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AGRICULTURAL DUALISM AND BRAZILIAN DEVELOPMENT

This research clearly demonstrated the disparities in agricultural growth between groups of farmers in Brazil, especially in the wheat region, and noted the broader interregional disparities which historically existed and appear to be even more accentuated in recent years. This process of growth has contributed to increased dualism in Brazilian agriculture: highly capitalized mechanized farms with low labor/land ratios, and under capitalized traditional small farms using large amounts of labor and little new technology. The dilemma appears to be the classic one of growth versus distributive equity, a theme of increasing importance in developing countries. As noted above, the policies affecting Brazilian agriculture to the greatest extent in the post World War II period are associated into two major sub-periods of development strategies in the country: the first characterized by general neglect and occasional discrimination against agriculture, especially in the 1947-61 period of intense import substitution industrialization, resulted in agricultural growth largely along the extensive margin; the second, beginning in the mid-1960's and continuing to the present, represents a period in which policies have been aimed at agricultural modernization and expanded traditional and nontraditional exports. In the first period, the objectives for agriculture were limited primarily to producing an adeuqate supply of reasonably priced food for urban wage earners and secondarily, generate foreign exchange to finance the importation of the industrial raw materials and capital goods. The assistance granted to agriculture consisted largely of improving extension and marketing services. Since the mid-1960's much greater emphasis has been given to modernization, and accelerating the growth of output and exportation. Emphasis on research increased in the early 1970's. Generally Brazil has been quite successful in meeting its economic objectives. In fact, the high growth rates since 1968 have caused people to speak of the "economic miracle" and make comparisons with countries like Japan. This euphoria may be a bit premature, particularly in view of current energy problems, but clearly the performance has been exceptional in the past few years, in large part due to expert decision making. The emphasis, at least in agriculture, however, has been largely on growth rather than growth with equity. Given the state of the economy when the military took power in 1964, it is easy to understand this orientation. But it is also necessary to call attention to the potential structural problems arising from this approach which may hamper future economic growth and development. The experience of other countries has demonstrated the difficulty in achieving equity, in spite of good intentions, once great inequities have arisen. Perhaps some loss in growth rate occurs when increased equity is pursued, but the results of this and other research, which suggest relatively constant returns to scale in agriculture over a wide range of output levels, imply that the losses might not be that great. If more broadly based growth is desired, the challenge to policy makers is clear and complex. It requires a fundamental rethinking of how millions of Brazilian farmers respond to policies. The tendency has been to view policy making as essentially a "top-down" activity with relatively little feedback about the dynamics of policy impacts. The observed inequalities in resource use, income and growth logically result. A growth-with-equity strategy would have to take into account the heterogeneity of farms and farmer response. Policy making would then involve identifying groups of farmers that are relatively more homogeneous and developing a specific set of policy incentives for each group. The recent efforts of the quasi-public national agricultural research institute (EMBRAPA) to develop region and crop specific technological packages is a promising attempt clearly in the right direction. The scientists and technicians of this institution are to be commended for this

initiative and their appreciation of the complexities of the agricultural development process. Another clear implication of this research is the crucial role which product and factor pricing has on the pattern of farm growth. Brazilian policy makers have consistently espoused the role of the market in allocating resources, yet continuously intervene in the market process in order to influence prices for some specific objective. Generally such intervention has been directed towards increasing the use of certain inputs, expanding output of selected products, or reducing consumer prices. The resulting distortions have helped meet the objectives, at least in the short-run, but have also contributed to resource misallocation and an unequal pattern of participation in the growth process by various groups of farmers. These inefficiencies and inequities could well frustrate future broad based rapid growth. Furthermore, the slow growth in effective demand of the marginalized segment of the rural population may frustrate the continued growth of the industrial sector. Solely removing pricing distortions, as important as that may be, may not constitute, however, the necessary and sufficient conditions for broader based agricultural development. Structural change needs to be attacked simultaneously. This research has shown how differential resource endowments and access to resources and policy incentives contributes to uneven farm growth. Land reform, credit for land purchases, effective land taxation, and improvements in the land market may be necessary to form the basis for more equitable growth where agricultural production is still largely a function of combining land with labor. More yield increasing technologies are also required so that increases in income are not restricted just to enterprise changes or mechanization. Rural education, now lamentably inadequate, must be improved and universalized so that farmers are better prepared to seek out and understand new information as well as provide a more productive source of labor when they choose urban employment. Extension workers must be provided with a larger stock of technological alternatives and must be freed of a myraid of administrative functions and a bias to concentrate their efforts on large farms. Lastly, signs are beginning to appear in Brazil that the past emphasis on the macro approach to the study of agricultural problems is waning and a new interest is emerging in the study of the microeconomics of the agricultural sector. The research reported in this volume has made a small dent in this vast uncharted field. Hopefully it will encourage some of the extremely talented young Brazilian men and women now studying at home and abroad to delve into the problems faced by farms and rural markets which have only been touched upon here. Studies related to such problems as the determinants of consumption and savings, creation of employment, returns from new technology, bottlenecks in input and product markets, impact of inflation and income distribution, exchange rate and other trade policy influences on agricultural trade, and financial market contributions to capital allocation and savings accumulation represent a few of the most crucial items in a long list of research priorities. Of immediate importance is the initiation of a nationwide system for the collection of farm level time series data absolutely essential to effective economic research. This research and the rapidly growing literature on economic and agricultural growth and development in Brazil show that the sleeping giant of the southern hemisphere awoke with a start in the latter half of the twentieth century and shows great potential for becoming a commanding influence in the economy and politics of Latin America. It holds untapped and underutilized agricultural resources that could become one of the important breadbaskets to help feed the hungry world. By achieving high growth rates for several years, it has demonstrated a capability to effectively draw some of these resources into production. But if it is to

realize its true economic potential and maintain long term high growth rates, it must begin to more effectively harness its most valuable resource, a resource largely overlooked in recent years - the growing quantity and quality of its peoples. When that occurs, we can justifiably refer to the "Brazilian Economic Miracle."

FINAL REPORT

June, 1975

FARM GROWTH IN BRAZIL
CHAPTER SEVEN

The Ohio State University Research Team

Dale W Adams
Choong-Yong Ahn
David G. Francis
Terrence F. Glover
Douglas H. Graham
Donald W. Larson
Richard L. Meyer, Field Director
Norman Rask, Project Director
Inderjit Singh

Under Research Contract AID/csd-2501

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and

The Research Foundation
The Ohio State University
Columbus, Ohio

Department of Agricultural Economics and Rural Sociology
The Ohio State University
2120 Fyffe Road
Columbus, Ohio 43210

PREFACE

In 1969 the U.S. Agency for International Development through its Technical Assistance Bureau contracted with the Research Foundation of The Ohio State University to conduct an "Analysis of Capital Formation and Technological Innovation at the Farm Level in LDC's," (hereafter referred to as the Capital Formation Project). USAID financial support covered the period July 1, 1969 through October 31, 1974.

Responsibility for the Capital Formation Project rested with the faculty of the Department of Agricultural Economics and Rural Sociology. Norman Rask was the research team leader throughout the life of the project. Richard Meyer served in Brazil as Project Chief of Party coordinating the extensive primary data collection and preliminary analysis efforts. Upon return to Columbus, he served as a member of the research team and with Norman Rask coordinated the writing of this monograph which constitutes the final report of the project. Members of the research team, responsible for specific areas of project research included Dale Adams, David Francis, Terry Glover, Donald Larson and Inderjit Singh.

The principal project objectives were: (1) To investigate and describe capital formation and utilization at the farm level, including the impact of technological change on the need for capital and on the capital formation process, and (2) To evaluate the implications and impact of selected policies designed to stimulate capital formation. Research was initiated in Brazil and was limited to that country when conditions prevented expanding the research to India as originally planned.

The farm firm was the principal unit of analysis for the investigation and was viewed as the primary building block in the chain of production and marketing firms involved in development of the agricultural sector. The research procedure was to discover, measure and better understand the impact on farm firm decisions of major changes in government programs, world market conditions, and new technology. Such analysis required extensive farm level data and little existed in Brazil. As a result, collaborative research arrangements were established with several Brazilian institutions. The institutions were selected because of their knowledge of particular agricultural regions and expertise to assist in designing survey instruments and in collecting the data through personal interviews with farmers.

Utilization of the research results and improvement of local research capabilities were also important considerations. Thus during the course of the research, several efforts were made to communicate and interpret preliminary results for several Brazilian agencies and professionals and the local USAID Mission through seminars, meetings, and informal contacts. Furthermore, students and faculty at each of the collaborating institutions were involved in questionnaire design, sampling, interviewing, data manipulation and analysis, and in all cases a set of data was retained by the local institution as part of data banks that were being developed.

