken from A. J. Rayner, An Econometric Analysis of the Demand for Farm Tractors, Bulletin No. 113 (University of Manchester: Manchester; October, 1966), 97.

purchased tractors was twenty-six in the United States and twenty-four in the United Kingdom.[1] A second explanation is that production costs per horsepower fall with larger models and this price advantage is at least partially passed on to the consumer. The purchase price data show a falling price per horsepower, holding special features constant (see Table C-10).

A third explanation is that for the international company producing tractors there is very little difference in models produced in developed and developing countries. If there is a demand for larger tractors in their primary and largest markets in the developed countries due to the large farm size and rapidly declining agricultural labor force there, then these models will also be produced in the secondary markets in the developing countries in spite of the existence of a different farming structure and relative factor prices. From the perspective of the international tractor firm substantial adaptation of the basic models produced in North America and Europe would require a much larger fixed investment in design staff and experimental facilities in Brazil than the small secondary market could justify. A branch of the company in Brazil attempting to short-cut these necessary adaptation expenditures may encounter mechanical problems in the field with a discrediting of its reputation among farmers. This above hypothesis about the market experience of companies attempting to adapt their basic models may be rele-

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[1]A. J. Rayner and K. Cowling, "Demand for Tractors in the United States and the United Kingdom," American Journal of Agricultural Economics, 50 (November 1968), 907, 908.

vant for at least one firm in the Brazilian industry.[2]

In the primary markets, especially in the United States, the shift to heavier horsepower tractors has been very rapid in the sixties as indicated below. However, the total tractor market in the primary markets is so much larger than the Brazilian market that the multi-national firms could still supply the secondary markets with their smaller horsepower models. Table

Table C-3

Percentage of Wheel Tractor Retail Sales
Over 100 Horsepower in the U.S.

Year	Percent
1964	2
1965	2
1966	6
1967	8
1968	9
1969	17
1970	18
1971	25

Source: Reports of the Farm and Industrial Equipment Institute provided by the USDA.

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[2]According to Brazilian industrial sources the body wasn't sufficiently "solid" for the locally produced motor and numerous cases of the tractor breaking apart in the field were reported. The rear axle component of this tractor was produced in the U.S. for a smaller horsepower motor than the motor used in Brazil. The initial models were four speeds. In response to consumer preferences there was a shift to eight speeds. The axle couldn't withstand this additional force and the tractor became known in Brazil as "bombas rolantes " (rolling bombs). Another firm whose head office actively resisted model adaptations was practically out of the industry by 1971.

See "Tra tores de rodas, A explosao do crescimento," Transporte Moderno (April, 1972), 16 for details on Brazilian tractor model features and a brief history of the industry.

C-5 indicates that three of the firms in the United States which are presently or have been in the Brazilian tractor industry produce an entire line of tractors with a wide horsepower distribution including many small tractors. Nevertheless, in Brazil these same companies have been shifting to production of larger models over time rather than introducing their smaller models.[3]

Domestic manufacturers of tractors receive market signals not only from the selection of farmers among their brands but also from imports. Tractor imports are allowed for those large horsepower tractors and other agricultural machinery, which are not produced domestically. In effect importers do marketing research for the domestic manufacturers. As demand grows for larger tractors or combine (see Table C-11), domestic firms begin production and receive protection from the tariff and quota treatment provided by the "Law of Similars."

Besides having higher per horsepower, purchase price smaller tractors require more time for the heavier, power demanding operations and thus are less economical than larger tractors for these particular operations. For these heavier operations, primarily land preparation, the higher variable costs of operation per time unit of larger tractors are compensated for by the greater speed of operation. For many field operations such as fertilizer application, spraying, and planting,

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[3]In 1972 Massey-Ferguson introduced the M-F 85, a 75 horsepower tractor, and Valmet introduced a 115 HP tractor.

there is no power advantage from the larger tractors. For these operations the higher variable costs and less maneuverability of larger tractors make them inferior to light or medium tractors.[4] Farmers then prefer to have several tractors for different operations, when their farm size and access to credit enables them to own several tractors.

The primary industrial reason for the shift to heavier horsepower models, according to one American industrial source, is that the price per horsepower on the market doesn't fall

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[4]G. W. Giles, "Towards a More Powerful Agriculture: A Report to the Government of West Pakistan on its Agricultural Power and Equipment Needs" (Planning Cell, Agriculture Department, West Pakistan: Lahore; 1967); P. E. Strickler and B. J. Harrington, Liquid Petroleum Fuel Used by Farmers in 1959--and Related Data, Statistical Bulletin No. 344 (ERS, USDA: Washington; May 1964), 9; D. Hunt, "Selecting an Economic Power Level for the Big Tractor," paper presented at the American Society of Agricultural Engineers, Pullman, Washington, June 1971, 12 pages.

nearly as rapidly as the cost of production per horsepower.[5] Hence, profits are highest to the tractor firms on the larger models, which are pushed with advertising to encourage purchase by farmers for prestige as well as economic motives. Smaller models are produced so that dealers have a range of tractor sizes but both manufacturers and dealers make higher profits on their larger models. This is an interesting phenomenon of the input dealers through oligopoly pricing and advertising encouraging farmers to buy larger tractors thereby encouraging

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[5]The above is a direct quote from an American industrial source. According to this same source Brazilian tractors are approximately two generations behind American models. Two generations of tractor models take place in approximately twelve years in the United States. In the United States where the tractor purchaser and tractor operator are often the same individual or related the larger basic model often includes a cabin, which can be heated in the fall or cooled in the summer. In Brazil,where the tractor operator is generally a hired worker, tractors are only provided with cushions. Another necessary modification for Brazilian tractors and other machines is more filtering equipment than in the United States due to a dust problem. More sophisticated cooling equipment is also necessary for the tropics. C.B.T. and Massey-Ferguson have the three point hitch and depth control. Valmet has synchromatic and differential lock. Other features associated with the latest tractor models in the United States are:

a) power shift. The Valmet tractors have synchromesh transmissions but the power shift is a more sophisticated extra.
b) There is a greater speed range in the United States usually from 8 to 12 speeds. Brazilian tractors generally have 6 speeds or a maximum of 8.
c) Power steering is common in the United States models. This feature is also found in the larger models of both Massey-Ferguson and Valmet.

Brazilian industrial sources presently consider most of these features found in the United States' latest models too expensive to be demanded in Brazil but expect with the continued migration northward of the "gaucho" owner operator, wheat-soybean operations, an increasing demand for those extras especially those associated with greater operator comfort and facility in manipulating the machine. The "gaucho" movement has been primarily into Parana but also has taken place into Goias and Mato Grosso.

shifts in land use.[6]

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[6] The recent literature on the process of technological change in agriculture has provided two contrasting positions. Hayami and Ruttan argue that farmers through a "dialectical" interaction with public and private agencies encourage the production of technological change appropriate to the particular bottlenecks, which farmers face in increasing output. Bieri, de Janvry and Schmitz argue that the oligopoly position of input suppliers enables them to produce and market inputs embodying new technology, which may not be completely appropriate to the present structure of agriculture. Hence, these input dealers could influence structural changes in agriculture.

One American industrial source interviewed in Brazil believed that the latter was the case. The latter position requires that the input suppliers can influence purchase decisions through advertising, access to public policy decision makers, and other methods. See Y. Hayami and V. W. Ruttan, *op. cit.*, 118-136 and J. Bieri, Alain de Janvry, and A. Schmitz, "Agricultural Technology and the Distribution of Welfare Gains," *American Journal of Agricultural Economics*, 54 (December, 1972), 802.

Table C-4

Tractor Sales[a] by Horsepower of the Models in the U.S. in 1971

Horsepower	United States	Exports	Total Sales
Under 35	8,593	182	8,775
35-40	19,648	235	19,883
40-50	5,850	97	5,947
50-60	15,944	176	16,120
60-70	14,804	378	15,182
70-80	6,742	341	7,083
80-90	4,180	223	4,403
90-100	22,969	2,300	25,269
100-110	7,930	657	8,587
110-120	11,644	72	11,716
120-130	2,467	155	2,622
130-140	8,203	195	8,398
140 plus	2,549	209	2,758
TOTAL	131,523	5,220	136,743

[a]Excludes four wheel drive tractors of which 2,547 were purchased domestically and 215 exported.

Source: Farm and Industrial Equipment Institute
410 North Michigan Avenue
Chicago, Illinois 60611
U.S.A.

Table C-5

Models Included in the Retail Sales Reporting Program in the U.S. (at the beginning of 1972) by Three of the Multi-National Tractor Firms Which Are or Have Been in the Brazilian Tractor Industry

PTO Horse-power	Number of Models and Horsepower		
	Massey-Ferguson	Deutz	Ford
20-35	I (27.0)	II (23, 32)	II (30.8, 32.1)
35-40	III(35.4, 37.8, 37.9)	I (37)	IV (37.8, 39.2 39, 39)
40-50			
50-60	II (51.9, 52.4)	I (55)	VI (3 models with 52.2) (3 models with 52.7)
60-70	IV (61.9, 63.3, 62.8, 63.7)	I (66)	V (2 models of 67.2) (2 models of 67.3) (1 model of 67.0)
70-80			
80-90	I (81.2)	I (85.5)	II (2 models of 83)
90-100	I (93.9)	I (96)	I (97)
110-120		I (105)	I (105.7)

Table C-5--continued

PTO Horse-power	Number of Models and Horsepower		
	Massey-Ferguson	Deutz	Ford
120-130	I (120.5)	I (125)	
130-140	I (135)		I (131.2)
above 140	II (165, 195)		

Source: Farm and Industrial Equipment Institute
410 North Michigan Avenue
Chicago, Illinois 60611
U.S.A.

