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9. ABSTRACT
The primary aim of this paper is to examine empirically the cropping patterns chosen by a group of peasant farmers in Surat District, India using a simple model of risk aversion. The data show that the observed behavior corresponds very closely to the hypothesis that farmers allocate land to different crops by striking some balance between the competing criteria of (a) increasing income and (b) decreasing risk measured by income variability. The actual definition of risk is in this case, the mean absolute deviation of income around its meanslevel. Secondly, the contrasting importance of risk and credit between irrigated and unirrigated farms is illustrated, and finally, some policy implications are discussed briefly.

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MANAGEMENT OBJECTIVES OF THE PEASANT FARMER: AN ANALYSIS OF RISK AVERSION IN THE CHOICE OF CROPPING PATTERN, SURAT DISTRICT, INDIA

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This work was done while Michael G. G. Schluter was a Graduate Research Assiatant in the Department of Agricultural Economics, Cornell University. Timothy D. Mount is an Assistant Professor in the Department of Agricultural Economics, Cornell University.

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Management Objectives of the Peasant Farmer: An Analysis of Risk Aversion in the Choice of Cropping Pattern, Surat District, India

Introduction

The basis of peasant farmers' decision-making is a critical factor in the formation of agricultural policy in developing countries. If farmers operate efficiently, implying that profits are maximized, then incomes can only be increased by introducing improved methods of production; if farmers do not act efficiently, it may be desirable to reallocate resources within traditional agriculture. Similarly, predictions of farmers' responses to price changes and thus the impact on aggregate production and employment[1/] are based on assumptions regarding farmers' management objectives.

The primary aim of this paper is to examine empirically the cropping patterns chosen by a group of peasant farmers in Surat District, India using a simple model of risk aversion. The data show that the observed behavior corresponds very closely to the hypothesis that farmers allocate land to different crops by striking some balance between the competing criteria of (a) increasing income and (b) decreasing risk measured by income variability. The actual definition of risk is in this case, the mean absolute deviation of income around its mean level. Secondly, the contrasting importance of risk and credit between irrigated and unirrigated farms is illustrated, and finally, some policy implications are discussed briefly.

Alternative Theories of Farmers' Management Objectives

T. W. Schultz concluded that peasant farmers do maximize profits and therefore use resources efficiently within the limits of traditional technology. His primary evidence is a study by W. D. Hopper in which the marginal products of different inputs used to produce different crops, evaluated from estimated Cobb-Douglas production functions, are found to be consistent with economic efficiency. Other less quantitative evidence of farmers' efficiency, such as observations in Sol Tax's Penny Capitalism, are used to corroborate Schultz's hypothesis.

D. K. Desai, writing slightly earlier than Schultz, concluded that farmers in West India did not allocate their resources efficiently. Using a linear programming model, he showed that incomes could be greatly increased if farmers specialized more in high-income crops. In his conclusions he suggests that the reason why income is not maximized is that the associated specialization involves a high risk; farmers diversify their cropping patterns to reduce risk.

M. Lipton, in an extensive criticism of Schultz's thesis, points out that the variability of production from year to year, due in part to changes in the quantity and distribution of rainfall, implies that economic efficiency is equivalent to maximizing the mean income over some time period. However, this criterion may increase the probability that a farmer will have to sell some land to repay outstanding debts after a bad harvest. The continuation of the farmer's control over his land is an important consideration as it represents the primary means for sustaining his family in the future. Consequently, Lipton believes that a farmer will choose a lower mean income in conjunction with less variability of income to

ensure a higher probability of keeping his land. In other words, farmers do not maximize profits as high income levels are associated with too much risk.[2/]

A major analytical advantage of using profit maximization as the criterion for management decisions is that it is then possible to determine exactly which production methods will be selected for any given set of production and price relationships. As a result, the magnitude of the effects of different policies on production practices can be predicted. In contrast, most alternative theories, such as those involving risk aversion, provide no direct way of determining which production methods will be selected in a particular situation. Exceptions to this rule generally require knowing certain parameters of the utility functions of individual farmers as well as parameters defining the production and price relationships. Thus, if the actual production practices chosen by farmers are not determined by their desire to maximize profits, little of the quantitative information required for policy analysis can be derived.

