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MODELLING THE USE AND ADOPTION OF TECHNOLOGIES BY UPLAND RICE AND SOYBEAN FARMERS IN CENTRAL-WEST BRAZIL

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MODELLING THE USE AND ADOPTION OF TECHNOLOGIES

BY UPLAND RICE AND SOYBEAN FARMERS

IN CENTRAL-WEST BRAZIL

Abstract

This paper explores reduced form determinants of the adoption of certain technologies by upland rice and soybean farmers in the central-west region of Brazil. We merge community level data on the availability and quality of publicly provided infrastructure, principally extension, to farm level data containing information on farmer human capital as well as land quantity and quality. By using community level measures of availability and quality of extension we avoid problems of endogeneity of farm level measures of extension use. We find positive impacts of farmer education on the diffusion process, in accordance with other studies. We also isolate effects of the quality of regional extension investment as measured by the average experience of technical extension staff. These results, which are relatively new in the agricultural diffusion literature, indicate that investments in human capital of extension workers does have a payoff in terms of farmer adoption of better cultivation practices.

1. INTRODUCTION

Since 1974 the Brazilian government has invested a considerable amount of resources in agricultural research. At present, there are only certain amounts of knowledge and technologies available and these appear to be adopted by farmers with a considerable lag. Furthermore, this lag is not the same for all products, for all farmers for all regions or for all communities.

It seems that several factors including structural transformations in the Brazilian economy and different agricultural policies can be related to the technological gap. Two factors which we focus on are farmer education and extension service quality. Education has been widely discussed as an important determinant of production efficiency and technology diffusion (e.g., Welch, 1970; Jamison and Lau, 1982; and Feder, Just and Zilberman, 1985). Studies of extension impacts have been much less common (see Birkhauser, Evenson and Feder, 1989, for a survey and Patrick and Kehrberg, 1973, for a study of Brazilian agriculture). Many of these studies fail to account for endogeneity of measures of farm level extension contacts, and even fewer account for the quality of extension services.

Within Brazil technology availability for different crops has been pointed out as a determinant factor of the disparity in the regional composition of agriculture in Brazil (Homem de Melo, 1983). The Center-West region has made a large contribution to Brazilian agricultural supply since the late 1970s. Of the total area planted with rice, soybeans, corn, beans and wheat in Brazil, 17.5% are in Center-West region. For rice, the share is 31.9% and for soybeans, it is 28.4%. The regional yields (kg/ha) are higher than the Brazilian average yields for soybeans, corn, cassava, cotton and sugar cane. For wheat and rice the Center-West yields are lower since the average for Brazil includes irrigated acres.

Agricultural supply dynamics has led to changes in land allocation for different crops. The growth of the area with soybeans in the Center-West region over the last decade is one of the most important events of this process of change (see Teixeira, 1987).

Upland rice has a long tradition[1] in the region and farmers who recently migrated there tend to cultivate it. Since 1970/71 the area with rice has considerably increased. In Mato Grosso do Sul,

[1]It has been historically cultivated before turning the land to pasture.

this occurred during 1970/79 then started to decline. In Mato Grosso the decline started in 1979/80 and in Goias in 1980/81. In 1985/86 in all 3 states the area with upland rice increased again.

The major purpose of this paper is to explore reduced form determinants of the adoption of certain technologies and cultural practices for upland rice and soybeans. We use one data set from the Centro Nacional de Pesquisa de Arroz e Feijao (CNPAF) for upland rice and soybeans. In the data used here, we know farmers' practices only at the time of the survey; no retrospective information is available. This means we are unable to model the complete diffusion process. Instead we examine reduced form determinants of the adoption and extent of adoption of a set of practices at one point in time.

We examine variables to represent farmer human capital, land quantity and quality, and the availability and quality of publically provided infrastructure. We find positive impacts of farmer education on the diffusion process, in accordance with other studies. We also isolate effects of the quality of regional extension investment as measured by the average experience of technical extension staff. These results, which are relatively new to the agriculture diffusion literature, indicate that investments in human capital of extension workers does have a payoff in terms of farmer adoption of better cultivation practices.

2. METHODOLOGY

We view the adoption of technology as an economic decision based on discounted expected marginal benefits and costs. The empirical specification used in this paper is consistent with a variety of models of farmer or farm household optimization: maximizing expected profits, excepted utility of profits or expected utility of consumption and leisure subject to production function and time constraints (see Roe and Graham-Tomasi, 1986). For convenience in exposition, let us take the first alternative. Discounted expected profits, $V(\cdot)$, will be composed of two parts: the difference in discounted expected value of production of all crops and livestock with and without adoption of the particular technology, minus the difference in costs. We can think of this as the difference of two profit functions, each of which is a function of the base year constraints and information of farmers. The constraint and information sets include four components; two at the farm level and two at the community levels. At the farm level we view as constraints, firstly, human capital factors associated with the farm decision making process and, secondly, factors associated with the quantity and quality of land owned. We view other quasi-fixed factors, such as machinery, as adjustable over the time horizon of the farmer, and therefore do not include them as exogenous or pre-determined covariates. At the community level, the information set includes the level of farm services, especially extension and input marketing services; and agro-climate factors related to yield levels and instability.

Two types of human capital, education and experience, are plausibly related to technology adoption. All else equal, both should be positively related to information available to the farmer. Experience may provide general farming knowledge as well as specific knowledge about his or her particular farm, while education may enable the farmer to better process the information provided by different sources, and may increase both the allocative and technical efficiency of the farmer (Jamison and Lau, 1982). We assume all farming decisions are made by the household head and use his (or her) years of education as our measure of education, his age as a measure of general farming experience, and the number of years he has lived in the region as a measure of more region-specific experience. We would prefer to use the amount of time the farmer has been farming in the area; unfortunately this information is not available. It would be useful to distinguish different types of education (such as technical and non-technical schools); again this information was not collected.