Table C-6--Production of 4-Wheel Tractors (excluding Micro Tractors), 1960-1971, in Brazil

Type-Firm-Model	Horsepower of Motor	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Light-up to 40 HP		--	25	1,984	3,989	1,329	241	96	56	39	22	--	--
Massey-Ferguson													
MF-50	37	--	7	1,528	3,287	478	---	---	---	---	---	---	---
Fendt													
F-41	31	--	18	456	702	851	241	52	56	32	22	---	---
Farmer Novo	34	--	--	---	---	---	---	44	---	---	---	---	---
Demisa-Deutz													
DM 45	38	--	--	---	---	---	---	---	---	7	---	---	---
Medium-40 to 60 HP		37	1,654	5,459	5,449	9,178	6,363	7,171	4,478	4,903	3,879	4,919	7,709
Massey-Ferguson													
MF-50X	44.5	--	--	---	---	3,556	2,723	3,604	1,907	2,720	1,904	2,998	3,436
MF-55X	44.5	--	--	---	---	---	---	---	---	---	---	---	302
MF-65R	56.5	--	--	---	---	---	---	---	---	---	---	---	75
Valmet													
360-D	42	5	327	1,600	1,638	269	---	---	---	---	---	---	---
600-D	50	--	--	---	---	1,956	1,570	1,340	252	2	---	---	---
Sincromatic	52	--	--	---	---	---	---	---	1,137	925	---	---	---
60 id	52	--	--	---	---	---	---	---	---	643	1,294	1,659	3,292
Demisa-Deutz													
DM 40	40	--	--	---	---	---	97	5	---	---	---	---	---
DM 55	55	--	60	680	1,270	1,231	553	503	370	---	---	---	---
DM 65	56	--	--	---	---	---	---	---	30	290	493	271	4
Fendt													
51	51	--	--	---	---	---	---	311	334	323	88	---	---
Ford													
BR 4	56	32	1,246	916	407	---	---	---	---	---	---	---	---
BR 8	56	--	1	2,253	2,134	2,166	1,420	1,468	449	---	---	---	---
Heavy-60 HP and above		--	---	143	469	1,030	1,517	1,802	1,667	4,626	5,599	9,131	14,801
Massey-Ferguson													
65X	60	--	--	---	---	---	101	501	534	2,339	2,742	4,099	5,622
95	90	--	--	---	---	---	---	---	---	---	---	653	1,355
Valmet													
80 id	70	--	--	---	---	---	---	---	---	87	915	1,902	2,959
CBT													
1000	61	--	--	---	---	---	---	---	---	---	---	717	2,234
1020	77	--	--	143	469	841	771	815	563	---	---	---	---
1090	90	--	--	---	---	---	---	---	165	1,793	1,495	1,639	2,530
1090A	92	--	--	---	---	---	---	---	---	---	---	---	---
Demisa-Deutz													
DM 75	75	--	--	---	---	139	645	486	325	---	---	---	---
DM 90	55	--	--	---	---	---	---	---	60	417	447	121	101
TOTALS		37	1,679	7,586	9,908	11,537	8,121	9,069	6,201[a]	9,568[a]	9,500[a]	14,050[a]	21,852[a]

Legend to Col. 1

Type-Firm-Model
- Light-up to 40 HP
  - Massey-Ferguson
    - MF-50
  - Fendt
    - F-41
    - Farmer Novo
  - Demisa-Deutz
    - DM 45
- Medium-40 to 60 HP
  - Massey-Ferguson
    - MF-50X
    - MF-55X
    - MF-65R
  - Valmet
    - 360-D
    - 600-D
    - Sincromatic
    - 60 id
  - Demisa-Deutz
    - DM 40
    - DM 55
    - DM 65
  - Fendt
    - 51
  - Ford
    - BR 4
    - BR 8
- Heavy-60 HP and above
  - Massey-Ferguson
    - 65X
    - 95
  - Valmet
    - 80 id
  - CBT
    - 1000
    - 1020
    - 1090
    - 1090A
  - Demisa-Deutz
    - DM 75
    - DM 90
- TOTALS

[a] There is a slight divergence between these production data and those of total industry production by factory of ANFAVEA from 1967-1971. Both CBT and Fendt have given different information to the above industry source than to ANFAVEA. For example in 1968 Fendt reported production of 323 to the industry source and 368 to ANFAVEA. CBT in that year reported 1,783 to the industry source and 1,886 to ANFAVEA. In 1971 ANFAVEA data also includes 289 industrial tractors and there is a difference between industry source and ANFAVEA production data of CBT. In most years from 1967-1971 this divergence is small.

Source: ANFAVEA, "A racionalizacao da industria de tratores e fundamental para a tecnificacao da nossa agricultura--passo decisivo na retomada do desenvolvimento economico do Pais"; Separata de Industria N° 10 a (April 1968), 8; Other industrial sources for data from 1968-1971.

Table C-7

The Brazilian Tractor Industry in 1971

	Production in 1971	Market Share in 1971	Models	HP of the Motor HP/SAE	Number of Cylinders	Tractor Weight	Origin of Patents and Design	First Year of Production	Total No. of Forward Velocities
4-wheel tractors	22,122								
			50X	44.5	3	1,623		1964	6
			55X	44.5	4	2,048		1971	6
Massey-Ferguson	11,003	49.7%	65X	60		2,226	Can.-US		
			65R	56.5	4	1,940		1965	
			95	90	6	3,629		1969	6
Valmet	6,250	28.3	60id	52	3	1,800	Finland	1967	6
			80id	70	4	2,200		1968	6
Companhia Brasileira de Trator	4,764	21.5	1000	61	4	3,320	Brazil[a]	1970	
			1090	90	6	5,306		1967	
Demisa-Deutz-Minas	105	0.5	65	58	3	2,600	West	1967	5
			90	85	4	2,800	Germany	1967	5
Micro Tractors	366								
Agrale	366	100%	415EHE	15		796		1968	
			T-416	18					
Motorized Cultivators	2,190								
Kubota-Tekko	1,729	78.9	KF-KNDR						
			-9	7-9	1	340	Japan		8
			MS-KR90	7-9					

Table C-7--continued

	Production in 1971	Market Share in 1971	Models	HP of the Motor HP/SAE	Number of Cylinders	Tractor Weight	Origin of Patents and Design	First Year of Production	Total No. of Forward Velocities
			MS-KR						
			907	7-9					
Iseki-Mitsui	451	20.6	K-14-BH	4-5	1	301	Japan		4
			K-14-						
			BH-85	5.5-6.5	1	365			4
Agrisa-Bungartz	10	0.5	IVT-85F	8					
(Agrale)				13					
Track Tractors	770								
Caterpillar	b		D4D	65		6,438	U.S.	1970	
Fiat	b		AD7B	76		6,450	Italy	1970	
Massey-Ferguson	b		3366	86		7,840	Can.-US	1970	

[a] Patent rights were obtained from Oliver, (U.S.), according to Brazilian industrial sources.

[b] The track tractor producers only released the industry total production.

Source: Various publications of ANFAVEA.

Table C-8

The Brazilian 4-Wheel Tractor Industry in 1971: Sales and Description

	Sales (No.)	Market Share of the Industry (%)	Horsepower HP/SAE	Tractor Weight (kg)	First Year of Production
Factories and Models					
Massey Ferguson	10,748	49.5			
50-X	3,427	15.8	44.5	1,538	1964
55-X	276	1.3	44.5	2,048	1971
65X	5,623	25.9	60	2,226	1965
65 R-Agr.	67	0.3	56.5	1,940	1969
95 without hydraulic	389	1.8	90	3,629	1970
95 with hydraulic	966	4.4	90		1970
Valmet	6,041	27.8			
60 id	3,195	14.7	52	1,800	1967
80 id	2,846	13.1	70	2,200	1968
CBT[a]	4,834	22.2			
1000	2,241	10.3	61[a]	3,320	1970
1090 A	2,593	11.9	91	5,506	1970
Demisa, Deutz-Minas	109	0.5			
65	10	0.05	58	2,600	1967
90	99	0.45	85	2,800	1964
TOTAL	21,732	100.0			

[a]According to Brazilian industrial sources the 1090 model basically is the Oliver design. The 1000 model is not based upon any specific patent but comines features of several models to produce a medium tractor. This is a recent innovation for CBT as in earlier years of the industry this firm only produced heavy tractors. Many of the CBT tractors are used for industrial or construction purposes.

Source: Industrial data provided by ANFAVEA and Massey-Ferguson.

Table C-9

Brazilian Tractor Price Per Horsepower, 1961-1971

Year	Horsepower of Basic Model	Tractor Price[a] (Cr$)	Tractor Price Per Horsepower of Basic Model (CR$)	Horsepower of Larger Model	Tractor Price[a] of the Larger Model (Cr$)	Tractor Price Per Horsepower of Larger Model (Cr$)	Market Share of the Medium Model	Weighted Tractor Price Per Horsepower of this Rep. Firm (Cr$)	Index (1971=100)
1961	42	1,039	24.7				100%	24.7	6.1
1962		1,707	40.6				100	40.6	10.1
1963		3,086	73.5				100	73.5	18.3
1964	50	5,946	118.9				100	118.9	29.5
1965		8,661	173.2				100	173.2	43.0
1966		9,817	196.3				100	196.3	48.8
1967		12,640	252.8				100	252.8	62.8
1968		18,401	368.0	70	21,520	307.4	94.8	364.8	90.6
1969	52	19,073	366.8		21,594	308.5	60.2	343.6	85.4
1970		20,095	386.4		23,191	331.3	48.5	358.0	88.9
1971		22,811	438.7		25,318	361.7	52.9	402.5	100

[a]Median price.

Source: Data from the files of a Brazilian firm for the prices of their standard models.

Table C-10

List Prices[a] of the Basic Brazilian Tractor Models in June, 1972

Firm	Model Number	Horsepower	List Purchase Price[b]	Price Per Horsepower	Comments
Massey-Ferguson	50 X	44.5	Cr $ 25,342	569	
	55 X	44.5	27,879	626	Special model
	65 X	60	29,958	499	
	65 R	56.5	35,810	634	Special model for cane lifting after cutting
	85	75	39,939	533	
	95 without hydr.	90	41,540	462	
	95 with hydr.	90	45,920	510	
Valmet	60 id	52	25,558	492	
	80 id	70	29,573	422	
CBT	1000 with hydr.	61	27,340	448	
	1090A without hydr.	101	35,984	356	
	1090 with hydr.	90	40,767	453	

[a] Discounts of many types are extremely common in the industry including discounts for early payment, for used tractors, and to members of cooperatives.

[b] There is much variation in price for the same model depending upon extras and accessories and the size of the wheels. These prices reflect the price of the basic model and the "standard" wheel size. "Standard" here refers only to the most commonly demanded tractor model.

Source: Industry.

Table C-11

Brazilian Sales of Massey-Ferguson Combines

Year	Imported	Domestic Production	Total
1962	8	---	8
1963	9	---	9
1964	33	---	33
1965	18	---	18
1966	53	---	53
1967	119	---	119
1968	258	---	258
1969	445	---	445
1970	439	153	592
1971	75	341	416

Source: Personal correspondence with Massey-Ferguson, September 1, 1972

APPENDIX D

THE IMPORTANCE OF AGRICULTURAL MECHANIZATION IN BRAZILIAN AGRICULTURE, 1950-1971

The Importance of Agricultural Mechanization in Brazilian Agriculture, 1950-1971

In 1950 there was almost no mechanization in Brazilian agriculture. Seventy-three percent of Brazilian farms used only human power while twenty-seven percent used animal and human power but no machinery (see Table D-1). Only 0.3 percent of the farms used any machinery at all; however, these were the larger farms hence the output effect was larger than the numerical percentage of farms using machinery.

There was a rapid increase in the number of farms from 1950 to 1960 but this increase primarily reflected an area expansion into the frontier areas with very little capital investment per worker. The relative importance of human power increased to almost seventy-seven percent with animal power use falling to twenty-two percent (Table D-2). In the fifties farms using some mechanical power increased from 2,657 to 19,449 in Sao Paulo and from 1,613 to 11,399 in Rio Grande do Sul.

In spite of the rapid absolute growth in the use of mechanized power in the fifties the ownership of mechanical power remained concentrated on a small sector of large farms. In 1950 eighty-seven percent of the tractors excluding micro-tractors were on farms over 100 hectares. In a sample of 2,000 farms in Sao Paulo in 1959, sixty-nine percent of the tractors were on farms with over 100 hectares.[1] In the 1960 Census sixty-one percent of the tractors and sixty-five percent of the total horsepower were on farms with over 100 hectares. Moreover, for farm sizes over 100 hectares the number of tractors per farm steadily increased (see Tables D-3 and D-4).