In any project of this scope many individuals play key roles and many institutions make significant contributions. We would like to mention some of those without whom the research could not have been initiated or conducted. In USAID/Washington Dr. Erven Long was an

instrumental force in the project's inception and provided counsel throughout its duration. Members of the USAID/Washington Technical Assistance Bureau who assisted were: Dr. Douglas Caton, Dr. Larry Witt, Dr. Arthur Coutu, Dr. Harold Jensen and Dr. Lehman Fletcher. In the USAID Mission to Brazil, William Ellis, Mission Director; Michael N. Galli, Deputy Chief of ARDO; William Rodgers, Chief of ARDO; Dr. Harlan Davis, Agricultural Economist; Ralph Miller, Deputy Chief USAID/PASA; Dr. Stanley Krause, Agricultural Economist; and David Cohen, Program Office; as well as several other members of ARDO and the USAID staff provided much appreciated in-country support and administrative backstopping.

The Central Bank and the Ministry of Agriculture served as official contact with the Brazilian government and provided encouragement for the initial studies. In particular Ary Burger, Director of the Central Bank provided valuable assistance. The Instituto de Estudos e Pesquisas Economicas da Universidade Federal do Rio Grande do Sul was the first institution to conduct a survey under the Project. We owe a great deal to the foresight and effort of Mauricio Filchtiner, Director and Eli de Moraes Souza, Chief of the Agricultural Economics and Rural Sociology Section, in getting that survey underway and to several other staff and students that so successfully completed subsequent surveys and analysis on the data collected in that state. Closely related to this first effort, a survey was conducted in the state of Santa Catarina in conjunction with the Instituto de Pesquisas e Estudos Economicos da Universidade Federal de Santa Catarina with Carlos Jose Gevaerd playing an important role in that work. An old friend and distinguished col-

league, Paulo F. Cidade de Araujo, was instrumental in assisting with the research that was conducted in Ribeirao Preto in the state of Sao Paulo in 1970. Several other staff members and students in the Departamento de Ciencias Sociais Aplicadas of the Escola Superior de Agricultura "Luiz de Queiroz," including Joaquim J. de Camargo Engler who later became head of the department, were very supportive of the several economic and sociological studies conducted in Sao Paulo, and were patient and much appreciated counselors and hosts to the several OSU staff that resided in and passed through Piracicaba. The research conducted in the state of Minas Gerais owed much to Helio Tollini, then Director of the Instituto de Economia Rural, Universidade de Minas Gerais in Vicosa; H. Evan Drummond, Ph.D. student at Purdue University; and Julian H. Atkinson, Chief of Party of the Purdue-Vicosa Institution Building Project.

While analysis of the data collected in these four states moved forward, the USAID Mission contracted with Ohio State University to provide support to the newly created Escritorio de Analise Economica e Politica Agricola of the Ministry of Agriculture. The first director of that office, Francisco Vera Filho, and his successor, Alberto Veiga, along with Iby Pedroso organized a survey in the state of Ceara which collected data similar to the type collected in the four other states and made it available to the Project. Faustino de Albuquerque Sobrinho of the Universidade Federal do Ceara and Roger Fox of the University of Arizona - Ceara Institution Building Contract were instrumental in making local arrangements. The Banco do Nordeste contributed resources and staff to that survey as well.

Special appreciation is also extended to the many interviewers and drivers in each survey region that spent long, hot, dusty hours locating and interviewing farmers. The Brazilian farmers we interviewed displayed great patience and excellent cooperation by completing long interviews as accurately and thoroughly as possible. To them we extend special thanks.

The research that went into this report involved many staff and students at both OSU and several of the institutions just mentioned. The training of graduate students was an integral aspect of the Project, both in the U.S. and Brazilian Universities and will no doubt remain one of its chief benefits long after the findings of this research become outdated.

Clearly, the research findings summarized in this report emanate from a successful team effort. However, it is appropriate to recognize explicitly those individuals most directly responsible for major parts of the report.

Chapter 2	Douglas Graham
Chapter 3	Richard Meyer
Chapter 4	Norman Rask and Richard Meyer
Chapter 5	Norman Rask
Chapter 6	Terry Glover
Chapter 7	Donald Larson and Richard Meyer
Chapter 8	David Francis
Chapter 9	Donald Larson
Chapter 10	Dale Adams
Chapter 11	Inderjit Singh and Choong Yong Ahn

Chapters 1 & 12 Group Effort

In addition, significant contributions to the Project were made by several other OSU faculty members, in particular Bernard Erven, John Sitterley, Francis Walker and Kelso Wessel. Kelso Wessel was a member of the OSU Institution Building Project at ESALQ, Piracicaba, during the initial phase of data collection in the state of São Paulo. He worked with Brazilian faculty and graduate students on questionnaire construction, survey design, and supervision of some of the interviewing.

Mrs. June Blind and Ms. Malinda Brenner shared most of the typing of the final version and were ably assisted by several other secretaries in the department on earlier drafts. Ms. Barbara Durman, and Mrs. Margie Butz were responsible for data organization and storage. Mark Hinnebusch did much of the computer programming during the latter part of the Project. The Statistics Laboratory helped with figures, tables and overload typing, while Ms. Marilyn Chute served as a most capable administrative assistant throughout the life of the Project.

While more than forty graduate students have assisted with the processing and analysis of data and many have used portions of the data for their own M.S. theses and Ph.D. dissertations, 9 individuals who were then Ph.D. candidates, deserve special recognition for contributions to the overall Project: John Stitzlein, William Nelson, Gerald Nehman, Hagop Kayayan and Solon Guerrero each spent a year or more in Brazil assisting with data collection and processing; Roger Baur and Choong Yong Ahn assisted with data processing and analysis in Columbus. Joaquim J. de Camargo Engler and Iby Pedroso worked with their respective institutions in data collection and used part of the data for their dissertations.

We would also like to express appreciation to G. Edward Schuh and Pan A. Yotopoulos for highly useful detailed comments each made on an earlier draft of this report. J. K. McDermott also contributed a helpful reaction as did several people in Brazil during a round of seminars conducted in October, 1974. Of course, the authors assume sole responsibility for the contents. The views and opinions expressed do not necessarily represent the views of any persons or institutions in Brazil or the U.S. that collaborated with the Project.

David Boyne
Project Supervisor

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CHAPTER 7

THE ECONOMICS OF FERTILIZER USE

INTRODUCTION

Information presented in Chapter 3 showed how Brazilian farmers have expanded usage of chemical fertilizers, especially in the late 1960's and early 1970's. Several price and policy changes occurred just prior to this period of rapid expansion and undoubtedly affected farmer behavior regarding fertilizer adoption and use. This chapter reports on research which attempts to assess the impact of these several factors on the firm-household decision process, and how agricultural output was affected by fertilizer use.

Fertilizer use was selected for intensive study within the context of firm growth and capital formation for four basic reasons. First, it represents a form of technological change like mechanization, improved seeds, chemicals, etc. which can alter farm level consumption and investment behavior. Following the Schultzian thesis, the introduction of new technology can increase the rate of return on farm investments thereby providing farmers the incentive to forego consumption and/or channel more savings into on-farm investments. Secondly, the increased cash flow from profitable investments subsequently permits greater consumption and savings by farm households. Thirdly, fertilizer offers the possibility of being a form of technological change which is more farm size neutral in its impact than, say, mechanization which frequently is most applicable and

profitable for large farms. Recent experience in many developing countries however suggests that this has not necessarily proved to be the case. Finally, the distribution and marketing of fertilizer represents an important link between farm level growth and expansion of the farm input sector. As noted in Chapter 9, the fertilizer industry provides a source of nonfarm employment and income generation while the efficiency of that industry in providing a reliable supply of appropriately packaged inexpensive fertilizer nutrients affects farmer receptivity and use.

This chapter begins with a discussion of fertilizer production, distribution and use both in the aggregate and at the firm level. The next section shows how government policies, fertilizer/product price changes, and improvements in fertilizer distribution and marketing provided incentives for farmers to use more fertilizer. The results of a fertilizer demand study which tested the responsiveness of farmers to price changes are then reported. The following section reviews yield response as indicated by some fertilizer experimental trials and analysis of farm level data. The implications of these research results for future farm level growth in Brazil are given in the concluding section.

Four questions are addressed in this chapter:

1. How widespread is fertilizer use, and how far have Brazilian farmers proceeded in the adoption process?

2. What are the principal factors which explain increased fertilizer use in the country?

3. Has fertilizer use contributed to yield increases?

4. What can be expected regarding future levels of fertilizer use and the probable impact on agricultural production and farm growth?

FERTILIZER PRODUCTION AND USE IN BRAZIL

Fertilizer use was a modest 88.5 thousand metric tons of plant nutrients in Brazil in 1950 but exceeded 1.1 million tons in 1971, representing a compound annual growth rate of 16.0 percent [27]. Fertilizer use has experienced three rather distinct phases. The period 1948 to 1960 was a period of gradual expansion, followed by a period of stagnation from 1960 to 1966. Price and policy changes described below contributed to an annual growth rate in excess of 30 percent from 1966 to 1972 when it reached 1.7 million tons (Table 7-1). Macronutrient use per hectare of arable land increased from five to 36 kilograms between 1950 and 1971 [6]. This represents one of the highest use levels in South America, and Brazil's consumption grew from approximately 15 percent of total Latin American fertilizer use in 1966 to 35 percent in 1971 [6].