Regarding land, we use the area owned rather than the area cultivated as our quantity variable. We do this because much land is rented, even in the short run, and is an input which farmers have choice over. One could argue that in the long run land sales are possible; we take a more medium run perspective here, while recognizing that larger farms may result from better managerial ability. The survey provides us with two types of variables relating to farm level land quality; the topography of the land (before any leveling or terracing is undertaken) and the degree of soil erosion. Both are somewhat crude measures; it might have been useful to have more precise data (see for instance Sidhu and Baanante, 1981, or Bhalla, 1988, for examples of input demand and yield analyses which indicate the usefulness of good land quality data).

Previous studies of farm technology adoption have used similar specifications; farmer education is almost always included, although experience measures other than age are seldom available; sometimes land quality data are also included. It is unusual, however, to find studies that use community level variables other than prices. We would argue, however, that the availability and quality of extension input provision and marketing services probably influence the adoption process, as do agro-climatic variables such as rainfall distribution (see Birkhauser, Evenson and Feder, 1989, for a survey of the extension impact literature). We take two approaches to modeling community influences.

We first include microregion-level dummy variables to capture these effects in an arbitrarily general way; we call this the fixed effect estimates. Secondly, we include variables designed to measure the community factors directly.[2] Among the community factors, we include municipio-level mean and standard deviations of rice and soy yields. These are derived from seven years of data on municipio-level rice and soy area and production. The source is independent of the sample, so there are no artificial correlations arising from data construction. These variables are designed to proxy for agro-climatic influences which affect both the level and variation in yields. A second set of variables attempts to measure the level of services available to farmers. We do not use information at the farm level, such as whether he or she has regular visits from an extension agent, because such a variable would be endogenous in our model. In particular extension visits may arise because both the agent and the farmer want them. Agents may go to better farm managers on better land (or land closer to their offices) so as to maximize their impact. Provided there is useful information to extend there is likely to be more demand for it by better farmers on better endowed land. Thus inclusion of a farm level variable on extension contact is likely to give an upward biased coefficient on extension, as well as biasing downwards the education, experience and land quality coefficients. This may explain the positive extension and negative education effects reported in the study of Brazilian agriculture by Patrick and Kehrberg (1973).

The *availability and quality* of extension and other services at the community level may be more plausibly taken as exogenous to farmers. We have gathered, independently from the farm survey, municipio level data on the number of EMATER technicians, their average experience in EMATER and the proportion who have at least a BS degree. In addition we have collected information on whether the municipio has service from a cooperative, CIBRAZEM (storage facilities), a radio diffusion program, as well as the number of banks servicing the municipio.

Based on the sample, we construct the percentage of farmers who have contact with EMBRAPA. Since there are too few sample observations in each municipio to use that as a

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[2]We cannot hope to capture all factors which influence farmer decisions; what we hope to do is identify among these factors, those which have a large influence on technology adoption.

meaningful level of aggregation, we define this variable at the microregion level. We run regressions both with and without this variable since averaging values over a microregion may not purge it of endogeneity problems.

Theory suggests prices should also enter the reduced form. Unfortunately we only have input prices at the state level, and the survey covers three states; there are not enough data points to measure price effects.

Having defined our variables we can outline the statistical model. Let

$$V_{iA} = X_i\beta_A + \varepsilon_{iA} \tag{1}$$

be the discounted expected profits function using the adopted technology for the ith farm, where X_i is a vector of characteristics defined above and ε_i is a random error. Let

$$V_{iN} = X_i\beta_N + \varepsilon_{iN} \tag{2}$$

be discounted expected profits without the new practice. Let $V_i = V_{iA} - V_{iN}$, then if $V_i > 0$ the technology or cultural practice is adopted, and not if $V_i < 0$. Note that we consider each practice separately. We do not observe V_i and ε_i but we do observe both X_i and whether the practice is adopted or not. Let $D_i = 1$ if the practice is adopted, that is if $V_i > 0$, then we have a standard model of qualitative choice. For this paper we assume ε_i to be distributed as a normal random variable with mean zero and unit variance, which is a probit model, and is estimated by maximum likelihood.

Two dependent variables are continuous[3] and are fitted by the method of least squares. The linear specification can be derived from a quadratic profit function (we abstract in this case from the possibility that coefficients may vary based on the technology used, see Pitt and Sumodiningrat, 1988).

[3]They are an index of technology adoption and fertilizer use per hectare. Since almost all farmeres use some fertilizer, data censoring at zero is not a problem.

3. DESCRIPTION OF DATA

The data set comes from a study conducted at CNPAF (Teixeira, 1987; Barbosa and Teixeira, 1987). Its main purpose was to explain, at the farm level, the reasons for soybeans expansion (sometimes at the expense of food crops such as rice in Center-West region) and to characterize the forms of production. The sample regions were selected based on total acreage and production data for the two crops from 1973 to 1984. The municipios were selected based on the increase over time of soybeans area and the decrease over time of rice areas. The number of farmers sampled was 200: 100 in Goias, and 50 each in Mato Grosso and Mato Grosso do Sul (Teixeira, 1987). Additional data at the municipio level were collected on some variables which characterize the agricultural sector such as storage facilities, credit, extension and education services, as well as production and area for rice and soybeans over the previous eight years.