With the exception of the states of Sao Paulo and Rio Grande do Sul tractorization in Brazil is a post-World War II phenomenon. In 1920 there were more tractors in the temperate, crop region of Rio Grande do Sul than in the coffee, mono-culture state of Sao Paulo. However, from 1920 to 1940 a diversification of Sao Paulo agriculture took place.[2] Agricultural mechanization in Sao Paulo is associated primarily with this diversification process. As of 1940 Sao Paulo had become the most mechanized agricultural state and would maintain an almost constant share of the Brazilian tractor stock through 1970 (see Table 8 in Chapter 3). This diversification extended from sugarcane and cotton to include corn, rice, potatoes, tomatoes, and later soybeans. Some operations in coffee were also mechanized.[3]

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[1] Salomao Schattan, "Estrutura economica da agricultura Paulista," Agricultura en Sao Paulo (Maio 1960), 9.

[2] From 1920 to 1940 the number of coffee trees in Sao Paulo increased from 823 to 1,093 million but cotton and cane production expanded even more rapidly from 105 to 841 thousand tons of cotton and from 1.1 to 2.2 million tons of sugar. See IBGE, Brasil, Censo Agricola, VI Recenseamento Geral do Brasil, 1950 (Rio de Janeiro; 1956), 134, 135.

[3] A. da Roche e Silva and N. R. Nobrega, "Contribuicao para o estudo do problema da moto-mecanizacao agricola no estado de Sao Paulo," paper presented at a meeting on mechanization, Piracicaba, Sao Paulo, 1954.

In the sixties mechanization of the crop shift into wheat-soybean operations occurred very rapidly in Rio Grande do Sul and these mechanized operations extended into other states as the Brazilian government promoted wheat production through high price supports and input subsidies.[4] From 1950 to 1970 mechanization grew rapidly in the frontier states of Parana, Goias, and Mato Grosso. This mechanization was associated with the diversification of frontier agriculture especially the crop shifts and the new land area in coffee, rice, cotton, and more recently, soybeans and wheat. Older agricultural states such as Minas Gerais, Rio de Janeiro, and Pernambuco declined in their relative share of the tractor stock (see Table 8 in Chapter 3). Very little mechanization has taken place in either the Northeast or the North.

In the 1971-1972 crop year according to one sample 52.6 percent of the farms surveyed used machinery for land preparation.[5] Rice, coffee, soybeans and wheat had the highest levels of mechanized land preparation. Mechanical power was

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[4]J. J. de Engler and R. L. Meyer, "Trigo: producao, precos, e productividade," paper presented at the Instituto de Economia Agricola, April 27, 1972, 20 pages.

[5]These data include 2,712 farms with over 140 observations on the production of each of ten crops. (See Tables E-5, E-6, and E-7). In this sample ten percent of Brazilian area by states with the lowest value of agricultural products were excluded and within states the smallest micro regions were excluded. Then regions were randomly selected from all over Brazil. Within these regions lists of farmers were obtained and farmers selected randomly.

employed for over two-thirds of the cultural operations, primarily cultivating and spraying, for wheat and soybeans with around one-third of these operations mechanized in rice, potatoes, coffee, and cane production. Mechanical harvesting was encountered on less than one-fourth of the total number of farms but on over two-thirds of the wheat and soybean farms. Mechanized harvesting was also found on more than one-fourth of the rice and potato production.

In the 1971-1972 crop year mechanization was used for land preparation on the majority of farms sampled producing ten of the principal Brazilian agricultural products. Nevertheless, two of the most important Brazilian food products, manioc and beans, were not included in the above sample and generally have low levels of mechanization, hence the above sample totals have an upward bias of the importance of mechanization. In this sample human and animal power were still the primary power sources for the other agricultural operations besides land preparation with the exception of operations for the highly mechanized wheat and soybean enterprises, which are concentrated in Rio Grande do Sul and Parana.

By the 1971-72 crop year the use of mechanized land preparation had become very important in Brazilian agriculture. The wheat-soybean combination was heavily mechanized but the more diversified Sao Paulo agriculture was more mechanized than the total agricultural complex of Rio Grande do Sul. The frontier states of Parana, Goias, and Mato Grosso were mechanizing at an even more rapid rate than either Sao Paulo or Rio Grande do Sul (see Tables 8 and 9 in Chapter 3). The extremely rapid growth of Brazilian mechanization from 1950 to the present then has at least three components, the wheat-soybeans combination principally in Rio Grande do Sul, which has been expanding out of the state and moving northward, the diversified large crop farming systems of Sao Paulo, and the frontier states with their rapid and continuing expansion of crop area in the last two decades. The farm level data in this thesis are from the latter two area (see Chapter 5 and Appendix F). Substantial micro analysis has been done on the mechanization of the wheat-soybean operation in Rio Grande do Sul by members of the Ohio State Capital Formation Project.

Table D-1

Type of Power Use on Farms: 1950 Census

	Total No. of Farms	Farms Using only Human Power		Farms Using Animal Power		Farms Using Animal and Mechanical Power		Farms Using Mechanical Power[b]	
		Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total
Brazil[a]	2,064,652	1,504,124	72.85%	554,441	26.85%	5,484	0.27%	593	0.03%
North									
Acre	1,701	1,671	98.23	27	1.59	3	0.18	---	----
Amazonas	15,220	15,152	99.55	64	0.42	4	0.03	---	----
Para	59,877	58,662	97.97	1,200	2.00	12	0.02	3	0.01
Northeast									
Maranhao	95,165	93,880	98.65	1,273	1.34	12	0.01	---	----
Piaui	34,106	33,024	96.82	1,073	3.15	7	0.02	2	0.01
Ceara	86,690	84,245	97.17	2,408	2.78	31	0.04	6	0.01
Rio Grande de Norte	34,391	29,699	86.35	4,673	13.59	17	0.05	2	0.01
Paraiba	69,117	66,074	95.60	3,002	4.34	39	0.06	2	0.00
Pernambuco	172,268	170,533	99.00	1,642	0.95	87	0.05	6	0.00
Alagoas	51,961	48,736	93.79	3,193	6.14	24	0.05	8	0.02
East									
Sergipe	42,769	42,192	98.65	534	1.25	38	0.09	5	0.01
Bahia	258,043	254,448	98.63	3,492	1.35	59	0.02	4	0.00
Minas Gerais	265,559	209,697	78.97	55,249	20.80	580	0.22	33	0.01
Rio de Janeiro	40,652	28,823	70.91	11,474	28.22	283	0.71	67	0.16
Guanabara	5,266	5,044	95.78	148	2.81	23	0.44	51	0.97
South									
Sao Paulo	221,611	100,991	45.57	117,963	53.23	2,379	1.07	278	0.13
Parana	89,461	52,498	58.68	36,759	41.09	176	0.20	28	0.03
Santa Catarina	104,429	46,919	44.93	57,476	55.04	32	0.03	2	0.00

Table D-1--continued

	Total No. of Farms	Farms Using only Human Power		Farms Using Animal Power		Farms Using Animal and Mechanical Power		Farms Using Mechanical Power[b]	
		Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total
Rio Grande do Sul	286,733	42,444	14.80	242,676	84.63	1,536	0.54	77	0.03
Center West									
Mato Grosso	16,015	14,431	90.11	1,548	9.67	32	0.20	4	0.02
Goias	63,736	57,674	90.49	6,010	9.43	47	0.07	5	0.01

a Most of the territories weren't included so the columns won't sum.

b According to the Census division this category apparently employed no animal power.

Source: IBGE, Brasil, Censo Agricola, VI Recenseamento Geral do Brasil-1950 (Rio de Janeiro, 1956), 36.

Table D-2

Type of Power Use on Farms: 1960 Census

	Total No. of Farms	Farms Using only Human Power		Farms Using Animal Power		Farms Using Animal and Mechanical Power		Farms Using Mechanical[c] Power	
		Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total
Brazil[a]	3,337,769	2,556,237	76.6%	734,110	22.0%	30,477	0.91%	16,945	0.51%
North									
Acre	3,676	3,657	99.5	6	0.16	4	0.11	9	0.24
Amazonas	48,477	48,398	99.8	59	0.12	4	0.01	16	0.03
Para	83,180	82,851	99.6	97	0.12	21	0.03	211	0.25
Northeast									
Maranhao	261,865	261,725	99.9	73	0.03	13	----	54	0.02
Piaui	87,303	85,924	98.4	1,307	1.50	25	0.03	47	0.05
Ceara	122,576	118,371	96.6	4,017	3.28	92	0.08	96	0.08
Rio Grande do Norte	49,840	38,715	77.7	10,905	21.88	124	0.02	96	0.[illegible]
Paraiba	117,836	107,731	91.4	9,817	8.33	115	0.10	173	0.15
Pernambuco	259,723	255,390	98.3	3,640	1.40	381	0.15	312	0.12
Alagoas	62,484	57,672	92.3	4,508	7.21	195	0.31	109	0.17
East									
Sergipe	65,014	64,551	99.3	376	0.58	40	0.06	47	0.07
Bahia	381,473	372,065	97.5	8,897	2.33	163	0.04	348	0.09
Minas Gerais	371,859	293,776	79.0	73,855	19.87	2,469	0.66	1,729	0.46
Rio de Janeiro	51,697	42,409	82.0	8,183	15.83	502	0.97	603	1.17
Guanabara	6,258	6,114	97.7	52	0.83	13	0.21	79	1.26
Espirito Santo	54,795	52,638	96.1	1,588	2.90	409	0.75	160	0.29
South									
Sao Paulo	317,374	135,621	42.7	162,254	51.12	12,705	4.00	6,794	2.14
Parana	269,146	196,577	73.0	68,301	25.38	2,270	0.84	1,998	0.74

Table D-2--continued

	Total No. of Farms	Farms Using only Human Power		Farms Using Animal Power		Farms Using Animal and Mechanical Power		Farms Using Mechanical Power	
		Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total
Santa Catarina	158,268	86,012	54.3	70,581	44.60	840	0.53	835	0.53
Rio Grande do Sul	380,201	76,300	20.1	292,502	76.93	9,077	2.39	2,322	0.61
Center West									
Mato Grosso	48,104	41,349	86.0	6,018	12.51	347	0.72	390	0.81
Goias[b]	111,288	103,221	92.8	6,923	6.22	648	0.58	487	0.44

[a]The columns do not sum due to exclusion of most of the territories.

[b]The Federal District was carved out of Goias so to analyze development from 1950 to 1960 it is necessary to combine data for the two.

[c]According to the Census categories this group employed no animal power.

Source: IBGE, Brasil, Censo Agricola, VII Recenseamento Geral do Brasil-1960 (Rio de Janeiro: 1970).