Domestic fertilizer production also rose sharply from 1964 to 1972, but domestic production as a proportion of total use actually declined from 42 to 22 percent. Nitrogen production rose from 14 to 21 percent of total use, but the proportion of phosphate production fell from 75 to 33 percent. No potash fertilizers are produced in the country. Total fertilizer imports rose to 1.3 million tons of nutrients by 1972, and in spite of international price decreases, the total annual import bill had risen to $U.S. 80 million by 1970 [5, p. 24].

Several fertilizer plants currently in various stages of planning and installation will eventually decrease dependency on imports. Potash will continue to be totally imported in the short-run, however, as commercial exploration of Brazilian deposits seems to be several years

TABLE 7-1

Brazil Fertilizer Use, Importation and Production 1964-1972

Year	NITROGEN			PHOSPHATE			POTASH			TOTAL		
	Apparent Use	Imports	Production	Apparent Use	Imports	Production	Apparent Use	Imports	Production	Apparent Use	Imports	Production
1964	50,808	43,565	7,243	135,052	34,113	100,939	69,564	69,564	---	255,424	147,242	108,182
1965	70,569	56,124	14,445	120,097	37,219	82,878	99,732	99,732	---	290,398	193,075	97,323
1966	71,134	64,734	6,400	116,648	32,559	84,089	93,337	93,337	---	281,119	190,630	90,489
1967	103,382	95,497	7,885	204,606	95,654	108,952	136,937	136,937	---	444,925	328,088	116,837
1968	144,320	135,028	9,292	273,094	105,611	122,483	184,295	184,295	---	601,709	469,934	131,775
1969	164,430	157,970	6,460	265,667	137,869	127,798	200,290	200,290	---	630,387	496,129	134,258
1970	275,936	255,575	20,361	415,938	246,540	169,398	306,692	306,692	---	998,566	808,807	189,759
1971	278,324	209,156	69,168	535,864	124,381	411,483	350,846	350,846	---	1,165,034	684,383	480,651
1972	411,605	323,112	88,493	874,935	585,658	289,277	459,984	459,984	---	1,746,524	1,368,754	377,700

SOURCE: ANDA as cited in [29].

off [7, p. 3]. Since several domestic plants use imported raw materials and others will not come into full production for several years, international fertilizer prices will continue to be important in determining the cost of Brazilian fertilizers.

The vast interregional differences in Brazilian agriculture noted in Chapter 3 are evident in fertilizer use [7]. The North and Northeast account for only 8 percent of all nutrient use, an amount which represents about 5.6 kilograms per hectare of cultivated land in the two regions. Approximately eighty-five percent is used on sugar cane, 10 percent on cocoa and 5 percent on other crops. The states of Santa Catarina and Rio Grande do Sul in the south use about 28 percent of the fertilizer at a rate of 46.6 kg/ha. of cultivated land. Approximately 78 percent is applied to the wheat-soybean rotation, 15 percent to rice and the remainder to other crops. The rest of the country accounts for 64 percent of the fertilizer, amounting to an average of 34.4 kg/ha. of cultivated land, but a large proportion of this is used in the state of Sao Paulo where average application rates are higher. Coffee, sugar cane, cotton, corn, cereals, and potatoes account for more than 80 percent of nutrient use in Central Brazil (Table 7-2). The heaviest rates of application are used on coffee, tomatoes, potatoes, vegetables, bananas and strawberries. Considering that only a fraction of total area planted is fertilized, the crops actually fertilized receive relatively high levels of application in this region.

The farm level data described in Chapter 4 were analyzed to determine how fertilizer use varied among farm sizes and agricultural regions. The findings were consistent with other sources cited above. A larger

TABLE 7-2

Nutrient Consumption in Central Brazil, a/ 1969

Crop	Area		Nutrient Use			NPK
	Planted	Fertilized	Total	Share	Rate	Ratios
	'000 ha		mt	%	kg/ha fert.	avg.
Coffee	2,460	195,000	126,535	29.7	648	1-0.5-1
Sugarcane	957	586,000	56,759	13.3	96	1-2-1.5
Cotton	1,127	446,000	53,473	12.5	119	1-1.8-1.3
Corn	5,261	235,000	38,750	9.1	164	1-3-1.5
Cereals	3,514	309,000	38,622	9.1	125	1-2.4-1
Potatoes	118	63,000	35,165	8.2	574	1-2.8-2.1
Citrus	141	98,000	20,058	4.7	204	1-1-1
Tomatoes	24	16,000	18,992	4.4	1,187	1-3.1-1.5
Banana	158	22,000	14,083	3.3	640	1-1-2.1
Vegetables	15	9,000	6,145	1.4	682	1-4-2
Peanuts	591	27,000	4,482	1.1	166	1-3-1
Onions	22	8,000	2,219	0.5	270	1-4-1
Strawberries	7	700	853	0.2	1,210	1-4-2
Other	2,728	89,300	10,626	2.5	118	1-2-1
Total	17,117	2,104,000	426,762	100		1-1.4-1.2 (avg.)

a/ The report from which these data were obtained apparently included in Central Brazil all the states which lie between Parana and the North and Northeast Region.

SOURCE: ANDA, as reported in (7).

proportion of farmers in Sao Paulo used fertilizer than in any other state where interviews were conducted (Table 7-3). Other analysis showed that by the 1969/70 agricultural year the adoption process was essentially complete in five of the nine Ribeirao Preto municipios, since all of the interviewed farmers used fertilizer. Including all farms in all municipios, many of which were cattle ranches, 87 percent of the farms were using fertilizer. In the same year, 55 percent of the farmers interviewed in Rio Grande do Sul and Santa Catarina used fertilizers and only 23 percent of the farmers interviewed in Minas Gerais. No fertilizer users were found in the survey of 132 farm owners and 123 sharecroppers in Ceara (Northeast Brazil) for the 1971/72 agricultural year.[1/] Intraregional differences are also evident in the case of Sao Paulo, where a smaller proportion of farmers in the Itapetininga region were fertilizer users compared to those in the more modern Ribeirao Preto region.

The rapid increase in aggregate fertilizer use is reflected in the results of two surveys conducted in Rio Grande do Sul and Santa Catarina. The first survey in 1965 showed that only 29 percent of the farmers used fertilizer, but the proportion had risen to 55 percent by 1969. It is interesting to note that the proportion of farmers using fertilizer approximately doubled in all farm size groups.

Although there is wide variation among regions in the proportion of farmers using fertilizer, there is a general tendency for the proportion of fertilizer users to increase as farm size increases. The only exception was in the Ribeirao Preto region, where many of the largest farms are

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1/ A 1967 study in several states of the Northeast also showed almost no farmers using fertilizer except for irrigated rise producers [33, p. 8-22].

TABLE 7-3

Percent of Brazil's Surveyed Farmers Using Fertilizer

Farm Size[a]	Region/Agricultural Year									
	Rio Grande do Sul/ Santa Catarina 1965		Rio Grande do Sul/ Santa Catarina 1969		Sao Paulo				Minas Gerais 1969/70	
					Ribeirao Preto 1969/70		Itapetininga 1970/71			
	No. of Farms	Percent Using Fertilizer	No. of Farms	Percent Using Fertilizer	No. of Farms	Percent Using Fertilizer	No. of Farms	Percent Using Fertilizer	No. of Farms	Percent Using Fertilizer
Small	527	22	418	39	45	96	78	55	25	20
Medium	202	36	183	67	73	94	36	64	62	15
Large	106	34	159	69	147	85	31	81	106	28
Very large	119	39	140	73	117	83	5	100	84	23
Total	954	29	900	55	382	87	150	64	277	23

a/ Farms were divided into the following strata based on total operating unit consisting of cultivated land, and natural and improved pasture:
Small - 4.9 to 19.9 hectares, medium - 20 to 49.9 hectares, Large - 50 to 199.9 hectares, and Very Large - over 200 hectares.

cattle ranches which have limited amounts of cultivated land, and pasture fertilization is not yet a widespread practice. Thus, it appears that fertilizer adoption is associated with farm size, and since much of the fertilizer is financed with agricultural credit, the distribution of credit as noted in Chapter 10 may be one of the explanations.

Two broad conclusions emerge from this data. First, fertilizer use has sharply expanded, especially after 1966. Second, there are wide intra- and inter- regional differences in fertilizer use. A high proportion of the fertilizer is used in the South, a larger proportion of large farmers use it compared to smaller farms, and its use is concentrated on a few crops.

The next section describes the changes in government policies, prices and fertilizer distribution which help explain the changes in fertilizer use which have occurred over time.