Table 3.1 shows that for the Center-West region, the sample is comprised of large farms (49.6% of the farms sampled have more than 500 ha), particularly in Mato Grosso, where farms larger than 1.000 ha represent 39.2% of the sample. In Mato Grosso do Sul the larger frequencies are for farms in the 501-1.000 ha, and 10-250 ha brackets, while for Goias, 251-500 ha farms are the most frequent.

Table 3.2 shows the composition of soybeans and rice production by farm size for the sample. Area farmed is larger than area owned reflecting rentals. The average area planted to soybeans is larger than for rice, and soybeans yields are higher than rice yields; this occurs for all farm sizes. Permanent crops tend to be grown on larger farms, although all sized farms in Goias grow such crops. The ratio of average area with cultivated pasture to average area with native fields is greater than one for farms larger than 1000 hectares, though in Goias this holds for all farm size classes. Rice yields tend to decline with farm size, while soybeans yields tend to increase.

Most of the farmers in the sample have migrated to the Center-West region--60% of them in the last 10 years (Table 3.3). Typically they are young and the average family size is 4 to 5 persons.

Table 3.4 shows the frequency of adoption of various cultural practices and technologies for soybeans and upland rice. Analysis of soils is more prevalent on soybeans. Use of some fertilizer is nearly universal, however use of cover fertilizer is not. Only one-third of soy plantings make use of seeds innoculated for nitrogen fixation capabilities. Almost one-third of rice fields had blast problems, but only one-fourth of those fields received any treatment.

Table 3.5 repeats some of the earlier tabulations, only stratified by level of farmer education. The level of education decreases with the farmers' age. More educated farmers have smaller families and larger farms. However, less educated farmers have better results in terms of rice yields and rice share of area planted is higher for those farmers. For soybeans, yields increase with level of education.

For rice, better educated farmers are more likely to use certified seeds, treated seed, fertilizer, incorporate residuals and attempt to control erosion.

For soybeans the relationship between adoption of technologies and level of farmers' education is not as clear as for rice. Better educated farmers are more likely to use cover fertilizer, plough deeper and terrace. Non-chemical weed control is more frequent among less educated farmers.

Table 3.6 provides means and standard deviations of farmer access to community infrastructure. Computing separate means by level of farmer education shows almost no discernable differences in availability, however this does not mean that use is invariant to education, as we demonstrate below.

4. TECHNOLOGY AND CULTURAL PRACTICES: REGRESSION RESULTS

Not all of the technology information collected in the survey is used in the regression analysis. Some practices are adopted by almost everyone and others by very few farmers; for these, there is no variation to explain. Some practices, such as use of herbicides for soy farmers, are very hard to explain with the covariates we use; others are sufficiently close to those we do report that they provide no additional information. We focus on nine practices, five for upland rice and four for soybeans. They are whether the farmer does soil analysis (for both rice and soy fields); whether the farmer uses certified rice seed or innoculated soy seed; whether he uses cover fertilizer (for rice) and total fertilizer usage per hectare (for rice and soybeans); whether action is taken against rice blast (brusone); whether soy fields are planted in (preferred) holes (or whether rows are used). Each dependent variable is estimated in isolation; these regressions cannot, therefore, take account of complementarities in technological practices. CNPAF and CPAC agronomists have, however, developed a scheme which assigns a score to packages of practices for soybean cultivation. We have created an overall soybean technology adoption index for each farmer: the higher the index (out of 100), the closer the farmer is to 'optimal' (or recommended) practices. We include this index as the tenth dependent variable, treating it as a continuous dependent variable. Relying on this index alone is unlikely to be a good empirical strategy; we therefore consider it in conjunction with the regressions explaining the adoption of individual practices.

The regression results are presented in Tables 4.1-4.2. They are discussed by group of covariates. We look, firstly, at the effect of farmer human capital on the dependent variables, secondly, at the effect of extension and research variables, thirdly, at the farm-level land quantity and quality variables and finally at community-level agro-climatic and infrastructure variables.

(a) Farmer Education and Experience Effects

Education of the farm operator has a positive, significant at the 10% level, effect in six of the ten regressions when microregion dummy variables are included and in four when municipio level covariates replace the microregion dummies. The overall index of soy cultivation practices rises six-tenths of a point for each year of education. Using soil analysis for rice cultivators is positively related to education, as is the quantity of fertilizer used on soybeans and the use (or not) of cover fertilizer for upland rice. These effects are robust to the inclusion of either region dummy variables or region-specific variables. It is possible that there exist interaction effects of education with the degree of regional EMBRAPA, EMATER or coop service, or with agro-climatic factors; none, however, are significant.

Age of operator, which should proxy for general experience, does not explain any of the adoption patterns. Time spent in the current region of residence is, however, strongly positively related for rice farmers to the use of methods to control blast and for soybean bean farmers to the probability of using preferred planting techniques. This suggests that learning about the particular conditions of the center-west region, and how to cope with them, does occur, for these largely immigrant (usually from the south) farmers.

(b) Regional Service Availability

In many of the regressions the microregion dummy variables are jointly and individually significant at the 5% level. It is thus interesting to include region-level variables which may be plausibly related to cultural practice adoption.

(i) Extension and Research Availability and Quality

The three EMATER extension variables, the number of technicians (or technicians per farm), the proportion with a BS degree and their average years of experience turn out to be too collinear for any robust results to emerge, yet they are jointly significant in a number of cases. However when using only the experience variable some regularities do appear. Farmers in municipios where EMATER technicians have more experience have higher scores of the soybean technology index and tend to use soy seeds which are innoculated. These farmers also tend to take soil analyses on their rice plots and use certified rice seed. The effects of an additional year of experience by EMATER technicians is comparable to, and sometimes larger than, the effect of a year of farmer education. Interactions between EMATER experience and farmer education proved not to be significant (not reported). Larger samples may be necessary to test for substitutability or complementarity between these factors.