Table D-3

Tractor Distribution Between Farms by Size: 1950 Census

Area Group (1)	No. of Farms (2)	Farms with Tractors[a] (3)	No. of Tractors (4)	Tractors Per Farm (4/3) (5)	Farms with Micro Tractors[b] (6)	No. of Micro Tractors[b] (7)	Micro Tractors Per Farm (7/6) (8)
Less than 10 Hectares	710,934	36	39	1.1	46	47	1.0
Less than 1 Hectare	50,252	--	--	--	--	--	--
1-2	113,614	2	4	2.	1	1	1.0
2-5	294,810	9	10	1.1	19	19	1.0
5-10	252,258	25	25	1	26	27	1.0
10 to 100 Hectares	1,052,557	770	859	1.1	271	293	1.1
10-20	345,185	70	74	1.1	57	61	1.1
20-50	488,044	254	282	1.1	102	109	1.1
50-100	219,328	446	503	1.1	112	123	1.1
100 to 1,000 Hectares	268,159	2,687	3,503	1.3	548	630	1.1
100-200	131,462	647	795	1.2	137	155	1.1
200-500	99,599	1,119	1,423	1.3	229	268	1.2
500-1,000	37,098	894	1,285	1.4	182	207	1.1
1,000 to 10,000 Hectares	31,017	1,283	2,387	1.9	207	276	1.3
1,000-2,000	18,417	698	1,110	1.6	114	139	1.2
2,000-5,000	10,108	446	920	2.1	70	89	1.3
5,000-10,000	2,493	139	357	2.6	23	48	2.1
More than 10,000	1,611	75	311	4.1	14	27	1.9
10,000-100,000	1,551	66	257	3.9	12	25	2.1
More than 100,000	60	9	54	6.0	2	2	1.0

Table D-3--continued

Area Group (1)	No. of Farms (2)	Farms with Tractors (3)	No. of Tractors (4)	Tractors Per Farm (4/3) (5)	Farms with Micro Tractors (6)	No. of Micro Tractors (7)	Micro Tractors Per Farm (7/6) (8)
Without area declaration	364	--	--	--	--	--	--
TOTALS	2,064,642	4,851	7,099	1.5	1,086	1,273	1.2

[a]Tractors greater than 10 C.V.

[b]Defined in the Census as tractors with less than 10 C.V.

Source: IBGE, Brasil, Censo Agricola: VI Recenseamento Geral do Brasil-1950 (Rio de Janeiro, 1956), 16.

Table D-4

Tractor Distribution Between Farms by Size: 1960 Census

Area Group (1)	Number of Farms (2)	Farms With Tractors[a] (3)	Number of Tractors (excl. micro tractors) (4)	Total Number of Tractors (5)	Tractors Per Farm[b] (5/3) (6)	Total Horsepower of the Tractor Stock[c] (7)	Horsepower Per Farm[b] (7/3) (8)
Less than 10 hectares	1,495,020	2,554	2,003	2,932	1.1	80,654	31.6
Less than 1 hectare	133,477	39	23	42	1.1	934	23.9
1-2	276,740	132	65	158	1.2	2,778	21.0
2-5	619,119	953	727	1,123	1.2	30,296	31.8
5-10	465,684	1,430	1,188	1,609	1.1	46,646	32.6
10-100 hectares	1,491,415	17,820	18,656	20,917	1.2	629,086	35.3
10-20	546,079	3,388	3,162	3,755	1.1	111,378	32.9
10-50	672,675	8,230	8,396	9,423	1.1	277,902	33.8
50-100	272,661	6,202	7,098	7,739	1.2	239,806	38.7
100-1,000 hectares	314,831	17,874	25,236	27,472	1.5	931,776	52.1
100-200	157,422	6,221	7,685	8,378	1.3	274,118	44.1
200-500	116,645	7,689	10,925	11,863	1.5	406,968	52.9
500-1,000	40,764	3,964	6,626	7,231	1.8	250,690	63.2
1,000-10,000 hectares	30,882	3,984	8,378	8,983	2.3	328,090	82.4
1,000-2,000	18,392	2,308	4,416	4,793	2.1	170,782	74.0
2,000-5,000	10,138	1,340	2,994	3,169	2.4	117,790	87.9
5,000-10,000	2,353	336	968	1,021	3.0	39,518	117.6
More than 10,000 hectares	1,597	217	989	1,034	4.8	42,890	197.6
10,000-100,000	1,569	207	910	952	4.6	38,972	188.3
More than 100,000	28	10	79	82	8.2	3,918	391.8
Without Declaration	4,023	5	7	7	1.4	320	64.0
TOTALS	3,337,769	42,454	55,269	61,345	1.4	2,012,816	47.4

Table D-4--continued

[a]In the 1960 Census the distinction of tractor ownership between micro and other tractors was not made but more information was provided on horsepower of the tractors.

[b]Includes only those farms with tractors.

[c]Estimated with the median horsepower for each category with 6 cv. for less than ten and sixty for more than 50 cv.

Source: IBGE, Censo Agricola, VII Recenseamento Geral do Brasil-1960, Parte II (Rio de Janeiro; 1970), 8.

Table D-5

Power Source Employed for Land Preparation: 1971-1972 Crop Year

Crop	Manual or Animal Power		Mechanized		Manual/Animal and Mechanized		No Response		Total
	No.	%	No.	%	No.	%	No.	%	No.
Cotton	186	61.59	107	35.43	9	2.98	0	0	302
Rice	137	29.03	300	63.56	35	7.41	0	0	472
Potatoes	63	42.29	58	38.92	27	18.12	1	0.67	149
Cacao	144	99.32	0	0	1	0.68	0	0	145
Coffee	119	35.20	190	56.22	27	7.99	2	0.59	339
Sugarcane	103	39.93	102	39.53	53	20.54	0	0	258
Corn	354	59.70	197	33.22	42	7.08	0	0	593
Soybeans	38	25.51	96	64.43	14	9.39	1	0.67	149
Tomato	88	61.12	49	34.02	7	4.86	0	0	144
Wheat	49	30.25	96	58.64	18	11.11	0	0	162
TOTALS	1,281	47.23	1,194	49.83	233	8.69	4	0.15	2,712

Source: Pesquisa Psico-Social, Projetos e Desenvolvimento SEITEC, 1972

Table D-6

Power Source Employed for Other Operations Including Cultivating and Spraying: 1971-1972 Crop Year

Crop	Manual or Animal Power		Mechanized		Both		No Response		Total
	No.	%	No.	%	No.	%	No.	%	No.
Cotton	244	80.80	31	10.26	27	8.94	0	0	302
Rice	273	57.84	126	26.70	73	15.46	0	0	472
Potatoes	95	63.76	41	27.52	13	8.72	0	0	149
Cacao	145	100.00	0	0	0	0	0	0	145
Coffee	217	64.21	32	9.47	87	25.73	2	0.59	338
Sugarcane	160	62.02	33	12.79	65	25.19	0	0	258
Corn	483	81.46	65	10.96	45	7.58	0	0	593
Soybeans		26.18	91	61.07	18	12.08	1	0.67	149
Tomato	109	75.70	27	18.75	8	5.55	0	0	144
Wheat	52	32.10	96	59.26	14	8.64	0	0	162
TOTALS	1,817	66.99	542	19.99	350	12.91	3	0.11	2,712

Source: Pesquisa Psico-Social, Projetos e Desenvolvimento SEITEC, 1972.

Table D-7

Power Source Employed for Harvesting: 1971-1972 Crop Year

Crop	Manual		Mechanized		Both		No Response		Total
	No.	%	No.	%	No.	%	No.	%	No.
Cotton	279	92.39	6	1.99	17	5.62	0	0	302
Rice	307	65.05	107	22.67	58	12.28	0	0	472
Potatoes	105	70.47	23	15.44	21	14.09	0	0	149
Cacao	145	100	0	0	0	0	0	0	145
Coffee	290	85.79	6	1.78	40	11.84	2	0.59	338
Sugarcane	244	94.58	0	0	14	5.42	0	0	258
Corn	518	87.36	48	8.09	27	4.55	0	0	593
Soybeans	32	21.48	96	64.43	20	13.42	1	0.67	149
Tomato	142	98.62	0	0	2	1.38	0	0	144
Wheat	49	30.25	104	64.20	9	5.55	0	0	162
TOTALS	2,111	77.34	390	14.38	203	7.67	3	0.11	2,712

Source: Pesquisa Psico-Social, Projetos e Desenvolvimento SEITEC, 1972.

APPENDIX E

TRACTOR FINANCING AND FARM SIZE

Tractor Financing and Farm Size

In this Appendix farm interview data are utilized to indicate the relative importance of subsidized tractor financing. Also the relationship between crop area and tractor ownership in one particular agricultural area is summarized. Finally, the relative importance of the Bank of Brazil in tractor financing is discussed.

Sao Paulo data on finance conditions and tractor ownership were obtained from a survey in the greater Riberao Preto area during the 1969/1970 crop year.[1] Of the 168 tractors employed in the sample of 145 farms in Batatais, Altinapolis, and Jardinapolis, Sao Paulo 58.3 percent were financed completely or partially by formal bank credit. Savings and informal credit were more important for used and imported tractors.

Table E-1 illustrates the relationship between tractor use, ownership, and area in annual crops. Those neither owning tractors nor renting tractor services for land preparation had an average of only fifty-nine percent of the crop area of those obtaining machinery services for land preparation. Tractor ownership of one tractor is associated with a crop area 2.75

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[1] I am indebted to many people at Ohio State University and "Luiz de Quieroz" Agricultural University for their cooperation in making these data available especially Norman Rask, Richard Meyer, Donald Larson, and Joaquin Engler. The data are from a small part of the Ohio State Capital Formation project.

times as large as those depending upon custom rental. There are similar expansions of crop area cultivated with the addition of one or more tractors until the farm has seven or eight tractors. At this point the on-farm tractor stock contains several old models apparently retained for emergency or supplemental power purposes and there isn't any difference between seven and eight tractors in their association with area in annual crops.

Almost one-half of the sample had one tractor and cultivated an average of fifty-one hectares of annual crops. The custom rental market made tractor services available to another twenty-one percent of the sample. Those owning over two tractors cultivated an average area of 250 hectares of annual crops. Tractor services were obtained by small farmers through financing, the used tractor market, and the availability of custom rental operations. Nevertheless, the multiple tractor owner could cultivate large areas and the financial subsidies for agricultural machinery have been increasingly available in recent years. Moreover, there have been minimum size provisions to obtain the subsidized credits (see Table E-2).

Table E-1

Tractor Use and Area in Annual Crops in the Greater Riberao Preto Area, Sao Paulo, 1969/70 Crop Year

Number of Tractors Owned	Average Area in Annual[a] Crops (Ha.)	Number of Observations (Farms)	Percentage of Total Sample	Variance in the area (s^2)	t-value for the test of the significance of the difference in annual crop areas between groups
0 — No custom rental for land preparation used	10.9	15	10.3%	11.09	2.38* (between no custom rental and custom rental)
0 — Custom rental for land preparation	18.6	31	21.4	16.94	3.34* (between custom rental and one tractor)
1	51.1	69	47.6	466.92	
2	92.0	15	10.3	538.03	
3	174.8	5	3.4		2.65* (between one and two tractors)
4	215.0	6	4.1		
7	399.3	2	1.4		4.73** (between two and more than two tractors)
8	396.8	2	1.4		
More than two tractors	250.5	15	10.3	2,201.79	
TOTAL		145	99.9		

Table E-1--continued

[a]sugarcane is considered an annual crop

* significant at 95%
** significant at 99%

Source: The data were taken from farm interviews of the Ohio State Capital Formation Project.