FERTILIZER POLICIES, PRICES AND DISTRIBUTION

Fertilizer Policies

Several of Brazil's fertilizer policies have been designed to increase fertilizer use by increasing the availability and reducing the cost of fertilizer to farmers. This has been accomplished through favorable treatment of imports, special credit for fertilizer purchases, and incentives for the domestic fertilizer industry. In the intense import substitution period of industrialization, exchange rate policies and tariffs were important in determining farm level fertilizer prices because imports provided most of the fertilizer used. Preferences were given to fertilizer imports during the 1947-53 period when quantitative import

controls were in effect. The multiple exchange rate system introduced in 1953 gave fertilizer a special rate until 1961. Federal and state sales tax exemptions for fertilizer were instituted in 1957-58, along with preferential rail freight rates and port fees to bring down fertilizer costs [34, p. 228].

The expansion in agricultural credit throughout the 1960's undoubtedly helped farmers acquire fertilizer, but after the creation of the Central Bank, additional special incentives were given through the creation of funds which tied credit to fertilizer purchases. FUNFERTIL (Fundo de Estimulo Financeiro ao Uso de Fertilizantes e Suplementos Minerais) was created in 1966 to finance interest and administrative costs on fertilizer loans for food crops which amounted to a 17 percent nominal rate. Because of the high inflation rates in Brazil during this period, the real rate of interest on these loans was still negative. The volume of this credit grew and it was estimated that in 1968 it financed approximately 75 percent of total fertilizer purchases [28, p. 37].

A second fund, FUNDAG (Fundo Especial de Desenvolvimento Agricola), superseded FUNFERTIL in 1970 with the objective of subsidizing credit costs for several modern inputs including fertilizer. A nominal interest rate of 7 percent was charged to the borrower and the remaining 10 percent was paid by the fund; however, the real rate of interest was once again negative. Additional credit incentives were granted beginning in February 1971 when the Central Bank required that banks give preference to farmers adopting integral finance plans including a minimum allocation of 15 percent of the loan for purchasing modern inputs. Loans which did not include this minimum could not be used by banks to satisfy their minimum lending

obligations to agriculture as set by law [5, p. 38-39]. This requirement undoubtedly led to the fact that in 1972 many banks would only make operating loans which met this criteria.[2/]

In 1965 the government took measures to accelerate domestic fertilizer production in order to reduce the rising foreign exchange bill for fertilizers. Import taxes on fertilizer used in domestic processing were reduced and the importation of equipment was facilitated. In mid-1970 additional incentives were given through import tax exemptions on manufacturing equipment not locally produced, increased credit for equipment purchases, and accelerated depreciation for investments in fertilizer production [5]. Import regulations were modified several times to strike a balance between providing adequate supplies and protecting domestic production. Recent regulations require mixing plants to purchase a minimum quantity of nutrients from domestic sources in return for the right to purchase imports. These regulations increased fertilizer prices to farmers because domestically produced fertilizer prices were normally much higher than import prices. The net effect of this protection of domestic industry is difficult to quantify, but Melo [25, p. 36] suggests that fertilizer prices could have been increased 10 to 20 percent over free market prices.

Fertilizer Distribution and Marketing

Another factor favoring increased fertilizer use has been the efforts of the private sector in the distribution, promotion and technical advice

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2/ Based on bank interviews conducted in Piracicaba by Charles L. Wright and in the Ribeirao Preto region by Zezuca Pereira da Silva.

on fertilizer use. Because of these efforts fertilizers are now readily available in almost every community in the commercial farming areas of Central and Southern Brazil. Fertilizer supplies are still limited, however, in subsistence farming regions, frontier areas, and the North and Northeast regions.

The fertilizer companies have been successful in organizing and expanding their marketing and distribution systems. The marketing system usually consists of salaried and/or commission salesman plus local dealers who work with regional sales managers in identifying the market area and setting sales quotas. Since the salesmen and dealers work on a commission basis, they aggressively seek out farmers in order to increase sales. These salesmen and dealers also provide a great deal of technical assistance and advice on fertilizer use and crop production practices generally. In at least some companies the salesmen generally have agronomy degrees and therefore should be technically well qualified to provide this assistance. However, in many instances they have little or no advanced training and are not well qualified to provide specific information on fertilization practices.

Although complete information is not available on the change in number of sales people, surveys conducted in the Ribeirao Preto region of Sao Paulo and the wheat-soybean region of Rio Grande do Sul indicate that the number of local salesmen increased rapidly in the last decade, with the largest increases since 1966. The number of dealers grew by nearly four times in the 1966 to 1970 period in each of these regions [27, p. 4; Chapter 9]. This rapid increase in number of dealers who work essentially full-time in fertilizer sales has been important in increasing the contacts made with farmers to encourage adoption.

In addition, company advertising through television, radio, billboards and pamphlets has increased the awareness of and technical knowledge about fertilizers. Several firms provide farmers with free soil analysis as part of their service and promotion activities. ANDA, the Brazilian Fertilizer Association, also promotes fertilizer use through advertising and locally conducted experimental fertilization trails.

Federal and state extension services have also included fertilizer promotion in their respective technical assistance programs. As noted in Chapter 3, however, these services have faced problems of high rural illiterary and lack of locally relevant research. Many of the smaller farms interviewed in this research considered that private firms rather than extension agents were more important sources of technical information (see Chapter 8).

Selected quality improvements in distribution have facilitated fertilizer use. The introduction of plastic bags and granulated materials has successfully solved the moisture absorption and hardening problem so common a few years ago. Secondly, the move toward concentrated fertilizer formulas has lowered distribution costs for mixed fertilizers.

In spite of these improvements, much remains to be done in reducing the cost of distribution. It was estimated that farm level fertilizer prices were approximately double C.I.F. import prices in 1972 (Appendix Table 7-1). Furthermore, the regression results presented in Chapter 9 which tested trends in gross marketing margins for some totally imported fertilizer materials such as potassium chloride indicate that these margins have increased in the 1948-72 period.

Fertilizer and Product Price Trends

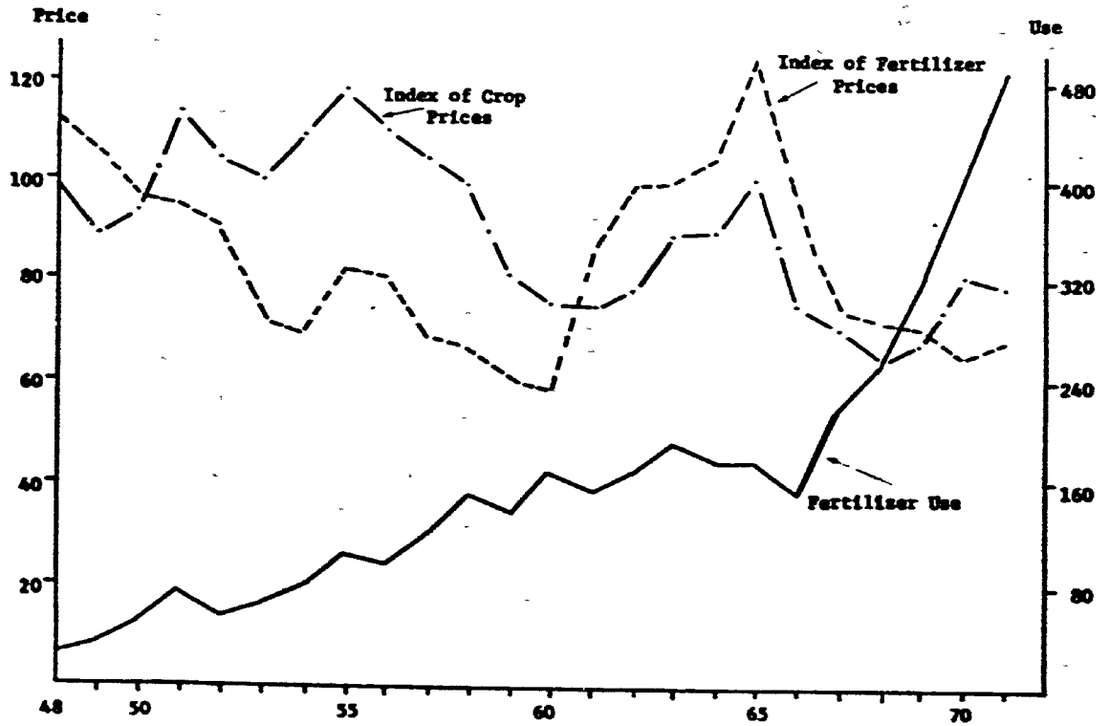
A third factor contributing to increased fertilizer use has been the secular trends in fertilizer prices. Government policies designed to maintain low fertilizer prices plus declines in international fertilizer prices have had a significant impact on fertilizer prices for farmers.

In Sao Paulo, for example, the index of deflated fertilizer prices declined 32 percent from 1948-52 to 1971 (Figure 7-1). There was a steady decline during the 1950's when favorable import policies were in effect. Prices increased considerably between 1960 and 1965, then fell drastically in 1966 and 1967, and continued to decline the rest of the decade. Prices began to rise in 1971, however, and recent reports suggest that 1974 prices are double those of 1973. The magnitude of these recent increases is similar to that which occurred in most countries of the world in the early 1970's. Prices of the individual fertilizer nutrients followed the same general trend in the 1948-71 period. Nitrogen prices decreased by 46 percent, phosphate prices by 29 percent and potash by 31 percent. Phosphate prices have experienced the least fluctuation while potash prices have undergone wide variation.