Interestingly fertilizer use is not associated with extension agent experience, nor is using methods to control blast. Also planting soybeans using preferred methods is negatively related to extension agent experience. Still the results do suggest a role for experience though not scale or education, crudely measured, in enhancing the effectiveness of extension agents. This is consistent with recent World Bank programs which emphasize intensive training of extension agents as one important ingredient for enhanced productivity (ref.).

When the degree of microregional contacts with EMBRAPA is added to the regressions, positive significant (at better than the .05 level) effects are found for various upland rice practices, but not for soybeans. The use of soil analysis, cover fertilizer and the quantity per hectare of fertilizer use are all positively related to the degree of EMBRAPA contacts within a region.

The net positive impacts of EMBRAPA and EMATER service availability is quite interesting and potentially important. In unreported probits explaining the probability of a farmer having EMBRAPA or EMATER contacts it was found that being better educated and younger made it more likely to have contacts from EMBRAPA. EMBRAPA also seems to work more in municipios with level land, no radio diffusion programs and with CIBRAZEM storage facilities. EMATER contacts are more likely in areas served by EMATER technicians with greater experience and with lower soy yields. Farmers having technicians with greater experience and in less well endowed areas, as measured by mean yields, are more likely to be associated with cooperatives.

(ii) Other Community Infrastructure

The other community covariates appear not to matter for adoption of these cultivation practices, although there are a few notable exceptions. The existence of a cooperative office in a municipio is positively related to using preferred planting methods for soybeans. Cooperatives also have a positive effect on fertilizer use for rice, although this is not robust to the inclusion of the EMBRAPA contact variable.

The number of banks in a municipio seems to increase the likelihood of taking soil analyses on soybean plots as well as increasing fertilizer use on soybeans. Use of innoculated seeds seems to be negatively associated with the number of banks.

The existence of a radio diffusion program has no effects on technology practices except on the use of innoculated soybean seeds, which seem to be promoted by the existence. Thus radio diffusion seems to be a poor substitute for extension services.

The existence of CIBRAZEM storage facilities in a municipio is positively associted with use of preferred planting practices for soybeans, but tends to be negatively related to fertilizer use, soil analysis and using certified seed for rice. Why is not clear. The existence of CIBRAZEM facilities tends to be in larger centers so there apparently is some effect these areas on certain farming practices.

(c) Land Quantity and Quality

Total area owned has no effect on the technology variables save on the use of certified rice seed. Topography does seem to be related to the use of preferred practices for soybean farmers. Farmers owning less level land are more likely to plant with preferred methods and use more fertilizer per hectare. For upland rice farmers topography has less impact, except for a positive effect on the use of cover fertilizer on farms with steeper slopes. The presence of soil erosion is associated with lower probabilities of using preferred planting methods for soybeans, but is not significantly related to other cultural practices.

(d) Regional Agro-Climatic Conditions

Agro-climatic conditions are proxied at the municipio level by mean soy and rice yields, and the standard deviation of those yields over a seven year period (1979/80-1985/86). For upland rice, it is in more productive municipios that more fertilizer per hectare is used. When EMBRAPA contacts are controlled for, higher mean yields are associated with use of certified seeds and cover fertilizer. The variability of yields has significant effects on rice cultural practices only when EMBRAPA contacts are not controlled. In those cases higher instability raises the chance of controlling for blast and for using certified seeds. For soybeans it is in better endowed areas that treated seeds and preferred planting methods are used. Higher agro-climatic variability also induces use of treated seeds.

5. SUMMARY

We would argue, on the basis of these results, that it is possible to identify some of the determinants of the adoption of new technologies and cultural practices, at least within the simple static model outlined in Section 2. Of the factors considered farmer education stands out as being important as does the experience of extension agents. The education result is consistent with numerous studies in the literature, however rather few studies have looked at extension effects in a true reduced form setting. Of these we are not aware of other studies which examine the human capital of extension agents as explicitly as we do.

It would be preferable to explain both the extent and process of technological adoption by farmers; this would be possible only with longitudinal data in which each farmer is tracked over several seasons. In any case, for both longitudinal and cross section surveys, the results reported above suggest that it may be prudent to adopt a rather broader strategy to technological survey data collection than is commonly found. In particular, in addition to technological use data, it would be advantageous to collect information on the human capital and socio-economic characteristics of farmers, on indicators of land quality and on community level factors. These should include both those related to underlying agro-climatic potentials and those related to the availability of relevant farm services. We think that widening the scope of these surveys will have high marginal returns in terms of helping program evaluators and policy makers understand the processes underlying technological adoption.

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TABLE 3.1

Classification of Farms Sampled by Total Area in States of Goias, Mato Grosso do Sul and Mato Grosso

Size (ha's)	Goias	States Mato Grosso do Sul	Mato Grosso	
< 10	2 2.00	0 0.00	0 0.00	2 1.00
10 - 250	26 26.00	17 34.69	7 13.73	50 25.00
250 - 500	27 27.00	11 22.45	11 21.57	49 24.50
501 - 1000	25 25.00	14 28.57	13 25.49	52 26.00
> 1000	20 20.00	7 14.29	20 39.22	47 23.50
Total	100 50.00	49 24.50	51 25.50	200 100.00