Table E-2

Area Requirements for a Farmer to be Eligible for Financing of a New Tractor in 1970 by the Primary Banks Financing These Purchases

Requirements of the Bank of Brazil:

Crop	Minimum Agricultural Area
Tomatoes	12.1 Hectares
Sugarcane	36.3 "
Cereals	72.6 "

Source: Banco do Brasil, Carteira Agricola

Requirements of the Bank of Sao Paulo:

Tractor Horsepower	Minimum Agricultural Area
Up to 55 Horsepower	72.6 Hectares
55 - 65	108.9 "
Above 65	145.2 "

Source: Banco do Estado de Sao Paulo, Carteira Agricola

Table E-3 gives an estimate of the importance of Bank of Brazil financing in tractor sales. Ignoring other types of tractors besides domestically produced wheel tractors[2] and assuming 100 percent financing of the basic tractor models the Bank of Brazil financing would account for the cash value of seventy-two to seventy-eight percent of tractor sales on the average from 1962-1971. More limited information was available on tractor financing of the Bank of Sao Paulo. In 1971 this Bank lent forty-eight million cruzeiros for tractor and implement financing (Table E-5). In the same year the Bank of Brazil lent 349 million cruzeiros. There may be some other lending at the subsidized rates by other partially governmentally owned banks; however, the Bank of Brazil is the most important lender. Finally in Table E-6 the interest rates of the Bank of Brazil on various types of agricultural credit are summarized.

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[2]This omitted group includes micro and track tractors, motorized cultivators, tractor imports, and used tractor financing. The wheel tractors are the largest tractor group and wheel tractor imports have been reduced to less than 100 in 1970 and 1971. Moreover, the Ohio State interviews indicate very little financing of used tractors. See Table E-4 for data on the different types of tractors produced in Brazil and Table B-1 for tractor import data.

Table E-3

Tractor Sales[a] and the Importance of Bank of Brazil Financing

Year (1)	4 Wheel Tractor Sales (No.) (2)	Horsepower of Tractor Sales[b] (No.) (3)	Nominal Value of Bank of Brazil Credits for Tractors (Cr $1,000) (4)	Number of Tractors which the Bank of Brazil Credits Could Finance[c] (No.) (5)	Percent of Tractors Sold which the Bank of Brazil Credits Could Finance (%) (5/2)	Number of Horsepower Units which the Bank of Brazil Credits Could Finance[d] (No.) (7)	Percent of Tractor Horsepower Sold which the Bank of Brazil Credits Could Finance (%) (7/3)
1960	19	1,028					
1961	1,645	37,020	2,968	2,857	175	120,162	138
1962	7,336	352,128	9,262	5,426	74	228,128	65
1963	9,368	435,612	17,914	5,805	62	243,728	56
1964	12,032	604,006	41,146	6,920	57	346,056	57
1965	8,072	431,852	50,010	5,774	71	288,741	67
1966	9,214	490,185	92,115	9,383	102	469,256	96
1967	6,470	359,085	95,191	7,531	116	391,571	109
1968	9,263	559,485	142,942	7,700	83	403,905	72
1969	9,671	602,503	151,943	7,568	78	414,239	69
1970	14,343	893,569	212,064	9,777	68	592,358	66
1971	21,732	1,371,289	348,749	14,536	67	866,457	63

[a]Excluding micro tractors.

[b]It is assumed here that the horsepower of sales and production are equal. See Table E-4 for data on inventories.

Table E-3--continued

[c]Based upon the tractor price of Table B-1. Total financing is assumed. There is some financing for tractor imports and for micro tractors, motorized cultivators and track tractors, none of which are included here.

[d]Based upon the average price per horsepower of Table C-9. The same assumptions of total financing and no financing for other tractors besides domestically produced wheeled tractors were also employed to make this calculation.

Source: Bank of Brasil, Relatorios (Rio de Janeiro), various issues.

Table E-4

Production, Sales, and Inventory[a] in the Brazilian Tractor Industry, 1960-1972

Year	4-Wheel Tractors, excluding micro			Micro Tractors			Motorized Cultivators			Track Tractors		
	Sales	Production	Change in Inventory	Sales	Production	Change in Inventory	Sales[b]	Production	Change in Inventory[b]	Sales	Pro-duction	Change in Inventory
1960	19	37	18	---	---	---	---	---	---	---	---	---
1961	1,645	1,679	34	---	---	---	---	---	---	---	---	---
1962	7,336	7,586	250	---	---	---	1,239	1,240	1	---	—	—
1963	9,368	9,908	540	---	---	---	1,096	1,110	14	---	—	—
1964	12,032	11,537	-495	---	---	---	990	1,710	720	---	—	—
1965	8,072	8,121	49	93	280	187	2,133	2,403	270	---	—	—
1966	9,214	9,069	-145	335	291	- 44	3,120	3,178	58	—	13	—
1967	6,470	6,233	-237	68	72	4	1,981	2,159	178	72	73	1
1968	9,263	9,671	408	120	148	28	2,616	2,465	-151	104	106	2
1969	9,671	9,547	-124	318	335	17	2,138	1,947	-191	54	91	36
1970	14,343	14,049	-294	N.A.	409		N.A.	2,065		N.A.	185	
1971	21,732	22,122	390	N.A.	366		N.A.	2,006		N.A.	750	
1972		29,142			858		N.A.	2,915			1,282	

[a] Very little inventory accumulation takes place. Tractors are not made to order but the distributors are in contact monthly with manufacturers reporting sales data.

[b] Sales of motorized cultivators were inaccurate due to the apparent omission of the sales of Agrale, which is located in Porto Alegre. Most of the industry is located in Sao Paulo.

N.A.: Not available

Source: Various reports of ANFAVEA.

Table E-5

Tractor and Implement Financing of the Banco do Estado de Sao Paulo

Year	Number of Tractors and Implements Financed	Nominal Value of Financing of Banco do Estado
1963/64	1,128	N.A.
1964/65	2,341	N.A.
1965/66	1,082	N.A.
1966/67	630	N.A.
1969	1,289	N.A.
1970	2,635	N.A.
1971	2,109	Cr$ 48,692,628

Source: Communications with the Banco de Estado de Sao Paulo, March 7, 1967, May 25, 1972 and May 30, 1972.

Table E-6

Bank of Brazil Handbook of Interest Rates, 1971-72

Category	Interest Rate: to 50 minimum salaries[a]	Interest Rate: Above 50 minimum salaries[a]	Percent of Interest Paid to Bank by Special Funds of Funagri/Fundag
1. For producers	10%	15%	none
2. To cooperatives to pass on to their members	8%	13%	none
3. For purchase of national tractors, machines and implements--new and used	10%	15%	none
4. For purchase of foreign tractors and other machinery--new and used	10%	17%	none
5. For purchase of "modern inputs"	7%	7%	10% per year
6. For purchase of "modern inputs" by coops	5%	5%	10%
7. For acquisition of vehicles	21.6%	21.6%	none

[a]The value of the loan is calculated as a multiple of the minimum monthly wage in order to determine the interest rate category. These minimum salaries are adjusted annually. All tractor loans would be expected to fall in the higher category.

Source: Banco do Brasil, Manual de Credito Rural, (Rio de Janeiro: 1972).

APPENDIX F

PRODUCTION COST COMPARISON OF ANIMAL AND MECHANICAL POWER IN SAO PAULO

Production Cost Comparison of Animal and Mechanical Power in Sao Paulo

One rationale for machinery subsidies is that production costs are reduced by the utilization of machinery rather than animal power. In this section this hypothesis is tested. Table F-1 summarizes the cost data calculated from several different studies of production costs, using the same methodology, with field interviews from the state of Sao Paulo. [1]

As is evident in Table F-1 mechanization is a selective process and for none of the crops were all operations completely mechanized. Before considering the methodological problems of these costs studies it is useful to review the primary results. Generally, production costs per unit of output were lower and yields higher with more mechanization. Most of the yield differences can be attributed to either (a) differences in utilization of "bio-chemical" inputs, or (b) the improved land

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[1] These cost data were variable costs plus straight line depreciation based upon expected working life of the capital goods. See the notes to Table F-1 for further details on this calculation.

I am indebted to the Instituto de Economia Agricola for providing their data. Special thanks go to Paulo Fernando Cidade de Araujo, Paul Frans Bemelmans, Evaristo Marzubal Neves, Minoro Matsunaga, and Caio T. Yamaguishi. I am not implying that they are in agreement with the results of the analysis.

preparation resulting from mechanization.[2] The yield advantage from mechanization alone can be calculated if the two groups utilizing different power sources employ approximately the same amounts of bio-chemical inputs. The last row of Table F-1 indicates that only for cotton, corn, and soybeans was this condition fulfilled. For potatoes, sugarcane, and the IPEA cost estimates for corn and soybeans, the effects on yields from bio-chemical input use and from mechanization cannot be separated as the expenditures on "bio-chemical" inputs were substantially higher for the mechanical technology than for the animal power group. The yield advantage of mechanical technology was estimated at fourteen percent for cotton, twenty percent for corn and twenty percent for soybeans.[3]

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[2]This differentiation and discussion draws upon Ministerio de Agricultura, Govierno de Colombia, "Consideraciones sobre el papel de la maquinaria en la agricultura Colombiana," mimeo, 1971, 35 pages plus annex.

Most cultivation in Table F-1 was done with human and animal power. Mechanical harvesting of soybeans may also increase yields but the remaining crops were not harvested mechanically.

[3]See Table F-1, rows 1 and 4 for the data employed in this calculation. In comparing group means between two power technologies it is possible that other things besides bio-chemical input levels such as initial soil fertility were not held constant. To the extent that these differences exist, the estimates of the yield increases ascribed to mechanized land preparation are biased. (continued next page)

Table F-1

Yields and Production Costs for Six Crops with Animal and Mechanical Power Technologies, 1971-1972, Sao Paulo

	Cotton[c]	Corn[d]	Rice-Upland[e]	Rice - Irrigated[f]	Soybeans[g]	Potatoes[h]	Sugarcane[i]	Corn (Study of IPEA)	Soybeans (Study of IPEA)
Animal Power									
a) Yield (kg./ha.)	1,364	2,479	1,860	—	1,240	9,917	31,496	1,500	960
b) Cost/Output (Cr $/100 kg.)	72.5	23.4	39.5	—	43.7	27.8	2.68	8.73	13.5
c) Labor Use (days/ha.)	40.7	28.7	52.5	—	29.8	47.9	61.1	---	---
Mechanical Power									
a) Yield (kg./ha.)	1,550	2,975	2,033	2,603 to 3,471	1,488	9,240	42,062	2,700	1,980
b) Cost/Output Unit (Cr $/ 100 kg.)	49.4	22.1	34.7	30.5 to 31.8	33.7	34.8	1.93	8.67	14.1
c) Labor Use (day/ha.)	31.8	18.0	24.5	37.5 to 59.8	11.0	42.1	42.1	---	---
Cost Savings with Mechanical Technology									
a) Cost Savings per Hectare[a] (Cr $)	358	38.7	97.6	—	148.8	-86.8	315	1.6	-0.6
b) Cost Savings from Reduced Labor Use[b] (Cr $)	73	87.8	230	—	154.3	47.6	156	---	---
c) Labor Cost Savings . 100 / Total Cost Savings	20.4%	227%	236%	—	104%		49.5%	---	---

Table F-1--continued

	Cotton[c]	Corn[d]	Rice-Upland[e]	Rice - Irrigated[f]	Soybeans[g]	Potatoes[h]	Sugarcane[i]	Corn (Study of IPEA)	Soybeans (Study of IPEA)
d) Reduction in Labor Use Per Hectare (man days)	8.9	10.7	28	—	18.8	5.8	19	---	---
Differences in Expenditure on Bio-chemical inputs									
a) Mechanical Power Expenditure Minus Animal Power Expenditure Per Hectare (Cr $)	5.8	no difference	-32.5	—	-6.1	1,269	107	94	114
b) Difference or a) • 100/Expenditures on Bio-chemical Inputs with Mechanical Technology	1.8%	---	-20.0%	—	-3.0%	38.3%	45.3%	94%	92%

[a] This row gives the cost advantage from using mechanical technology per unit of output times the yield with mechanical technology. The cost advantage per hectare is employed to compare it with the labor use per hectare and estimate the importance of labor costs in the total cost saving with mechanization. The cost per output unit was given above for both animal and mechanical power.