During this same period, real crop prices also declined but only 16 percent compared to the 32 percent decline in fertilizer prices. This improvement in the fertilizer/crop price ratio should have stimulated fertilizer use, and the more rapid decline in nitrogen prices should have contributed to a more rapid expansion in use of that nutrient. It should be recognized also that these fertilizer prices underestimate the real price for farmers that obtained concessional credit to finance fertilizer purchases.

FIGURE 7-1

Indices of Real Prices of Fertilizers and Crops and Fertilizer Use in the State of Sao Paulo, 1948-71. a/



a/ Index deflated by National Index "2" of the "Conjuntura Economica" Getulio Vargas Foudation (base: 1948-52 = 100) and use in 1,000 metric tons of macronutrients (N, P_2O_5, K_2O).

The trends in fertilizer use in Sao Paulo are consistent with the price trends. Use increased at a steady rate from 1948 to 1960 when fertilizer prices were declining. Fertilizer use reached a peak in 1963 and then decreased as fertilizer prices reached a new record high in 1965. Use then increased rapidly from 1966 to 1971 when fertilizer prices declined sharply.

DEMAND FOR FERTILIZER IN SAO PAULO

These several public and private efforts to stimulate fertilizer use and the rapid expansion which occurred, especially in the last 6 or 7 years, logically pose the questions: What is the relative importance of the factors which accounted for this rapid increase in demand? Has the increase in demand been largely due to price changes or to adoption of more fertilizer responsive varieties which have shifted the demand function upward and to the right? This section reports on empirical results with respect to the price issue, and the next section examines the role of fertilizer productivity in explaining fertilizer use.

An aggregate demand function for fertilizer in the state of Sao Paulo was specified and estimated to investigate factors affecting variations in fertilizer use. Sao Paulo was selected for this study because of the rapid changes in fertilizer prices and use which have occurred, and because the necessary data were more readily available and reliable.

The Models

A traditional demand model and the Nerlove adjustment model were

selected for this study.[3/] The demand function considers fertilizer use to be a function of the relevant product and input prices, area cultivated, crop yields and time.

The functional forms chosen for the estimation of the demand function were a linear equation and an equation linear in the logarithms of the variables; the former is not reported here because of its generally poorer fit.

Traditional Model

1. $Y_t = a_o + a_1X_{1t} + a_2X_{2t} + a_3X_{3(t-1)} + a_4X_{4(t-1)} + a_5X_{5t} + e_t$

Where Y = total consumption of N, P_2O_5, K_2O in kilograms

X_1 = index of deflated prices of fertilizers

X_2 = index of area cultivated in hectares

X_3 = index of crop yields lagged one year

X_4 = index of deflated crop prices lagged one year

X_5 = time in years

e = error term

The fertilizer and crop price variables in these demand functions have traditionally been handled in two ways. The first and most common method is a current or expected price ratio similar to that used by Griliches [12]. A second method used by Heady and Yeh [13] specifies separate variables for fertilizer and crop prices. The latter approach was adopted in this study because it does not impose the zero homogeneity condition predicted by economic theory. This approach is consistent

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3/ The demand functions were estimated directly from time series data by using the ordinary least squares method. Fertilizer prices in Brazil are generally considered to be "administered" with disequilibrium being expressed largely in seller's inventories. Thus, in the short-run price may be assumed to be predetermined.

with Krishna's [20] contention that the impact on fertilizer demand of a one percent increase in a crop price is not equivalent to a one percent decline in the price of fertilizer.

Area cultivated was included to determine its importance in explaining fertilizer use. The index of crop yields lagged one year is similar to that of lagged rice yields in Hsu's study in Taiwan and to cash income from farming lagged one year in Heady and Yeh's demand function for fertilizer [13, 17]. This variable was introduced as a proxy for net cash farm income since the latter was not available for the state of Sao Paulo. It attempts to measure the importance of the income or capital constraint on demand for fertilizer.

The time variable represents the farmers' increasing familiarity with and willingness to use chemical fertilizers.

Adjustment Model

(2) $Y^*_t = a_o + a_1X_{1t} + a_2X_{2t} + a_3X_{3(t-1)} + a_4X_{4(t-1)} + e_t$

(3) $Y_t - Y_{t-1} = b\ (Y^*_t - Y_{t-1})\quad o<b<1$

where Y^* = desired or long run equilibrium level of fertilizer use; a_1 = long run coefficient of demand for fertilizer (or elasticity of demand if the variables are in logarithms); and b = adjustment coefficient.

This is a Nerlove adjustment model, used by Griliches and others [11, 12, 16]. It assumes that the long run equilibrium demand for fertilizers is a function of the specified variables and that the change in fertilizer use between periods takes place in proportion "b" to the disequilibrium $(Y^*_t - Y_{t-1})$.

Substituting equation 2 in 3 and solving for Y_t, one obtains:

(4) $Y_t = a_o\, b + a_1 b\, X_{1t} + a_2\, b\, X_{2t} + a_3 b X_{3(t-1)} + a_4 b X_{4(t-1)} + (1-b)\, Y_{t-1} + b\, e_t$

When the variables are in logarithms, the short run elasticity of demand for fertilizer with respect to its price is given by the estimate of $a_1 b$ and the long run elasticity is given by $\frac{a_1 b}{1 - (1-b)}$.

This is the equation estimated in the following sections for the period 1948-1971, and for two sub-periods 1948-1960 and 1966-1971. The sub-period estimations were made because the total period included the years 1961-1965 when inflation in Brazil reached its highest levels and perhaps adversely affected the price relationships in many sectors of the economy including agriculture. It was a period of great political and economic instability, as noted in Chapter 2.

The Data and The Variables

The basic data used in this study were obtained from the Institute of Agricultural Economics of the Secretary of Agriculture of the state of Sao Paulo, an agency which collects, processes and publishes economic information for the agricultural sector of Sao Paulo. All variables expressed as indices have as their base period 1948-52 = 100.

Fertilizer consumption for the state of Sao Paulo was measured in thousands of tons of the three basic macronutrients (N, P_2O_5, K_2O). Since data on carry-over stocks from year to year are not available, this actually refers to apparent total use.

The fertilizer price index refers to average sales price to farmers of the principal fertilizers in the city of Sao Paulo, weighted annually by the relationship among the three macronutrients (N, P_2O_5, K_2O). The

fertilizers included in this price index were sodium nitrate, ammonium sulphate, calcium nitrate, single and triple superphosphate, rock phosphate and potassium chloride.

The area cultivated index was calculated from the hectares planted to the 17 main crops of Sao Paulo which according to Table 7-2 account for almost all fertilizer consumption. The products included were cotton, potatoes, sugar cane, silkworm, oranges, soybeans, tomatoes, peanuts, coffee, tea, bananas, onions, manioc, corn, rice, beans and castor beans.

The index of crop yields for these same 17 crops was obtained from the annual physical yield data using a Paasche index with a weighted moving average of the area cultivated. The crop prices index for these 17 products represents average annual prices received by farmers for crop products in the state, using the Laspeyres method weighted by the average production in the five-year period 1956-1960.

Regression Results

The regression results for the models of each period are given in Tables 7-4, 7-5 and 7-6 respectively.[4/] The "best" results in terms of statistical significance, expected signs and stability of values are obtained with the distributed lag model.

For the period 1949-71, the signs for the price variable are consistent in the traditional model, and the coefficients are statistically significant; however, their values change considerably as other variables are included in the regression (See Table 7-4). Another problem of

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4/ Not all the equations adjusted and variables tested are included here because of space limitations. These are available in Cibantos [3].

TABLE 7-4

Regression Results: Demand for Fertilizers in the State of Sao Paulo, 1949-71

	Constant Term	X_1	X_2	X_3	X_4	X_5	Y_{t-1}	R^2	D-W
Traditional Model (in Logs)									
Equation I.....	4,305	-1.136** (1.68)	-	-	-	-	-	0.120	0.14
Equation II.....	9,169	-1,119**** (2.90)	6.518**** (6.64)	-	-	-	-	0.726	0.84
Equation III.....	0,014	-0.400** (1.43)	1.099 (0.93)	-	-	0.658**** (5.44)	-	0.893	0.51
Adjustment Model (in Logs)									
Equation IV.....	0,732	-0.248** (1.35)	-	-	-	-	0.903**** (16.99)	0.943	2.04
Equation V.....	0,531	-0.322*** (1.60)	0.753 (0.94)	-	-	-	0.834**** (8.75)	0.942	-
Equation VI.....	0,351	-0.242* (1.30)	-	0.203 (0.68)	-	-	0.883**** (14.44)	0.944	2.19
Equation VII.....	1,116	-0.240* (1.29)	-	-	0.177 (0.69)	-	0.878**** (13.52)	0.944	2.20

Note: Dependent Variable: Y = Apparent consumption of fertilizers in terms of macronutrients (N-P-K); X_1 = real average price of fertilizers; X_2 = Area cultivated of the 17 principal crops; X_3 = Average physical yields of these 17 crops lagged one year; X_4 = General index of real prices received by Sao Paulo farmers lagged one year; X_5 = Trend (1948 = 0), and Y_{t-1} = the same as Y lagged one year. Figures in parentheses are the "t" values. Significance levels: **** to 5% or less; *** to 10%; ** to 20%; and * to 30%.

equations I to III of the traditional model is the low value of "d", the Durbin-Watson statistic, indicating the existence of serial correlation in the residuals.