TABLE 3.2

Total Area, Composition, Rice and Soybeans Yields, and Production of Farm Size

		Size (ha)			
		10-250	251-500	501-1000	> 1000
1) Areas (ha)					
a) Total	mean	139.8	362.2	686.2	2339.1
	standard deviation	63.2	77.3	150.6	1557.5
b) Owned	mean	82.4	225.6	434.8	1814.4
	standard deviation	80.1	162.6	314.3	1507.4
c) Rice	mean	10.8	28.7	49.1	116.9
	standard deviation	19.7	58.6	81.0	168.0
d) Soybeans	mean	84.0	205.7	274.6	562.6
	standard deviation	111.5	148.7	190.2	493.2
e) Permanent crops	mean	0.1	2.1	1.4	35.9
	standard deviation	0.7	14.1	9.0	213.1
f) Cultivated pasture	mean	17.7	26.3	59.4	582.0
	standard deviation	35.3	50.0	101.6	1171.0
g) Native fields	mean	18.4	30.0	81.2	352.0
	standard deviation	52.4	56.6	139.7	580.1
h) Forests	mean	6.5	15.6	32.3	279.6
	standard deviation	18.8	33.2	70.7	554.2
i) Not productive	mean	1.4	2.2	4.8	36.7
	standard deviation	3.9	12.4	20.3	112.0
2) Yields (kg/ha)					
a) Rice	mean	1565.9	1436.0	1075.8	1254.4
	standard deviation	769.0	769.8	708.6	782.5
b) Soybeans	mean	1815.6	2016.8	1954.7	2157.1
	standard deviation	389.5	1011.5	629.6	401.3
Sample Size		50	50	52	47

TABLE 3.3

Description of the Producers and the Farms,
%, Mean and Standard Deviation

Variables	Number	%
Farmers Age		
30 years	48	24
30-40 years	65	32.5
41-50 years	60	30.
50 years	27	13.5
Experience in the Region		
5 years	73	38
5-10 years	42	22
10 years	76	40
Education		
< 4 years	104	54
4-8 years	52	27
< 8 years	37	17

	Number	Mean	S.D.
Family Size	194	4.7	1.7
Area Owned (ha)	200	614.3	1009.9
Total Area (ha)	200	851.2	1137.0

TABLE 3.4

Frequency of Adoption of Technologies for Rice and for Soybeans

	# Obs.	% Adopt
1) Soil analysis[a]		
a) Rice	189	47
b) Soybeans	189	73
2) Use fertilizer when planting[a]		
a) Rice	188	90
b) Soybeans	189	94
3) Use of residuals[a]		
a) Rice	143	83
4) Broadcasting application[b]		
a) Rice	209	3
5) Plant in line[b]		
a) Rice	206	96
6) Conventional planting[b]		
b) Soybeans	360	73
7) Use of cover fertilizer[a]		
a) Rice	188	17
b) Soybeans	189	9
8) Use of innoculated seeds[b]		
b) Soybeans	360	31
9) Blast control measures[b]		
a) Rice	205	10
10) Had blast attact and used control measures[b]		
a) Rice	62	26

[a]Farm is level of observation.

[b]Cultivar is level of observation.

TABLE 3.5A

Description of the Producers and the Farms
by Years of Farmer Education

		Education		
		Less than 4 years	4 to 8 years	More than 8 years
1) Producer's age	n	105	53	34
a) < 30 years	%	14.3	33.9	41.2
b) 40-40 years	%	24.8	39.6	47.0
c) 51-50 years	%	40.9	16.9	8.8
d) > 50 years	%	20.0	9.4	0.3
2) Experience in the region	n	98	52	33
a) < 5 years	%	37.7	38.5	36.4
b) 5-10 years	%	18.4	26.9	27.3
c) > 10 years	%	43.9	34.6	36.4
3) Family size	n	104	50	33
	mean	5.14	4.34	3.9
	standard deviation	1.59	1.67	1.46
4) Number of adults	n	101	43	23
	mean	2.13	2.21	2.3
	standard deviation	0.99	1.22	0.63
5) Number of children	n	101	43	23
	mean	3.08	2.65	2.17
	standard deviation	1.37	1.51	0.89
6) Area owned	n	105	53	34
	mean	494.27	681.36	844.9
	standard deviation	768.05	1186.93	1326.92
7) Total area	n	105	53	34
	mean	637.82	1020.17	1215.4
	standard deviation	811.46	1273.61	1606.66
8) Rice yields	n	66	35	23
	mean	1395.57	1364.29	1048.0
	standard deviation	798.24	807.52	651.32
9) Soybeans yields	n	86	44	30
	mean	1919.56	2125.46	1965.4
	standard deviation	523.05	1021.29	467.4
10) Rice share of area	n	103	52	34
	mean	0.12	0.06	0.09
	standard deviation	0.50	0.12	0.14
11) Soybeans share of area	n	103	52	34
	mean	0.56	0.46	0.38
	standard deviation	0.94	0.39	0.29

TABLE 3.5B

Topography and Technologies for Rice
by Years of Farmer Education

		Education		
		Less than 4 years	4 to 8 years	More than 8 years
1) Topography	n	105	53	34
a) < 3 degrees	%	70.5	65.4	52.9
b) 3-8 degrees	%	25.8	30.8	44.1
c) > 8 degrees	%	2.8	3.8	2.9
2) Erosion	n	105	53	34
	%	5.7	3.8	17.6
3) Soil analysis	n	105	53	34
	%	35.2	54.7	70.6
4) Greenbrook	n	105	53	34
	%	15.2	18.9	17.6
5) Terracing	n	105	53	34
	%	5.7	16.9	2.9
6) Plowing	n	105	53	31
	%	93.3	98.1	88.2
7) Deep plowing	n	99	51	31
a) < 20 cm	%	37.4	31.4	35.5
b) 20-30 cm	%	54.5	54.9	61.3
c) > 30 cm	%	8.1	13.7	3.2
8) Harrowing	n	13	3	5
	%	0.0	0.0	0.0
9) Fertilizer at planting time	n	104	53	34
	%	88.5	92.4	97.1
10) Cover fertilizer	n	104	53	34
	%	13.5	22.6	17.6
11) Amount of total fertilizer (kg/ha)	n	104	53	34
	mean	190.0	212.9	204.9
12) Residuals incorporated	n	90	40	27
	%	78.7	97.5	92.6
13) Certified seeds	n	104	53	34
	%	40.4	47.2	50
14) Treated seeds	n	104	53	34
	%	75.0	79.2	82.3
15) Use of credit	n	105	53	34
	%	60.0	54.7	50
16) % of area with blast	n	105	53	34
	mean	15.54	18.1	13.1
17) % of area with insect	n	105	53	34
	mean	3.1	5.0	4.1