[b] The reduction in labor use per hectare times the minimum wage.

[c] Tractors were used for ploughing, grading, planting, fertilizing, internal transport, and clearing the field after picking. Animal power was used for cultivating and opening the furrows in both technologies. Human labor was used for all other operations including harvesting. Labor use excludes harvesting which is contracted on a piece work basis.

[d]Tractors were employed for ploughing, grading, planting, fertilizing, some cultivation, and internal transportation. Human power was utilized for most of cultivation and harvesting.

[e]The mechanical technology included primarily human power in cultivating but very little human power in harvesting. The fact, that with animal power the yields were lower but the expenditures on bio-chemical inputs were greater, results from the substantially greater expenditure on insecticide with the animal power technology. The difference in insecticide expenditures per hectare between the two amounts to Cr $ 42.4. These higher insecticide expenditures may have given different degrees of risk avoidance or insect problems may have been different in different regions.

[f]The difference between the two estimates for irrigated rice was for direct seeding and manual transplanting. The latter cultural practice required more labor but gave higher yields.

[g]For animal technology animal power was employed for all land preparation and planting activities. Harvesting was by hand. For mechanical technology animal power was still used for cultivating but harvesting was mechanized. Again the expenditures on insecticide were greater in the animal technology with Cr $65.8/ha. as compared with Cr $16.9/ha.

[h]The difference between the two technologies was that the first used only 1.86 days/ha. of tractor services while the second used 4.8 days/ha. of tractor services and 0.4days/ha. of a mechanical harvester. With the second technology cultivating, making furrows, fertilizing, planting, and covering were done by machine rather than by animal as in the first. In this case the difference in per unit costs resulted from the very large difference in bio-chemical expenditures between technologies. The potato cost data were for 1971.

[i]It was necessary to combine several sources of IEA data to obtain these data. The smallest strata farms were assumed to correspond with the animal power farms and the largest strata farms were assumed to correspond with the farms owning their own mechanical equipment.

Method of Cost Calculation: In the IEA method the technical coefficients of production were estimated in terms of days of input use per alquiere. Alquieres were converted to hectares at the rate of 2.42 ha/alq. Labor was priced at the minimum wage prevailing in 1971/1972, Cr $ 8.21/day. Animal power costs were the summation of land rental, feed, labor cost, and depreciation of Cr $ 1.25/day. Machinery costs included gas, oil, estimated repairs and straight line depreciation based upon the expected life of the machine.

Table F-1--continued

Interest Costs were not included. Note that these costs are variable costs per unit plus depreciation. Returns to fixed factors were not included and operator labor was paid the minimum wage. There was no return to entrepreneurs. Other machinery was handled in the same manner as tractors.

The IPEA study included interest costs on machinery but their fixed costs such as the return to the farmer and to land were excluded in Table F-1. The IPEA study included these returns to fixed factors; however, there was no information presented on how these costs were calculated. Returns to entrepreneurs and to the fixed factors should be included in returns rather than estimating an arbitrary rate of return to land and entrepreneurs.

Sources: IEA unpublished data and C. B. Doellinger and H. de Barros Castro Faria, Exportacao de productos primarios nao-tradicionais, (Milho, soja, carnes, productos de madeira, derivados de cacau,e alimentos processados), (IPEA/INPES: Rio de Janeiro; 1971), 55,70. The data were taken from PLANASEM.

The price data of the IEA were for the 1971/72 crop year but the input and yield data were based upon field interviews taken in previous years.

For most crops the savings in labor costs were the most important component of the cost savings from mechanization. For corn, upland rice, soybeans, and potatoes the other costs besides labor were greater for mechanical than for the animal technology so that without the substantial savings in labor costs the cost advantage would be with animal technology. Labor costs may have been overstated by pricing them at the minimum wage. This was especially true on smaller farms dependent upon family labor. The minimum wage does not even apply for labor under 21 years of age; moreover, much of the labor force earns the minimum wage or less so that putting the opportunity cost of farm family labor at the minimum wage tends to overstate its potential earning power.

In Table F-1, with the exception of potatoes and accepting the methodology employed, the production costs of animal power per output unit are larger than those of mechanical power. Moreover, it has already been shown in Appendices D and E that mechanization has been concentrated on the larger farms. These two results can be graphically illustrated with the cost

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For another study employing this same methodology to calculate the yield difference from mechanization alone see Ministerio de Agricultura, Govierno de Colombia, op. cit., p. 32. This report estimated a yield effect of 10 percent for land preparation and 12 to 15 percent if all operations were mechanized.

Also note that there was a 9 percent yield advantage to mechanized upland rice production in spite of the utilization of higher levels of bio-chemical inputs on non-mechanized farms in Table F-1.

curves of Figure F-1. Note that there are two types of cost savings in this figure, the private and the public savings. A farm of a given crop size, S_2, would face the upward sloping part of the animal technology cost curve due to high seasonal wages or other costs associated with large seasonal labor forces (see Chapter 3). By mechanizing this large crop farm achieves the private cost saving (CD). However, the public saving, is the difference in per unit costs between the optimum crop farm size for animal power (S_1) and for mechanical power (S_2) or AB. The public saving thus involves the cropland distribution by farm size and the choice of technologies.

The public saving can be calculated from Table F-1 and is illustrated for four major crops in Table F-2. The primary problem with the methodology of cost calculation employed in Table F-1 is the omission of the interest charge on capital inputs. To correct this omission interest costs were calculated on all capital inputs excluding land but including both machinery and bio-chemical inputs. The cost of machinery is equal to fuel, repair, and other variable costs, plus depreciation and interest costs. Depreciation and interest costs were calculated in the usual manner, $(d + \frac{r}{2})C$, where

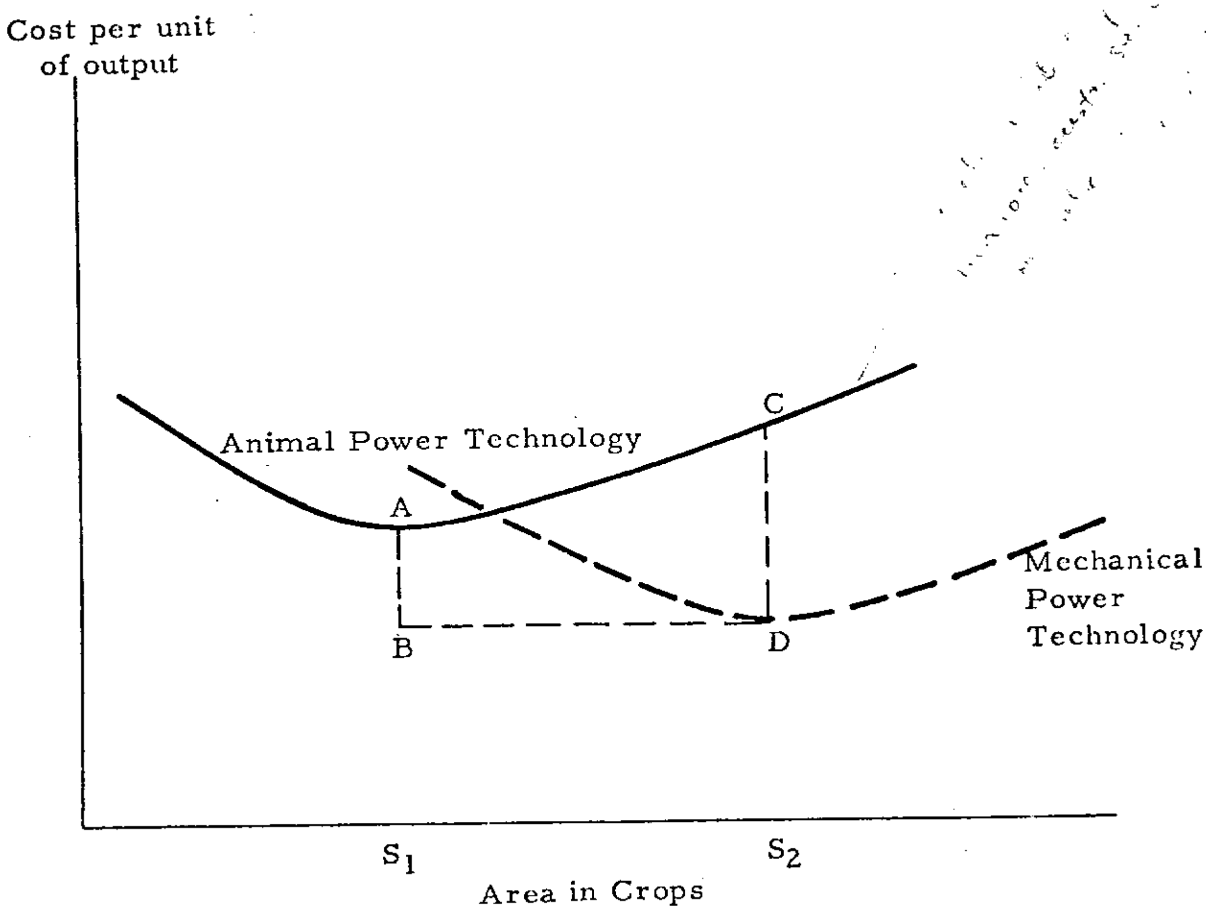

Figure F-1. Hypothetical Production Cost Curves of Two Alternative Power Technologies.

d is depreciation, r is the interest rate or cost of capital, and C is the price of the machine.[4]

Given the important governmental role in the capital market, the real cost of capital is unknown. However, introducing a charge on capital has a substantial effect on the public saving resulting from mechanization. For the interest rate both the subsidized rate currently prevailing of fifteen percent and one estimate for the unsubsidized rate or real cost of capital of thirty percent were employed to recalculate the public saving (AB in Figure F-1).

At all interest costs the mechanized potato production had higher costs than the animal power group.[5] At the subsidized interest rate of fifteen percent animal power

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[4]The interest rate is divided by two to allow for the assumption that the capital good is half-way through the repayment period, hence interest is only paid on one-half of the principal.

For an excellent treatment of mechanical innovation with cost curve analysis see P. A. David, "Mechanization of Reaping in the Ante-Bellum Midwest," in H. Rosovsky (ed.), Industrialization in Two Systems (Wiley and Sons: New York; 1966), 20-39.