In what follows, we argue that farmers act 'proficiently' rather than efficiently. Proficiency is defined to mean that farmers accept less than the maximum mean income in order to reduce risk, but that their decisions are rational because for any level of mean income, the associated risk is minimized. It should be noted that this particular model of risk aversion can be used to derive quantitative results for policy analysis as well as to provide a more realistic explanation of observed behavior.

The Theoretical Framework for Analyzing Risk Aversion

The most widely used method for deriving rational diversification strategies is to minimize the variance of income, which is specified as the measure of risk, for a given level of the mean of income.[3/] As the mean is increased from zero to the maximum, different solutions are determined, and the maximum attainable mean, which is necessarily associated with the highest variance or risk, gives the solution corresponding to profit maximization. A number of alternative methods of accounting for risk have been proposed in other studies. Measuring income variability represents only one of the possibilities. However, most risk criteria are closely related to each other, and the real test of a criterion for our purposes is to determine whether it gives reasonable predictions of farmers' behavior.

One of the practical limitations of applying a model that involves minimizing a variance has been the capacity of quadratic programming algorithms. However, P. B. R. Hazell has proposed an alternative procedure which can be solved with a linear programming algorithm; minimization of the mean (or the total) absolute deviation around the mean is used in place of the variance as the risk criterion. Although Hazell finds that both criteria give very similar results, the computational advantages of the linear model make it more tractable in practice.

Inadequate data has also handicapped the application of risk aversion models to farm management problems. Most studies in India, for example, are based on cross-section data so that the risk parameters associated with the seasonal variation of income cannot be estimated. Ideally,

pooled cross-section (farms) and time-series (years) data of both production and price variables should be available for each crop.[4/] Although suitable data of this type could not be obtained, we were able to develop single time series of average yields and prices for six consecutive years by amalgamating information from several studies in Surat District. With this set of data, the risk parameters associated with seasonal variation can be estimated; however, the variation caused by differences in the levels of inputs from year to year are attributed to risk, and differences between farms are ignored. Improving future analyses of farmers' behavior towards risk will depend to a large extent on whether or not better sources of time-series data are developed.

Diversification of the cropping pattern can be an effective strategy for averting risk if the yields or revenues of some of the alternative crops are negatively correlated. In addition, risk can be averted by using relatively few purchased inputs such as chemical fertilizers,[5/] and also by growing staple foods to cover family needs rather than buying them at the local market. The effectiveness of these latter strategies depends to a large extent on the fact that income variability is directly related to the variability of gross revenue, whereas income itself is the difference between gross revenue and expenses. In our model, risk is specified in terms of the variation of net cash income after paying for all purchased inputs including cash advances, and for purchases of food to meet home consumption requirements. No risk is attached to crops grown for home consumption as farmers are assumed not to consider the yield variability of these crops in the same way that they regard the variability of cash income.[6/] We suggest farmers may account for the yield variability of food crops by storing the excess in good years and consuming it in poor years.[7/]

The major part of the empirical analysis that follows is conducted with data collected from a sample of 33 unirrigated farms in Surat District. An equivalent analysis of a sample of irrigated farms is restricted by inadequate time-series data for all of the crops that can be grown in the region. However, a limited assessment of the effect of irrigation is presented. For the unirrigated farms, the basic linear programming model may be summarized as follows:

Minimize the mean absolute deviation of annual net cash income over the six year period 1966/67 to 1971/72, subject to:

(1) A given level of net cash income which is parameterized from zero to the maximum attainable level

(2) Given levels of rice, jowar and fodder to represent the consumption needs of the farmer's household and bullocks (these may be produced on the farm or purchased)

(3) Available land of various types

(4) Available family labor for weeding and for harvesting

(5) Limits on personal savings, credit from a co-operative and credit from a money-lender

(6) Various rotation requirements.

A single set of production coefficients, estimated from data collected in 1971/72, is used for all farms. The wage rate for weeding, the interest rate on credit, and the constraint levels are changed for each farm, and consequently the solutions vary between farms. The complete model for one farm, which illustrates the form of the risk criterion, and a list of the sources of data used to derive the six annual observations of prices and yields are shown in the Appendix.[8/]

Cropping patterns can be selected from the following production alternatives; two staples, rice and jowar, and two cash-crops, groundnuts and cotton. The two staples may be grown for home consumption or for sale in the market, and in addition, all four crops can be grown using either high or low production intensities which reflect the levels of fertilizer and labor inputs. Each farmer is assumed to choose a crop combination prior to the agricultutal season, and later decisions, such as selecting the level of fertilizer in accordance with the actual rainfall during the season, are not considered in the model.