The price elasticity of demand estimated from equation II of the traditional model is -1.12 and is significant at the 5% level. This equation also shows an elasticity of area cultivated equal to 6.52. The latter variable, however, is highly correlated with the time trend and loses all significance when the trend variable is introduced. The strong influence of the trend variable in these results parallels those of Knight for Rio Grande do Sul and Hsu for Taiwan [19, 17].

The adjustment model provides the "best" overall results for the 1949-51 period. The equations have the expected signs on the variables, the values are stable and the coefficients are statistically significant. The value of "d" does not indicate the presence of serial correlation in the residuals.[5/]

The own price elasticity of demand from Equation V equals -0.32 in the short run, the adjustment coefficient "b" equals 0.17 and the long run price elasticity is -1.94. An adjustment coefficient of 0.17 indicates that approximately 17 percent of the difference between actual and desired consumption is completed within one year. The adjustment coefficient in equations LV-VII averages 0.12, which is about half the value that Griliches

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5/ As Griliches [11, 12] indicated the Durbin Watson statistic is not a very powerful test in the presence of a lagged dependent variable.

found for the U.S.[6/] The short run elasticity of -0.32 is less than the -0.5 for the Griliches study; however, the long run elasticities are approximately equal [11]. The elasticity of -1.12 in the traditional model is about half way between the short run and long run elasticities estimated with the dynamic adjustment model.

The regression results for the first subregion, 1949-1960, are shown in Table 7-5 for the traditional and adjustment models. They are different from those of Table 7-4 because the results of the adjustment model are less satisfactory than those of the traditional model. This is because the price variable is only significant at the 30 percent level in three equations and is not significant in the fourth. The sign of the price coefficient continues to be consistent; however, the value of the price elasticity is less stable. The short run price elasticity ranges from -0.39 to -0.76 which is much higher than for the entire period. Likewise, the adjustment coefficient "b" is also higher ranging from 0.35 to 0.39. The long run price elasticity ranges from -1.74 in equation IV to -1.95 in equation VI. Thus, results for this subperiod indicate more price elastic short run and slightly less price elastic long run demand than that estimated for the entire period.

Results from the 1966-71 subperiod (Table 7-6) are generally better than for the entire period 1949-71 or the subperiod 1949-60 for both the traditional model as well as the adjustment model. The adjustment model

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6/ It is recognized that failure to include a trend variable in the distributing lag model may bias downward the adjustment coefficient when the lagged dependent variable and the trend are highly correlated as they are in this study. However, Melo's results [25] for Sao Paulo which used the same adjustment model with a trend variable indicated an adjustment coefficient of 0.08 to 0.12 which is equal to or less than the coefficients reported here.

TABLE 7-5

Regression Results: Demand for Fertilizers in the State of Sao Paulo 1949-60

	Constant Term	X_1	X_2	X_3	X_4	X_5	Y_{t-1}	R^2
Traditional Model (in logs)								
Equation I.....	6,106	-2,210**** (5,64)	-	-	-	-	-	0,762
Equation II.....	0,663	-1,677**** (3,09)	2,175** (1,36)	-	-	-	-	0,802
Equation III.....	0,437	-0,070 (0,12)	0,587 (0,50)	-	-	0,586**** (3,50)	-	0,922
Adjustment Model (in logs)								
Equation IV.....	1,879	-0,608* (1,21)	-	-	-	-	0,646**** (3,73)	0,906
Equation V.....	1,23	-0,391 (0,75)	1,365* (1,25)	-	-	-	0,601**** (3,49)	0,923
Equation VI.....	2,553	-0,701* (1,24)	-	0,227 (0,43)	-	-	0,621**** (3,26)	0,908
Equation VII.....	0,173	-0,758* (1,30)	-	-	0,252 (0,56)	-	0,610**** (3,21)	0,910

Note: Dependent Variable: Y = Apparent consumption of fertilizers in terms of macronutrients (N-P-K): X_1 = Real average price of fertilizers; X_2 = Area cultivated of the 17 principal crops; X_3 = Average physical yields of these 17 crops lagged one year; X_4 = General index of real prices received by Sao Paulo farmers lagged one year; X_5 = Trend (1948 = 0), and Y_{t-1} = the same as Y lagged one year. Figures in parentheses are the "t" values. Significance levels: **** to 5% or less, *** to 10%, ** to 20%, * to 30%.

in the 1966-71 sub-period has price coefficients significant at the 5 percent level, with short run price elasticities ranging from -1.60 to -1.69, and long run price elasticities ranging from -4.48 to -5.28.[7/] The adjustment coefficient "b" for this period varies from 0.32 to 0.37; these values are about the same as those for the 1949-60 sub-period. None of the other variables tested such as area cultivated, crop yields, or crop prices were significant in this model. Thus the demand for fertilizer in this sub-period is considerably more price elastic in both the short and long run than that observed for the 1949-71 period or the 1949-60 sub-period.

We have seen from the above results that the adjustment model provides a better fit of the demand function for fertilizer in the state of Sao Paulo than does the traditional model. The results indicate that price is important in explaining the demand for fertilizer and that Paulista farmers are quite responsive to changes in the prices of their inputs. Even though the elasticities are quite high, the adjustment coefficient is low. Among the other variables tested only area cultivated had some statistical significance; crop prices received and crop yields were generally not significant.

The price elasticity of demand for fertilizers from equation V is inelastic in the short run and elastic in the long run, -0.32 and -1.94, respectively, for the entire period. It appears, however, as though the demand for fertilizers has changed structurally between the 1949-60 sub-

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7/ Due to a limited number of degrees of freedom, the results for this subperiod must be treated with caution.

TABLE 7-6

Regressions Results: Demand for Fertilizers in the State of Sao Paulo 1966-71.

Constant Term	X_1	X_2	X_3	X_4	X_5	Y_{t-1}	R^2
Traditional Model (in logs)							
Equation I..... 7,814	-2,865**** (4,07)	-	-	-	-	-	0,806
Equation II..... 10,399	-2,379**** (3,45)	2,838** (1,51)	-	-	-	-	0,890
Equation III..... 2,18	-0,41* (1,62)	-	-	-	4,11**** (11,28)	-	0,990
Adjustment Model (in logs)							
Equation IV..... 3,849	-1,599**** (4,92)	-	-	-	-	0,671**** (5,68)	0,984
Equation V..... 3,062	-1,613**** (4,19)	0,444 (0,40)	-	-	-	0,634**** (3,52)	0,981
Equation VI..... 3,261	-1,694**** (3,97)	-	0,359 (0,47)	-	-	0,676**** (4,92)	0,985
Equation VII..... 0,362	-1,660**** (4,19)	-	-	0,244 (0,48)	-	0,626**** (3,80)	0,985

Note: Dependent Variable: Y = Apparent consumption of fertilizers in terms of macronutrients (N-P-K); X_1 = real average price of fertilizers; X_2 = Area cultivated of the 17 principal crops; X_3 = Average physical yields of these 17 crops lagged one year; X_4 = General index of real prices received by Sao Paulo farmers lagged one year; X_5 = Trend (1948 = 0), and Y_{t-1} = the same as Y lagged one year. Figures in parentheses are the "t" values. Significance levels: **** to 5% or less, *** to 10%, ** to 20%, * to 30%.

period and the 1966-70 subperiod, perhaps due to greater political and economic stability, more stable agricultural prices and government policies specifically designed to increase the use of modern inputs. The short run price elasticity of Equation V increased from about -0.39 in the first subperiod to -1.61 in the latter, and the long run price elasticity increased from -0.98 to -4.41, respectively. Thus, demand for fertilizer has become more price elastic in recent years: for any given percentage increase in the price of fertilizer, farmers will make a more than proportional reduction in the quantity used, other things unchanged. This result, however, must be interpreted with caution because of the limited number of observations in the second subperiod. In addition, the coefficient of the price variable could be biased owing to data limitations which did not permit inclusion of a credit variable. Additional research a few years hence will be able to measure the influence of credit.

Theoretically, the elasticity of demand for a factor of production depends upon the availability of good substitutes; the greater the elasticity of substitution between two factors of production such as land and fertilizer, the greater will be the price elasticity of demand [14]. Research conducted by Heady and Tweeten [14] indicates that the elasticity of substitution between factors of production in U.S. agriculture has been quite high. Non-farm capital inputs have been substituted for farm capital inputs at relatively high rates. The extent of this substitution was caused primarily by technological improvements and changing relative factor prices. Additional research is needed in the case of Sao Paulo to determine these elasticities of substitution and how they are changing over time. Technological improvements which substitute for fertilizer will increase

the price elasticity of demand for fertilizer. Other innovations such as the introduction of new crop varieties that simply shift the demand for fertilizer to the right without changing its slope will cause the fertilizer demand elasticity to decrease [14, p. 143].