TABLE 3.5C

Topography and Technologies for Soybeans
by Years of Farmer Education

		Education		
		Less than 4 years	4 to 8 years	More than 8 years
1) Topography	n	105	53	34
a) < 3 degrees	%	56.1	58.5	64.7
c) > 3 degrees	%	40.9	42.5	35.3
2) Erosion	n	105	53	34
	%	7.6	3.8	8.8
3) Greenbrook	n	105	53	34
	%	35.2	28.3	41.2
4) Terracing	n	105	53	34
	%	16.2	18.9	26.5
5) Plowing	n	105	53	34
	%	87.6	94.3	91.2
6) Deep plowing	n	85	45	26
a) < 20 cm	%	31.7	26.7	46.1
b) 20-30 cm	%	60.0	53.3	42.3
c) > 30 cm	%	8.2	20.0	11.5
7) Fertilizer at planting time	n	105	53	34
	%	91.4	98.1	94.1
9) Cover fertilizer	n	105	53	34
	%	6.7	7.5	14.7
10) Total amount of fertilizer	n	105	53	34
(kg/ha)	mean	256.0	279.2	309.7
11) Soil analysis	n	105	53	34
	%	69.5	67.9	91.2
12) Manual weeds control	n	105	53	34
	%	26.7	20.7	20.6
13 Use of herbicides	n	105	53	34
	%	45.7	50.9	47.0
14) % of area with disease	n	105	53	34
	mean	2.6	3.5	2.6
15) % of area with insect	n	105	53	34
	mean	23.7	22.8	23.2

TABLE 3.6

Means of Community Infrastructure Variables[a]

Avg. years experience of EMATER technicians	8.25 (2.8)
No. of EMATER technicians	3.89 (1.2)
% of EMATER technicians with BS degree	.60 (.26)
Municipio has coop	.76
Municipio has radio diffusion program	.42
Municipio has CIBRAZEM storage facilities	.61
No. of banks	5.9 (2.8)

[a]Standard deviations in parentheses.