Estimated E-M Frontiers and Farmers' Observed Behavior

A set of proficient solutions was derived for each farm by determining the cropping patterns that minimized the risk (mean absolute deviation of income) for different levels of income (mean net cash income). The resulting relationship between risk and income derived from any set of proficient solutions will be termed the E-M frontier.[9/] The estimated E-M frontiers for nine representative farms are shown in Figure 1 together with a point corresponding to each farmer's actual choice of cropping pattern.[10/] This latter point is obtained by specifying the observed acreages under each crop as additional constraints in the model and then finding the associated income and mean absolute deviation. It should be noted that the measure of income used throughout this section is real income which is defined as the value of all crops produced on the farm minus the cost of purchased inputs.[11/] This is a more useful measure of income for making comparisons between farms even though the risk behavior is specified in terms of net cash income.

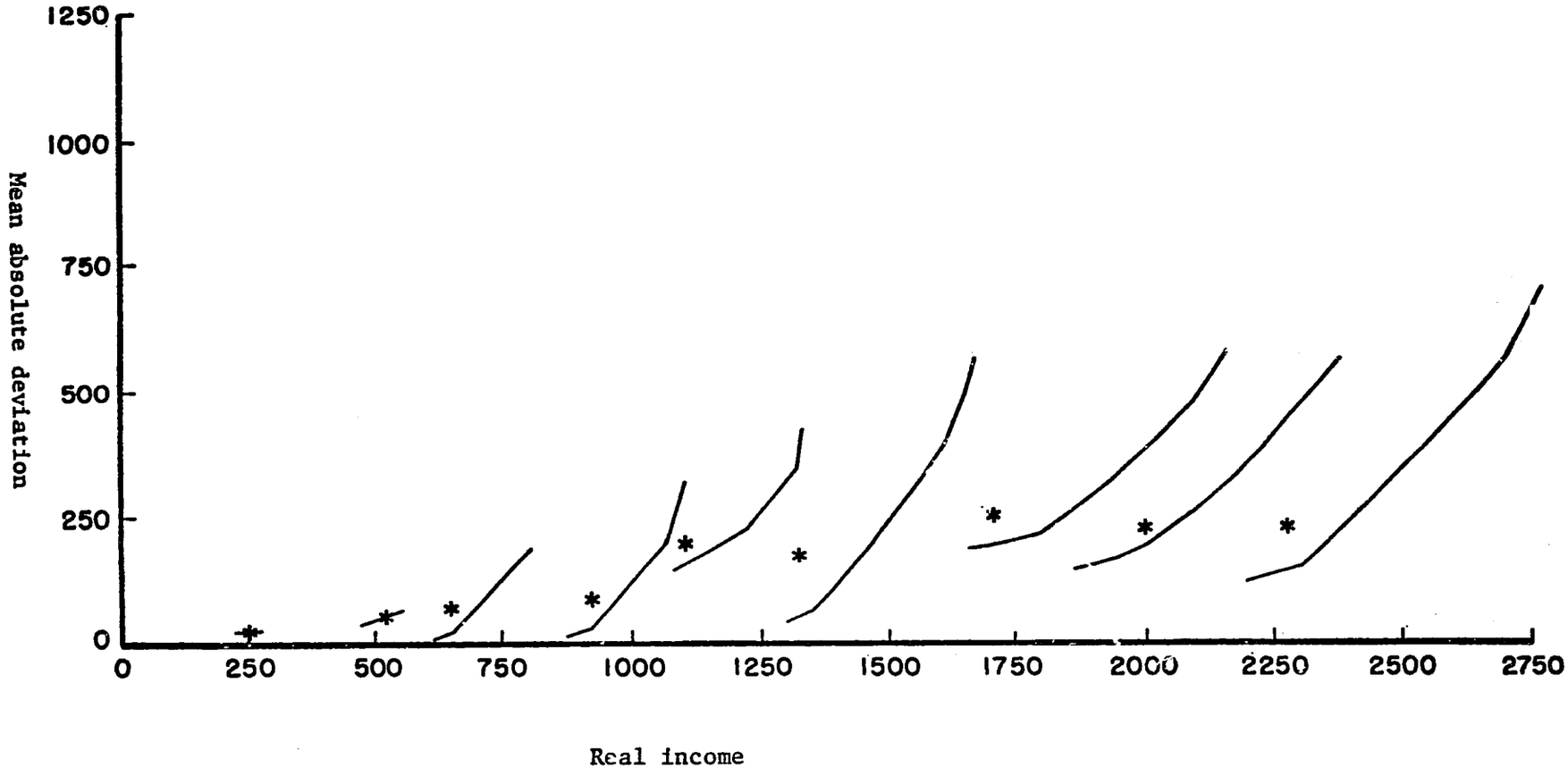

Figure 1. Estimated E-M frontiers and their relationship to observed cropping paterns for nine farmers.

*Corresponds to each observed farmer's cropping pattern for 1972-73.

Two conclusions may be drawn from Figure 1. First, observed incomes are generally much lower than the maximum levels corresponding to economic efficiency. Secondly, the points representing the observed cropping patterns are close to the estimated E-M frontiers. These results are surprisingly good considering the poor quality of the time-series data on yields and prices. Hence, the model does provide a reasonable framework for analyzing risk aversion. This conclusion is also borne out by the results summarized in Table 1. In our sample of 33 farmers, three have points on the E-M frontiers, and 14 would increase real income less than five percent if they shifted onto the E-M frontiers given the same level of risk; this increase is between five and 10 percent for 12 of the farmers, and over 10 percent for the other four farmers.