[5]Since the mechanized group used more capital inputs, both machinery and bio-chemical inputs, the estimate of AB becomes larger absolutely or shows an even greater advantage for animal power when the cost of capital is increased from zero in the methodology of Table F-1 to 15 or 30 percent.

production costs were lower for cotton but still higher for corn and soybeans. At the thirty percent interest rate animal power also became the lower cost technique for corn but mechanized soybean production still retained its advantage. Only for soybeans was there a clear advantage of lower production costs per unit from using machinery at the thirty percent interest rate.

The public saving of mechanization (AB) was still biased in favor of mechanical power even in Table F-2 for several reasons. First, labor costs on small, non-mechanized farms were overstated by pricing family labor at the minimum wage hence animal power costs were overstated. The appropriate labor cost is the "shadow price" or opportunity cost of family labor, seasonally adjusted. Secondly, the real cost of capital without governmental subsidies may be even higher than the thirty percent nominal interest rates.

For three of the four commodities, the public saving was negative at the unsubsidized interest rate indicating a cost advantage for the animal power technology. However, caution is necessary in generalizing from these data as there are regional cost differences and continuing introduction of mechanical and other inputs which may modify the cost comparisons. For

Table F-2

The Public Saving (AB) of Mechanical Over Animal Power for Four Crops With and Without the Interest Costs, 1971/1972 Crop Year

	Cotton	Corn	Soybeans	Potatoes
Cost Advantage (AB in Figure F-1)				
No Interest: Cost/100 kg. With Animal Power Minus Cost/100 kg. With Mechanical Power (Cr $/100kg)	23.1	1.3	10	-7
15% Interest Animal-Mechanical Power (Cr. $/100kg)	-0.21	0.24	7.64	Not calculated
30% Interest Animal Power-Mechanical Power (Cr $/100 kg)	-2.28	-0.92	5.30	Not calculated

Note: Insufficient data were available to make this calculation for rice or sugarcane. The AB calculated in Table F-1 was Cr $ 4.8/100 kg. for rice and Cr $ 0.75/100 kg. for sugarcane. For sugarcane the use of bio-chemical inputs was forty-five percent higher on the mechanized operations and yields were substantially higher on the mechanized operations. This was not true for rice. See Table F-1.

Source: IEA data. See Table F-1.

large crop farms demanding a large labor force at peak seasonal demand periods, labor costs are often higher than the minimum wage. Piece workers in cotton harvesting in Sao Paulo reportedly can earn 1.5 times the minimum wage at peak season demand time. For these large farmers mechanization may substantially reduce their private costs (CD) and those shifting into crop production may take advantage of these private savings. From the public viewpoint, however, the smaller farmers using animal power and bio-chemical inputs produced at the same or lower per unit costs for three of the four crops evaluated (at the thirty percent nominal cost of capital).

BIBLIOGRAPHY

Abercrombie, K. C., "Agricultural Mechanization and Employment in Latin America," International Labor Review 106 (July 1972): 11-45.

________, "Preliminary Note on Agricultural Employment Problems in Brazil," mimeo, December 1971, 14 pages.

Ahn, C. Y., "A Recursive Programming Model of Regional Agricultural Development in Southern Brazil (1960-1970): An Application of Farm Size Decomposition," unpublished Ph. D. dissertation, Ohio State University, 1972.

________, and I. J. Singh, "Distribution of Farm Incomes Under Alternative Policy Regimes: A Dynamic Analysis of Recent Developments in Southern Brazil, (1960-1970)," Economics and Sociology Occasional Paper No. 89, (Ohio State University: Columbus; August 1972).

ANFAVEA, "A racionalizacao da industria de tratores e fundamental para a tecnificao da nossa agricultura - passo decisivo na retomada do desenvolvimento economico do Pais," Separata de Industria Automotiva 106 (April 1968), mimeo, 15 pages.

Arrow, K. J., H. B. Chenery, B. S. Minhas, and R. M. Solow, "Capital-Labor Substitution and Economic Efficiency," Review of Economics and Statistics 63 (August 1961): 225-250.

Bacha, E. L., "O subemprego, o custo social da mao-de-obra e a estrategia brasileira de crescimento," Revista Brasileira de Economia 26 (Jan. /Mar. 1972): 105-116.

Baklanoff, E. N., "Foreign Private Investment and Industrialization in Brazil," in E. N. Baklanoff (ed.), New Perspectives of Brazil (Vanderbilt University Press: Nashville; 1966), pp. 101-136.

Banco Central, Manual de Credito Agricola (Rio de Janeiro; May 1970).

Banco do Brasil, Relatorios (Rio de Janeiro; annual publication) various issues cited.

Behrman, J. R., "Sectoral Elasticities of Substitution Between Capital and Labor in a Developing Economy: Time Series Analysis in the Case of Postwar Chile," Econometrica 40 (March 1972): 311-327.

Bergsman, J., Brazil, Industrialization and Trade Policies (Oxford University Press: New York; 1970).

Bieri, J., A. de Janvry, and A. Schmitz, "Agricultural Technology and The Distribution of Welfare Gains," American Journal of Agricultural Economics 54 (December 1972): 801-809.

Billings, M. H., and A. Singh, "Mechanization and Rural Employment," Economic and Political Weekly 5 (Bombay: June 27, 1970): A61-A72.

Brodell, P. R., and A. R. Kendall, Fuel and Motor Oil Consumption and Annual Use of Farm Tractors, F. M. 80 (Bureau of Agricultural Economics, USDA: Washington; 1950).

Brown, M., On the Theory and Measurement of Technological Change (Cambridge University Press: London; 1968).

Chow, G. C., "Tests of Equality Between Sets of Coefficients in Two Linear Regressions," Econometrica (July 1960): 591-605.

Christoffersen, L. E., "Taxas de juros e a estrutura de um sistema de bancos comerciais em condicoes inflacionarias - o caso do Brasil," Revista Brasileira de Economia 23 (Junho 1969): 5-35.

Cowling, K., and A. J. Rayner, "Price-Quality and Market Share," Journal of Political Economy 78 (November-December 1970): 1292-1309.

Cromarty, W. A., The Demand for Farm Machinery and Tractors, Technical Bulletin 275 (Michigan State University: East Lansing; November 1959).

David, P. A., and T. v. d. Klundert, "Biased Efficiency Growth and Capital-Labor Substitution in the U. S., 1899-1960," American Economic Review 55 (June 1965): 357-395.

________, "Mechanization of Reaping in the Ante-Bellum Midwest," in H. Rosovsky (ed.), Industrialization in Two Systems (Wiley and Sons: New York; 1966), pp. 20-39.

Day, R. H., "The Economics of Technological Change and the Demise of the Share Cropper," American Economic Review 57 (June 1967), 427-450.

Doellinger, C. V., and H. de Barros Castro Faria, Exportacao de productos primarios nao-tradicionais (Milho, soja, carnes productos de madeira, derivadas de cacau e alimentos processados) (IPEA/INPES: Rio de Janeiro; 1971).

Durbin, J., "Testing for Serial Correlation in Least Squares Regression When Some of the Regressions Are Lagged Dependent Variables," Econometrica 38 (May 1970): 410-421.

Eckaus, R. S., "The Factor Proportions Problem in Underdeveloped Areas," in N. A. Agarwala and S. P. Singh (ed.), The Economics of Underdevelopment (Oxford University Press: New York; 1963), pp. 328-380.

Engler, J. J. de C., "Alternative Enterprise Combinations Under Various Price Policies on Wheat and Cattle Farms in Southern Brazil," unpublished Ph. D. dissertation, Ohio State University, 1971.

________, and R. L. Meyer, "Trigo: producao, precos, productividade," mimeo, April 1972, 20 pages.

Fettig, L. P., "Adjusting Farm Tractor Prices for Quality Changes, 1950-1962," Journal of Farm Economics 45 (August 1963): 599-611.

Fishlow, A., "Brazilian Size Distribution of Income," American Economic Review, Papers and Proceedings (May 1972): 391-403.

Fox, A., Demand for Farm Tractors in the United States - A Regression Analysis, Agricultural Economic Report No. 103 (Economic Research Service, USDA: Washington; November 1966).

Fundacao Getulio Vargas, "Evolucao da mao-de-obra Brasileira," Conjuntura Economica 10 (Junho 1956): 84-90.

________, and IBGE, 25 Anos de Economia Brasileira (Comissao Mista Brasil - Estados Unidos: Rio de Janeiro; 1965).

________,"Balanco de uma decada," Conjuntura Economica 24 (Enero 1970).

________, "O censo demografico de 1970," Conjuntura Economica 26 (Fevereiro 1972): 149-157.

________, "Encargos sociais do empregador," Conjuntura Economica 26 (April 1972): 59-61.

________, "25 anos da politica do cafe - alguns aspectos," Conjuntura Economica 26 (Novembro 1972): 32-40.

Giles, G. M., "Towards a More Powerful Agriculture: A Report to The Government of West Pakistan on its Agricultural Power and Equipment Needs," (Planning Cell, Agriculture Department, West Pakistan: Lahore; 1967).

Goodman, D. E., J. F. Ferreira Sena, and R. Cavalcanti de Albuerque," Os incentivos financeiros a industrializacao do Nordeste e a escolha de tecnologias," Pesquisa e Planejamento(IPEA: Rio de Janeiro; Dezembro 1971).

Gotsch, C. H., "Technical Change and the Distribution of Income in Rural Areas," American Journal of Agricultural Economics 54 (May 1972): 326-342.

Graham, D. H., and S. B. de Hollanda Filho, Migration, Regional and Urban Growth and Development in Brazil: A Selective Analysis of the Historical Record: 1872-1970, Vol. 1 (Instituto de Pesquisas Economicas, USP: Sao Paulo; 1971).

Griliches, Z., "Capital Stock in Investment Functions: Some Problems of Concept and Measurement," in C. F. Christ et al., Measurement in Economics and Econometrics (Stanford University Press: Palo Alto; 1963), pp. 115-137.

_________, "The Demand for a Durable Input: Farm Tractors in the United States, 1921-1957," in A. C. Harburger (ed.), The Demand for Durable Goods (University of Chicago Press: Chicago; 1960), 181-207.

Harberger, A. C., "The Incidence of the Corporate Income Tax," Journal of Political Economy 70 (June 1962): 215-240.

_________, "Taxation, Resource Allocation and Welfare," in National Bureau of Economic Research and the Brookings Institution, The Role of Direct and Indirect Taxes in the Federal Revenue System (Princeton University Press: Princeton; 1964).

Hayami, Y., and V. W. Ruttan, Agricultural Development: An International Perspective (Johns Hopkins Press: Baltimore; 1971).

Heady, E. O., and L. G. Tweeten, Resource Demand and Structure of the Agricultural Industry (Iowa State University Press: Ames; 1963).

Herrmann, L. F., Changes in Agricultural Production in Brazil, 1947-65, Foreign Agriculture Economic Report No. 79 (Economic Research Service, USDA: Washington; June 1972).

Hoffmann, R., and J. C. Duarte, "A distribuicao da renda no Brasil," Revista de Administracao de Empresas 12 (Junho 1972): 46-67.

Hottel, J. B., W. R. Grant, and T. Mullins, Equipment Technology and Weather on Rice Farms in the Grand Prairie, Arkansas, Part I: Farm Organization and Risk Bulletin 734 (Agricultural Experiment Station, University of Arkansas: Fayetteville; December 1968).