The low adjustment coefficient and the rather large difference between short run and long run elasticities of demand in these equations implies that some rigidities exist in the adjustment process. Although farmers are price responsive, they are not adjusting as rapidly and as fully in a given year as might be expected with the rather large price changes which have been observed.

The factors which influence this coefficient of adjustment have been the subject of much discussion in fertilizer demand studies, especially those of Griliches [12] and Heady and Tweeten [14]. Additional research, however, is needed to clarify the impact which these factors have on the adjustment process.

Timmer [35] in a recent review of this issue indicated that some of the main factors influencing the adjustment coefficient are risk, uncertainty and knowledge about fertilizer use, and the nature of the underlying yield response function. The risk and uncertainty associated with price variability, yield variability, etc. may be far different in Brazil than in most developed countries, causing farmers to adjust more slowly to a given level of price changes. Secondly, farmers who have had more experience with fertilizer use and who have high use levels could be expected to adjust more rapidly to price changes. Compared to many developed countries, Sao Paulo is a relatively low and recent fertilizer using area, so farmers cannot be expected to adjust rapidly to price changes [12].

Finally, the nature of the yield response function is important in determining the rate of adjustment. A relatively flat fertilizer response function implies, ceteris paribus, relatively large changes in fertilizer use for small changes in price while the steeper more rounded function implies, ceteris paribus, relatively smaller changes. According to Timmer [35, p. 22]: "Areas of long-standing fertilizer use can be expected to adjust fairly quickly, but the response will be fairly small if they are near optimum levels of use. Areas where use is more recent will be slower to react, but the magnitude of change is likely to be large because they are still on the steep part of their response function." Thus, the nature of the response function may help explain the adjustment process, and that issue is treated in the next section.

YIELD RESPONSE TO FERTILIZER

Giver the experience of developed countries and the Green Revolution impact in developing countries, we are accustomed to automatically associate fertilizer use with yield increases. Yet it is now becoming clear that this is not always the case, and in fact considerable agronomic research may be required to develop and adapt high response seed varieties and associated fertilization practices. Furthermore, with fertilizer/product price ratios that exist in some countries, modest response levels may not cover fertilizer costs if normal yield variability and risks are taken into account. The empirical results which follow suggest that yield response may be limited in Brazil, and the existence of a low profile response function would help explain the lag in farm response to the price changes noted above. The apparent lack of yield response needs to be intrepreted with caution. U.S. research has also encountered diffi ities

in getting reliable results to explain yield response [16].

Experimental Results

The first indication that yield response is uncertain is found in the mixed results reported from experimental fertilizer trials. Trials for some crops in some regions have produced favorable response [1, 10, 21, 32]. Other experiments, however, have produced little response, while still others have shown a great deal of variability from one set of trials to another [15, 24]. On a comparative level, new Brazilian wheat and rice varieties showed considerably less response than Indian wheat and Philippine rice varieties at comparable levels of fertilization [19].[8/]

When economic analysis has been conducted on the experimental data, wide year to year fluctuations in factor/product price ratios produce highly variable optimum use levels and complicate the task of making generalized fertilizer recommendations [2, 36]. Regional climatic conditions also affect results. One researcher concluded that plant diseases in the humid coastal region of the Northeast and uncertain rainfall in the interior made sugar cane the only crop on which fertilizer could be profitably used [9].

One of the chief difficulties with interpreting these results is that the experimentation has not always been conducted in a highly structured

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8/ It should be noted that much of the emphasis in Brazilian wheat research has been directed toward reducing the risk of losses through disease, and only recently has research expanded on fertilization. For a discussion of the impact of this research see [4].

and controlled manner,[9/] and there has been little interaction between agronomists and economists to obtain necessary data for economic research [2]. Little research has been done on yield response in actual farming conditions in order to determine the extent to which experimental results are dependent on control of other inputs.

Farm Level Yield Response

This section reviews the analysis of some of the farm level data to assess fertilizer response as reported by farmers. The Ribeirao Preto region of Sao Paulo was selected for this study because, as was noted above, farmers were well into the adoption process. Research was first conducted by Nelson using data for the 1969/70 agricultural year from 174 farms specializing in annual crop production [28]. Later Wright conducted essentially the same analysis for 120 of the same farms using data for the 1971/72 agricultural year [37]. Both studies analyzed fertilizer use on dryland rice, corn, cotton and soybeans.

Almost all the sample farms used fertilizer both years, but only one third of the farmers analyzed their soil in the preceding two years and only two-thirds used lime within the past five years. Fertilizer use was quite high as compared to the regional averages indicated above. Average use levels ranged from a low of 50 kilograms per hectare on rice to a high of 140 kilograms on cotton (Table 7-7). Even so, the first reaction of U.S. trained agronomists is that these levels are low for such porous, tropical soils, and heavy rainfall after application could leach away

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9/ There are allegations that some trials which show little or no fertilizer response are never reported.

most of the nutrients. Between the two years, average levels of fertilization declined slightly for rice and soybeans, and there was a 2 kg./ha. decline for soybeans, but a 10 kg./ha. increase for corn.

Table 7-7 also shows that current average usage was above minimum statewide recommendations made for "new" soils for all crops except rice. For just those farms that fertilized rice, the average amount of fertilizer applied was close to minimum recommendations. Actual usage on three of the crops, however, was 50 percent of the maximum which was recommended for "medium" and "tired" soils. Considering the individual nutrients, it can be seen that potash use consistently exceeded the minimum, phosphate was always below and nitrogen use exceeded the minimum for 2 of the 4 crops.

Crop yields were above state averages both years. Although yields varied between the two years, no distinct pattern emerged for any crop across municipios or size strata of producers. Climatic conditions were generally good both years and should not have been an important factor in affecting average yields even though some individual farmers may have been affected by weather.

Cobb-Douglas and quadratic functions were used to estimate yield response in both studies. The conclusions were essentially the same, and only the results with the Cobb-Douglas model using 1971/72 data are reported here.[10/] Due to the limited variation in formulas and resulting multicolinearity, attempts to analyze yield response to individual nutrients had to be eliminated. Placing the highly corre-

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10/ A detailed description of the models and results are found in [35].

TABLE 7-7

Recommended and Actual Use of Fertilizer 1969/70 and 1971/72 Agricultural Year

Nutrient and Crop	Recommendation Kg/ha[a]	Level Used on Sample Farms		Usage in 1971/72 As A Percent of Recommendation	
		1969/70[b]	1971/72[c]	Minimum	Maximum
Corn					
(1) N	9-71	14	17	191	25
(2) P	45-90	33	36	80	40
(3) K	9-18	21	25	273	136
Total	63-179	68	78	124	44
Cotton					
(1) N	12-66	18	33	279	51
(2) P	60-120	76	54	90	45
(3) K	12-120	47	50	417	42
Total	84-306	141	138	164	45
Rice[d]					
(1) N	12	7	10	83	--
(2) P	60	31	24	41	--
(3) K	12	13	15	128	--
Total	84	51	50	59	--
Soybeans					
(1) N	9-12	9	6	64	48
(2) P	45-60	46	39	87	66
(3) K	9-60	33	21	236	36
Total	63-132	88	67	105	50

a/ ANDA, Manual de Adubacao, Sao Paulo: Editora Ave Maria, Ltda., 1971, pp. 176-183. Numbers rounded to nearest integer.
b/ [28, p. 59]. Numbers rounded to nearest integer.
c/ [37, p. 58]. Mean of rates of application on the sample farm including the cases of zero usage for rice. Numbers rounded to nearest integer.
d/ No maximum recommendation was made for dryland rice, the type encountered in the region.

lated nutrient variables N, P, and K in the same regression produced large errors in the estimation of the parameters.[11/] Typically, two of the estimated coefficients and "t" tests would have approximately the same magnitudes but opposite signs. The third variable would be near zero with the sign opposite to the estimated coefficient with the largest absolute value. Since levels of fertilization varied widely, however, regressions were used to test yield response to aggregate fertilizer use, liming, and the traditional inputs of capital and labor.

The variables were defined as follows for the Cobb-Douglas function:

Y = Yield in units of 60 kg/alqueire for corn, rice and soybeans, and 15 kg/alqueire for cotton (alqueire = 2.42 hectares).

X_1 = Number of alqueires of land in the specific crop. This variable was included to permit an evaluation of association between yields and farm size or specialization.

X_2 = Man-days of labor used per alqueire on the specific crop

X_3 = Number of kilograms of lime applied per alqueire.

X_4 = Number of kilograms of nutrients (N, P_2O_5 and K_2O) applied per alqueire.