TABLE 4.1
Soy Technology and Cultivation Practice Adoption Regressions

	Technology Adoption Index			Soil Analysis			Use Treated Seeds[a]			Plant with Preferred Methods[a]			Total Fertilizer/Ha		
Total Area Owned Ha/1000	-.597 [0.64]	-.568 [0.61]	-.550 [0.59]	-.175 [1.48]	-.115 [0.98]	-.129 [1.08]	-.063 [0.89]	-.001 [0.01]	.002 [0.02]	.052 [0.69]	.053 [0.66]	.051 [0.64]	-.316 [0.04]	1.526 [0.21]	1.104 [0.15]
Age of Operator yrs/100	10.429 [1.21]	11.002 [1.31]	10.489 [1.22]	1.391 [1.12]	.910 [0.74]	1.325 [1.05]	1.255 [1.80]	.786 [1.11]	.689 [0.95]	-.920 [1.17]	-1.232 [1.53]	-1.134 [1.38]	-78.970 [1.19]	-84.773 [1.28]	-75.185 [1.11]
Education of Operator (years)	.564 [2.40]	.605 [2.58]	.612 [2.58]	.067 [1.99]	.054 [1.57]	.055 [1.59]	.006 [0.30]	.019 [0.93]	.019 [0.96]	-.019 [0.92]	-.014 [0.65]	-.015 [0.66]	3.727 [2.14]	3.174 [1.79]	3.110 [1.75]
Regional experience of Operator, years/100	-2.308 [0.27]	.552 [0.07]	1.054 [0.13]	-.714 [0.62]	-.685 [0.62]	-.882 [0.78]	.081 [0.01]	.232 [0.30]	.271 [0.35]	2.532 [2.90]	2.111 [2.49]	2.098 [2.48]	-33.036 [0.50]	-58.790 [0.94]	-66.557 [1.05]
Land Inclined > 3°	2.324 [1.28]	1.969 [1.09]	2.072 [1.12]	.385 [1.57]	.225 [0.89]	.170 [0.66]	-.057 [0.38]	-.033 [0.21]	-.014 [0.09]	.341 [2.03]	.448 [2.47]	.434 [2.37]	35.610 [2.64]	30.445 [2.21]	28.562 [2.03]
Erosion Present	.349 [0.09]	-.795 [0.22]	-.852 [0.23]	.821 [1.23]	.716 [1.18]	.777 [1.27]	.265 [0.86]	.232 [0.76]	.233 [0.77]	-1.165 [2.74]	-1.078 [2.64]	-1.094 [2.65]	13.923 [0.52]	22.385 [0.85]	29.064 [0.90]
Micro-region:[b]															
Rodonopolis (MT)	2.949 [0.96]			-.312 [0.73]			.818 [3.11]			.126 [0.44]			-16.419 [0.73]		
Alto Taquari (MS)	4.849 [1.38]			.138 [0.27]			.698 [2.38]			.173 [0.55]			-37.805 [1.44]		
Planalto Goiano (GO)	3.663 [0.94]			.712 [1.00]			.402 [1.28]			.631 [1.93]			2.711 [0.09]		
Serra do Caiapo (GO)	2.458 [0.67]			-.614 [1.26]			.518 [1.64]			-.214 [0.60]			-24.123 [0.88]		
Meia-Ponte (GO)	4.606 [1.07]			-1.054 [1.98]			.859 [2.24]			.447 [1.09]			-38.183 [1.23]		
Vertente Goiana do Paranaiba (GO)	6.211 [1.89]			-.646 [1.43]			.658 [2.27]			-.849 [2.39]			-53.948 [2.21]		
% Farmers with EMBRAPA Contact			-3.244 [0.30]			1.917 [1.23]			-.574 [0.61]			.788 [0.60]			57.836 [0.70]
Municipio:															
Ave. Exp. of EMATER		.706 [2.01]	.702 [1.99]		.051 [1.05]	.051 [1.03]		.054 [1.69]	.051 [1.60]		-.117 [2.83]	-.116 [2.77]		.151 [0.06]	.228 [0.09]
Cooperative (= 1 if exist)		-2.631 [0.90]	-2.471 [0.85]		-.456 [1.18]	-.521 [1.31]		-.214 [0.90]	-.193 [0.81]		1.428 [4.69]	1.434 [4.66]		5.099 [0.24]	2.187 [0.10]
CIBRAZEM Storage (= 1 if exist)		-.619 [0.28]	-.296 [0.12]		-.256 [0.80]	-.434 [1.23]		-.086 [0.47]	-.032 [0.16]		.835 [2.99]	.764 [2.55]		-23.431 [1.42]	-28.593 [7.58]
Number of Banks		-.211 [0.42]	-.220 [0.43]		.149 [2.15]	.158 [2.24]		-.184 [4.00]	-.186 [4.02]		-.004 [0.08]	.004 [0.07]		7.862 [2.01]	8.010 [2.04]
Radio Diffusion Program		-2.326 [0.82]	-2.463 [0.86]		-.264 [0.73]	-.250 [0.68]		.567 [2.21]	.548 [2.11]		-.202 [0.65]	-.180 [0.58]		-16.052 [0.75]	-13.83 [0.64]
Mean Soy Yields (1979/80-1985/6)		-5.018 [1.16]	-4.542 [0.99]		.826 [1.52]	.572 [0.96]		.587 [1.63]	.666 [1.74]		2.686 [4.34]	2.809 [4.01]		44.750 [1.42]	36.099 [1.07]
Standard Deviation of Soy Yields (1979/80-1985/6)		.870 [0.11]	1.345 [0.13]		1.643 [1.56]	.477 [0.33]		.678 [1.13]	1.100 [1.20]		3.564 [4.36]	3.104 [2.78]		52.807 [0.93]	14.588 [0.19]
Constant	64.292 [12.86]	73.688 [6.26]	72.553 [5.85]	.029 [0.40]	-2.643 [1.66]	-2.150 [1.29]	-1.103 [2.55]	-1.078 [1.12]	1.255 [1.24]	-.611 [1.29]	-6.883 [4.72]	-7.103 [4.45]	300.909 [7.98]	163.912 [1.87]	183.239 [1.99]
-2 log likelihood/ F-statistic	1.1	1.5	1.4	21.8	22.7	24.3	17.9	36.8	37.1	42.5	69.1	69.4	2.4	2.3	2.2
Sample Size	144	144	144	160	160	160	315	315	315	315	315	315	160	160	160
# Engaging in Practice	—	—	—	118	118	118	151	151	151	82	82	82	153	153	153
Estimator	OLS	OLS	OLS	Probit	Probit	Probit	Probit	Probit	Probit	Probit	Probit	Probit	OLS	OLS	OLS

Notes: [a]Level of observation is the cultivar. [b]Omitted micro region is Paranaiba.