Huddle, D. L., "Balanco de pagamentos e control de cambios no Brasil: eficacia, ben-estar e desenvolvimento economico," Revista Brasileira de Economia 18 (June 1964): 1-34.

Hunt, D., "Selecting an Economic Power Level for the Big Tractor," paper presented at the American Society of Agricultural Engineers, Pullman, Washington, June 1971, mimeo, 12 pages.

Hymer, S., and S. Resnick, "A Model of an Agrarian Economy with Non-Agricultural Activities," American Economic Review 59 (September 1969): 493-506.

Instituto Brasileira de Estatistica, Annuario Estatistico (Rio de Janeiro: 1952).

________, Brasil-Censo Agricola, VI Recenseamento Geral do Brasil-1950 (Rio de Janeiro: 1956).

________, Annuario Estatistico (Rio de Janeiro: 1962).

________, Brasil-Censo Agricola, VII Recenseamento Geral do Brasil-1960 (Rio de Janeiro: 1970).

________, Sinopse Preliminar do Censo Demografico, VIII Recenseamento Geral 1970 (Rio de Janeiro: July 1971).

________, Annuario Estatistico (Rio de Janeiro: 1971).

________, Censo Agricola Preliminar, VIII Recenseamento Geral 1970 (Rio de Janeiro: 1972).

Inukai, I., "Farm Mechanization, Output and Labor Input: A Case Study in Thailand," International Labor Review 101 (May 1970): 453-473.

Janvry, A. de, "Optimal Levels of Fertilization Under Risk: The Potential for Corn and Wheat Fertilization Under Alternative Price Policies in Argentina," American Journal of Agricultural Economics 54 (February 1972): 1-10.

________, "A Socio-economic Model of Induced Innovation for Argentine Agricultural Development," Quarterly Journal of Economics, forthcoming.

Johl, S. S., "Mechanization, Labor Use, and Productivity in Agriculture," (Department of Agricultural Economics: Ohio State; 1971), mimeo, 27 pages.

Johnston, B. F., and J. Cownie, "The Seed-Fertilizer Revolution and Labor Force Absorption," American Economic Review 49 (September 1969): 569-583.

Kafka, A., "The Brazilian Exchange Auction System," Review of Economics and Statistics 38 (August 1956): 308-323.

Kmenta, J., Elements of Econometrics (Macmillan Co.: New York; 1971).

Leff, N. H., "Export Stagnation and Autarkic Development in Brazil 1947-1962," Quarterly Journal of Economics 81 (May 1967): 286-302.

________, "Import Constraints and Development: Causes of the Recent Decline of Brazilian Economic Growth," Review of Economics and Statistics 49 (November 1967): 494-502.

Leme, H. d. A., "A fabricacao de tratores e maquinas agricolas no Brasil," Noticias Automobilisticas No. 305 (April 1960): 17-19.

Lidman, R. M., "The Tractor Factor: Agricultural Mechanization in Peru," Public and International Affairs (Princeton University Press: Princeton; 1968), pp. 5-30.

Mandell, P. I., "The Development of the Southern Goias Brasilia Region: Agricultural Development in a Land Rich Economy," unpublished Ph. D. dissertation, Columbia University, 1969.

Marshall, F. R., "Some Rural Economic Development Problems in the South," American Economic Review, Papers and Proceedings 62 (May 1972): 204-212.

McLure, C., "The Theory of Tax Incidence with Imperfect Factor Mobility," mimeo, 1968.

"Mecanizacao agricola ganha desenvolvimento no Brasil," O Dirigente Rural 11 (Enero/Fevereiro 1972): 9-18.

Ministerio de Agricultura, Govierno de Colombia, "Consideraciones sobre el papel de la maquinaria en la agricultura Colombiana," mimeo, 1971, 35 pages plus annex.

Ministerio da Agricultura, Plano Nacional de Mecanizacao Agricola, Planame (Carta de Brasilia; 1967), Anexo 1.

Mieszkowski, P., "On the Theory of Tax Incidence," Journal of Political Economy 75 (June 1967): 250-262.

Nehman, G., "Uso do credito agricola em propriedades de baixo nivel de renda em uma communidade rural atrasada do estado de Sao Paulo," mimeo, 1972, 9 pages.

Nerlove, M., and K. F. Wallis, "Use of the Durbin-Watson Statistic in Inappropriate Situations," Econometrica 34 (January 1966): 235-238.

Nicholls, W. H., "The Transformation of Agriculture in a Semi-Industrialized Country: The Case of Brazil," in E. Thorbecke (ed.), The Role of Agriculture in Economic Development (National Bureau of Economic Research: New York; 1969), pp. 311-379.

________, "A agricultura e o desenvolvimento economico do Brasil," Revista Brasileira de Economia 27 (Out./Dez. 1972): 169-207.

O'Brien, F. S., and C. L. Salm, "Employment and Unemployment in Brazil," Revista Brasileira de Economia 24 (Outubro/Dezembro 1970): 129-137.

"Pesquisa sobre condicoes e custos de producao de lavoura canavieira," Revista Brasileira de Economia 19 (Dezembro 1965): 24-55.

Rao, C. H. H., "Farm Mechanization in a Labor Abundant Economy," Economic and Political Weekly 7 (February 1972): 393-400.

Rayner, A. J., An Econometric Analysis of the Demand for Farm Tractors, Bulletin No. 113 (University of Manchester: Manchester; October 1966).

________, and K. Cowling, "Demand for a Durable Input: An Analysis of the United Kingdom Market for Farm Tractors," Review of Economics and Statistics 49 (November 1967): 590-598.

________, "Price-Quality Relationships in a Durable Asset: Estimation of a Constant Quality Price Index for New Farm Tractors, 1948-1965," Journal of Agricultural Economics 29 (May 1968).

________, "Demand for Farm Tractors in the United States and the United Kingdom," American Journal of Agricultural Economics 50 (November 1968): 896-913.

Republica Federativa do Brasil, I Plano Nacional de Desenvolvimento PND 1972/1974 (Brasilia; November 1971).

Roche e Silva, A. d., and N. R. Nobrega, "Contribucao para o estado do problema da moto-mechnizacao agricola no estudo de Sao Paulo, mimeo, 1954.

Rosenberg, N., "The Direction of Technological Change: Inducement Mechanisms and Focusing Devices," Economic Development and Cultural Change 18 (October 1969): 1-24.

Sahota, G. S., "An Economic Analysis of Internal Migration in Brazil," Journal of Political Economy 76 (March-April 1968): 218-245.

Sanders, J. H., "The Performance of the Brazilian Agricultural Sector from 1950 to 1971: Demand or Supply Constraints," mimeo, 1973, 18 pages.

Sato, K., "A Two Level Constant-Elasticity of Substitution Production Function," Review of Economic Studies 34 (April 1967): 201-208.

Sato, R., "The Estimation of Biased Technical Progress and the Production Function," International Economic Review 11 (June 1970): 179-201.

Schattan, S., "Estrutura economica da agricultura Paulista," Agricultura en Sao Paulo 7 (Maio 1960): 1-12.

Schmitz, A., and D. Seckler, "Mechanized Agriculture and Social Welfare: The Case of the Tomato Harvester," American Journal of Agricultural Economics 52 (November 1970): 509-577.

Schuh, G. E., "Algumas observacoes sobre o desenvolvimento economico do Brasil," Revista Brasileira de Economia 26 (Out./Dez. 1972): 207-227.

________, "Patterns of Equity Under Agricultural Development in Latin America," in A. G. Ball and E. O. Heady (eds.), Externalities in the Transformation of Agriculture: The Distribution of Benefits and Costs from Development (Iowa State University Press: Ames; forthcoming).

Schuh, M. I. A., "Some Aspects of Recent Trends in Brazilian Agriculture," mimeo, October 1972, 121 pages.

Scott, H. G., and D. J. Smyth, Demand for Farm Machinery--Western Europe, Study No. 9, Royal Commission on Farm Machinery (Queens Printer: Ottawa; 1970).

Secretaria da Agricultura, "Informacoes sobre mecanizacao da lavoura no Brasil, especialmente tratores," mimeo, 1955.

________, I Simposio sobre Fabricacao do Trator e Implementos Agricolas no Brasil (Sao Paulo; Novembro 1959).

________, Resultados Comparativos da Contabilidade Agricola, 1968-69 (Instituto de Economia Agricola: Sao Paulo; 1970).

________, Desenvolvimento da Agricultura Paulista (Instituto de Economia Agricola: Sao Paulo; 1972).

________, Prognostico, Ano Agricola, 1972/73 (Instituto de Economia Agricola: Sao Paulo; 1972).

Sen, A. K., Choice of Technique, An Aspect of the Theory of Planned Economic Development (Oxford University Press: London; 1962).

Singh, I. J., and C. Y. Ahn, "Employment and Capital-Labor Substitution in South Brazilian Agriculture," Economics and Sociology Occasional Paper No. 72 (Ohio State University: Columbus; March 1972).

Smith, G. W., "Brazilian Agricultural Policy, 1950-1967," in H. S. Ellis (ed.), The Economy of Brazil (University of California Press: Berkeley; 1969), pp. 213-265

Strickler, P. E., and B. J. Harrington, Liquid Petroleum Fuel Used by Farmers in 1959 - and Related Data, Statistical Bulletin No. 344 (Economic Research Service, USDA: Washington; May 1964).

Syvrud, D., "Estrutura e politica de juros no Brasil - 1960/70," Revista Brasileira de Economia 26 (Enero/Marzo 1972): 117-141.

Thirsk, W. R., "The Economics of Colombian Farm Mechanization," unpublished Ph. D. dissertation, Yale University, 1972.

________, "Income Distribution, Efficiency and the Experience of Colombian Farm Mechanization," Program of Development Studies, Rice University, Fall 1972, 54 pages.

Todaro, M., "A Model of Labor Migration and Urban Unemployment in Less Developed Countries," American Economic Review 59 (March 1969): 138-148.

"Tratores de rodas, A explosao do crescimento," Transporte Moderno (April 1972): 9-14.

United States Department of Agriculture, 1971: Changes in Farm Production and Efficiency, A Summary Report, Statistical Bulletin No. 233 (Economic Research Service, USDA: Washington; June 1972).

Wallace, T. D., and D. M. Hoover, "Income Effects of Innovation: The Case of Labor in Agriculture," Journal of Farm Economics 48 (May 1966): 325-336.

Whitaker, M., "Labor Absorption in the Industrial Sector of Brazil: An Econometric Analysis," unpublished Ph. D. dissertation, Purdue University, 1970.

Wills, I. R., "Projections of Effects of Modern Inputs on Agricultural Income and Employment in a Community Development Block, Uttar Pradesh, India," American Journal of Agricultural Economics 54 (August 1972): 452-461.

Wonnacott, R. J., and T. H. Wonnacott, Econometrics (John Wiley and Sons, Inc., New York; 1970).

Youmans, R., and G. E. Schuh, "An Empirical Study of the Agricultural Labor Market in a Developing Economy: Brazil," American Journal of Agricultural Economics 50 (November 1968): 943-961.

Yudelman, M., G. Butler, and R. Banerji, Technological Change in Agriculture and Employment in Developing Countries (OECD: Paris; 1971).

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