X_5 = Cruzeiros of capital per alqueire. This variable includes actual expenditures on seed, insecticides etc., plus 12% of the value of machinery inventories.

11/ Such results in the presence of high multicolinearity are described by J. Johnston, Econometric Methods, New York: McGraw-Hill Book Company, 1972 (2nd edition), pp. 160-169.

All variables except (X_1) were hypothesized to have positive effects on yields. One tailed "t" tests were therefore used for X_2 through X_5 and a two tailed test for X_1.

The results are given in Table 7-8. The "F" test for the regressions was significant only in the case of cotton. The adjusted coefficient of determination ($\bar{R}^2$) was low for corn and cotton, and negative for rice and soybeans. The estimated coefficient for fertilizer nutrients was not significant in any case. Capital was the only variable whose estimate was statistically significant for more than one crop (corn and cotton). Several other formulations of both the Cobb-Douglas and quadratic models were tried including variables for location, soil testing, timing of fertilizer applications, and plant spacing. None of the estimated coefficients were statistically different from zero.

The general conclusion is that these models failed to explain yield variations of annual crops. This suggests that uncontrolled and perhaps even random effects determine yields more than the variables included in the equations. It is possible that the residual effect of increasing or maintaining soil fertility may not have been picked up by the models, or the response may have been hidden by initial variations in soil fertility or other factors. Whatever the reason, the yield response was not strong enough to override the effects of other variables in these models.

These results provide some insights into why average fertilizer application rates did not undergo more rapid change between the two years, and why a relatively low coefficient of adjustment was estimated in the demand study reported above. As noted in Chapter 4, there has been a general shift from coffee to annual crops in this region. Al-

TABLE 7-8

Cobb-Douglas Regression Estimates for Annual Crop Yields
Ribeirao Preto Region
1971/72 Agricultural Year

Variable	Crop			
	Corn	Cotton	Rice	Soybeans
Constant	1.26 (5.00)a/	0.225 (0.39)	1.34 (4.25)	1.66 (0.81)
Land	0.044 (1.07)	0.129 (2.12)b/	-0.010 (-0.14)	0.066 (0.96)
Labor/alq.	0.109 (1.40)	0.317 (2.53)b/	-0.034 (-0.39)	-0.045 (-0.50)
Lime/alq.	0.015 (0.97)	0.007 (0.42)	-0.035 (-1.13)	0.009 (0.62)
Nutrients/alq.	0.032 (0.52)	0.044 (0.27)	0.031 (1.07)	0.074 (0.57)
Capital/alq.	0.187 (2.04)b/	0.428 (2.82)b/	0.149 (1.35)	-0.011 (-0.06)
R^2	0.16	0.37	0.08	0.06
$\bar{R}^2$	0.09	0.28	-0.02	-0.10
F	2.22	4.37	0.78	0.38
N	66	43	53	35

a/ Values for the t-statistic are in parentheses

b/ Significantly different from zero at the 5 percent level.

though it was one of the first regions to use high levels of fertilizer, the farmers have probably not had that much opportunity to identify the yield response function for specific crops on their farms. Furthermore, the year to year variation in yields on an individual farm due to other factors such as weather, cropping patterns, rotations, etc. may be so great that it is difficult if not impossible to clearly observe the effect of fertilizer applications. Thus, when weather and product price uncertainties are taken into account, it would be understandable why farmers might not make rapid changes in fertilizer use in response to price changes. Additional rigidities are built in through the credit system when access to credit is tied to fertilizer purchases. Finally, the lack of locale specific fertilizer experiments means that farmers must rely largely on their own experience and the recommendations of the fertilizer dealers when deciding upon fertilizer rates and formulas. In such a situation, it would be logical to expect relatively fixed ratios between productive inputs, and fertilizer use would be largely a question of adopting fertilizer as part of a production package rather than adjusting intensity of usage to changes in factor and product prices.

FERTILIZER USE AND FARM LEVEL GROWTH

Four major points have emerged in this chapter.

1. Fertilizer use has sharply expanded in Brazil but it is still largely concentrated in the southern half of the country, and a greater proportion of large farmers use it compared to small farmers. Average application rates in the South and in Sao Paulo are high compared to Latin America but low compared to developed countries.

2. Changes in price and credit policies, and improvements in private sector marketing and distribution have been aimed at increasing the availability and reducing the cost of fertilizer, and these efforts have been directly related to increased usage.

3. Sao Paulo farmers are responsive to fertilizer price changes, but the large difference between the short and long term price elasticities suggests a significant adjustment lag to such changes.

4. Farm level annual crop yields as reported in the farm interviews could not be explained by fertilization. Experimental trials and these farm level results suggest that yield response is low in Brazil although much additional research is required before this could be concluded with greater confidence. If true, low response would help explain the adjustment lag.

Admittedly much work must be done before we have a complete understanding of the impact of fertilizer policies on farm level growth and capital formation. Yet these results provide some additional insights into the growth process.

The first major implication concerns farmer behavior. A fundamental question frequently raised regarding agricultural modernization is the magnitude of economic returns required to induce farmers to switch from traditional to modern techniques. The case of fertilizer in Brazil suggests that the return can be limited and even doubtful but adoption can still be accelerated if farmers are stimulated by comprehensive market and policy forces. Fertilizer price reductions brought about through international price declines, governmental policies, and the marketing system made it a more attractive input. Credit policies helped relax farmers' financial constraints permitting larger expenditures for purchased inputs

generally, while tying credit to fertilizer purchases represented an attempt to influence how credit was used. Finally, extension agents and especially fertilizer companies aggressively promoted fertilizer, frequently made credit sales and helped farmers arrange formal credit. Thus fertilizer spread to more and more farmers even though it is not clear if they clearly perceived great economic benefits before adoption, or if in fact significant economic returns were realized.

These results may also be helpful in explaining the results obtained in other chapters. The small changes in average fertilizer application rates on these Sao Paulo farms, as noted earlier in this chapter, appear to be consistent with both the fertilizer demand study and the yield response study. If fertilizer response on other crops and in other regions is as doubtful as that found here, then it would be logical to find 1) that fertilizer users would be slow to increase application rates, and 2) thus, increasing total consumption would be attributed primarily to increased adoption rather than intensified usage. Since most of the large crop farms in the southern part of Brazil are already using fertilizer, then future adoption will occur largely on smaller farms and in other regions of the country. Furthermore, if other yield increasing techniques such as improved seed and liming have no greater impact on land productivity, (as appears to be the case in the production functions in Chapter 6) then in order to increase incomes, farmers would have to rely primarily on improvements in labor productivity. The fastest way to achieve such productivity increases is, undoubtedly, through mechanization, first of tillage and cultivation operations and later of harvesting. Through mechanization farmers can often change enterprises, engage in more in-

tensive agriculture such as in wheat-soybean double cropping, and yet save enough labor to perhaps even operate more land. Per unit production costs may rise but this can be more than offset by an increase in number of units produced per unit of labor input. Thus, expansion at the extensive margin is the logical growth path if yield increases are limited due to unavailability of improved biological technology.

Brazil faces a limit to continual expansion of the agricultural frontier and that limit has already been reached in some states. Furthermore, the research reported in this volume helps explain the process and causes of an increasing bimodel distribution of land: large mechanized farms vs. small subsistent units. One way to help alleviate this pattern and reduce some of the need for rapid frontier expansion to meet domestic demand for agricultural products and capitalize on foreign markets is to further emphasize agricultural research leading to yield increasing technology. Past research concentrated on developing varieties with reasonably good yield potential for new soils. This approach was logical when chemical fertilizers were expensive, government price policies uncertain, land was cheap, and natural soil fertility fairly high. Current conditions require a more systematic approach to the development of indigeneous research capabilities to adopt and create local specific practices and technologies. Fertilizer response ranks high on the research agenda.

APPENDIX TABLE 7-1

Average Cost Components of Fertilizer in Brazil

Cost (1972)	Urea	Percent of Sales Price F.O.B. Plant	DAP	Percent of Sales Price F.O.B. Plant
		(US $)		
C.I.F. - Santoes, Recife, or Porto Alegre	50.00	45	75.00	49
Exchange cost 1.09 x C.I.F.	54.50	4.2	81.75	4.4
Port cost $7.42/ton	61.92	6.7	89.17	4.9
Transportation - port to plant 4.20/ton	66.12	3.8	93.37	2.8
Plant cost - mixing, bagging and loading[a] 5.88/ton	72.00	5.3	99.25	3.9
Gross margin - 35% of selling price F.O.B. plant	38.76	35	53.44	35
Composed of				
Agent's commissions - 6-8%				
Cash discount 3-5%				
Administrative overhead 10-13%				
Depreciation 2-5%				
Residual net margin 14-4%				
Price F.O.B. plant	110.76	100	152.69	100
Truck transportation plant to farm 3.50-6.00/ton				
Retail cost to farmer	114-117/ton		156-159/ton	

a/ While this summary is for urea and DAP, the reader should keep in mind that the farmer most likely will buy these materials mixed in N-P-K blends.

SOURCE: (7, p. 11)

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