TABLE 4.2
Upland Rice Cultivation Practice and Adoption Regressions

	Soil Analysis			Use Certified Seed			Use Cover Fertilizer			Total Fertilizer/Ha			Brusone Control[a]		
Total Area Owned Ha/1000	.124	.181	.175	.294	.340	.328	.156	.171	.162	-.619	5.795	3.938	.112	.048	.017
	[1.13]	[1.63]	[1.58]	[2.40]	[2.80]	[2.66]	[1.31]	[1.42]	[1.32]	[0.07]	[0.63]	[0.44]	[0.49]	[0.221]	[0.08]
Age of Operator yrs/100	.623	.522	.741	-.628	-1.261	-.776	2.250	1.171	1.987	39.079	-6.428	34.877	-1.464	-1.851	-1.519
	[0.58]	[0.48]	[0.67]	[0.51]	[1.08]	[0.64]	[1.67]	[0.90]	[1.42]	[0.48]	[0.68]	[0.41]	[0.86]	[1.10]	[0.90]
Education of Operator (years)	.113	.109	.109	.020	.031	.033	.072	.069	.072	3.811	3.140	3.156	-.005	-.029	-.019
	[3.92]	[3.73]	[3.75]	[0.69]	[1.10]	[1.13]	[2.16]	[2.06]	[2.08]	[1.84]	[1.45]	[1.49]	[0.11]	[0.59]	[0.40]
Regional experience of Operator, years/100	.491	.082	.048	-1.163	-.437	-.476	-.433	-.288	-.539	-5.629	-41.481	51.897	3.639	3.993	4.022
	[0.42]	[0.74]	[0.04]	[0.97]	[0.39]	[0.41]	[0.30]	[0.20]	[0.37]	[0.06]	[0.49]	[0.62]	[2.34]	[2.58]	[2.58]
Land Inclined > 3-8°	-.060	-.081	-.104	-.169	-.183	-.240	.080	.074	.058	5.230	.369	-5.031	-.140	-.281	-.245
	[0.25]	[0.33]	[0.43]	[0.67]	[0.74]	[0.94]	[0.29]	[0.26]	[0.20]	[0.29]	[0.02]	[0.28]	[0.31]	[0.63]	[0.56]
Land Inclined > 8°	-.223	-.206	-.298	-.327	-.330	-.491	1.347	1.486	1.503	14.921	21.627	9.829	.156	.500	.511
	[0.29]	[0.25]	[0.36]	[0.42]	[0.40]	[0.56]	[1.66]	[1.79]	[1.77]	[0.27]	[0.38]	[0.18]	[0.15]	[0.47]	[0.47]
Erosion Present	.207	.315	.327	.129	.235	.231	-.843	-.789	.962	-49.177	-45.322	-46.225	.761	.316	.254
	[0.42]	[0.64]	[0.66]	[0.24]	[0.48]	[0.46]	[1.18]	[1.17]	[1.34]	[1.36]	[1.22]	[1.27]	[0.72]	[0.33]	[0.25]
Micro-region:[b]															
Rodonopolis (MT)	.753			3.312			.355			90.720			1.808		
	[2.04]			[1.91]			[0.75]			[3.31]			[0.40]		
Alto Taquari (MS)	.174			2.951			.426			-23.582			-.254		
	[0.39]			[1.69]			[0.76]			[0.73]			[0.04]		
Planalto Goiano (GO)	.700			3.971			1.033			126.916			3.738		
	[1.42]			[2.25]			[1.78]			[3.45]			[0.83]		
Serra do Caiapo (GO)	.491			3.164			.446			20.735			2.905		
	[1.14]			[1.81]			[0.84]			[0.65]			[0.64]		
Meia-Ponte (GO)	.938			3.171			-.049			34.234			-.039		
	[1.83]			[1.80]			[0.07]			[0.92]			[0.01]		
Vertente Goiana do Paranaiba (GO)	.328			3.383			.295			45.849			2.313		
	[0.86]			[1.95]			[0.60]			[1.61]			[0.51]		
% Farmers with EMBRAPA Contact			1.771			3.750			4.805			296.592			3.287
			[1.31]			[2.51]			[2.41]			[2.83]			[1.34]
Municipio:[b]															
Ave. Exp. of EMATER Technicians		.111	.108		.162	.168		-.028	.007		5.634	5.204		-.028	-.010
		[1.99]	[1.95]		[2.88]	[2.93]		[0.40]	[0.09]		[1.32]	[1.24]		[0.19]	[0.06]
Cooperative (= 1 if exist)		.116	.010		.034	-.178		-.353	-.973		51.278	32.208		2.548	.952
		[0.40]	[0.03]		[0.12]	[0.60]		[0.99]	[1.86]		[2.28]	[1.40]		[1.60]	[0.73]
CIBRAZEM Storage (= 1 if exist)		-.724	-.759		-.835	-.991		.024	-.177		-70.218	-75.687		-.426	-.580
		[2.21]	[2.30]		[2.57]	[2.88]		[0.06]	[0.45]		[2.84]	[3.13]		[0.65]	[0.89]
Number of Banks		.083	.076		-.008	-.014		.025	.096		5.356	4.796		.234	.221
		[0.92]	[0.85]		[0.09]	[0.16]		[0.22]	[0.67]		[0.76]	[0.69]		[1.33]	[1.30]
Radio Diffusion Program		-.406	-.225		-.516	-.228		.024	.651		-36.186	-7.247		-.665	-.319
		[1.10]	[0.57]		[1.40]	[0.59]		[0.06]	[1.41]		[1.23]	[0.24]		[0.82]	[0.40]
Mean Rice Yields (1979/80-1985/6)		.639	1.537		.386	2.253		.409	3.333		119.187	264.944		-1.937	.710
		[0.87]	[1.53]		[0.52]	[2.15]		[0.44]	[1.92]		[2.02]	[3.43]		[1.17]	[0.29]
Standard Deviation of Soy Yields (1979/80-1985/6)		.889	.369		2.869	2.205		1.533	2.047		110.434	34.995		7.404	4.600
		[0.63]	[0.25]		[2.04]	[1.53]		[0.85]	[0.89]		[1.01]	[0.32]		[2.24]	[1.39]
Constant	-1.687	-3.010	-4.249	-3.225	-1.970	-4.761	-2.804	-2.705	-7.880	113.778	-41.114	-247.405	-3.743	-4.238	-5.894
	[2.76]	[1.98]	[2.37]	[1.77]	[1.31]	[2.52]	[3.44]	[1.39]	[2.22]	[2.54]	[0.35]	[1.82]	[0.82]	[1.25]	[1.65]
-2 log likelihood/ F-statistic	27.0	29.0	30.8	41.0	33.3	39.9	15.0	15.9	22.9	2.8	1.8	2.3	40.3	37.7	39.2
Sample Size	161	161	161	161	161	161	161	161	161	161	161	161	173	173	173
# Engaging in Practice	74	74	74	69	69	69	27	27	27	148	148	148	16	16	16
Estimator	Probit	Probit	Probit	Probit	Probit	Probit	Probit	Probit	Probit	OLS	OLS	Probit	Probit	Probit	Probit

Notes: [a]Level of observation is the cultivar. [b]Omitted micro region is Paranaiba.