The two most important production resources at each farmer's disposal are land and family labor. Increases of land tend to shift the E-M frontiers upwards and to the right, whereas increases of family labor shift them to the right only. Hence, in the latter situation real income can be increased with no additional risk due to the reduction of expenditures on hired labor, but this is no longer possible when all hired labor is replaced by family labor.

To increase income to the maximum level, farmers must specialize in growing cash crops. This is illustrated in Table 2 for a representative farm. Specialization in cash crops is, however, associated with very high levels of risk as farmers are compelled to enter the market not only to sell their crops but also to buy food. Under these circumstances, a farmer's decision to grow jowar, a low-income food crop, may be readily understood. Subsistence farming is a rational response to risk in this situation.

Table 1. A comparison of the observed levels of income and risk with the E-M frontier for a sample of 33 farmers.

Number	Observed Levels		Maximum Real Income with the same Mean Absolute Deviation	Minimum Mean Absolute Deviation with the same Real Income
	Real Income	Mean Absolute Deviation		
1	276.60	35.90	319.70	10.07
2	247.30	21.80	266.80	20.99
3	275.50	29.03	285.34	27.06
4	398.70	61.03	398.70	61.03
5	425.44	67.39	428.20	43.15
6	511.84	58.92	517.60	40.92
7	454.44	67.83	489.92	47.72
8	574.70	63.90	627.04	13.21
9	643.96	73.22	696.64	19.16
10	494.30	24.10	514.48	21.15
11	651.90	36.00	686.52	28.41
12	510.95	122.81	512.33	122.23
13	748.27	132.51	748.27	132.51
14	688.70	48.20	699.87	41.29
15	745.60	27.90	760.39	12.34
16	781.40	105.30	815.03	85.54
17	849.70	103.30	987.83	54.58
18	1097.50	116.10	1210.85	11.39
19	1028.10	108.20	1092.91	59.61
20	705.60	98.20	779.17	49.14
21	916.60	90.10	969.55	32.93

Table 1 continued on the next page

Table 1 continued--

Number	Observed Levels		Maximum Real Income with the same Mean Absolute Deviation	Minimum Mean Absolute Deviation with the same Real Income
	Real Income	Mean Absolute Deviation		
22	1105.80	205.80	1183.93	158.55
23	1041.50	98.60	1041.50	98.60
24	1706.20	252.90	1838.59	198.05
25	1598.00	219.30	1675.86	161.73
26	1321.80	174.70	1447.96	48.57
27	2002.60	226.90	2043.60	198.10
28	1986.56	366.34	2080.97	308.64
29	2270.10	226.00	2379.02	144.57
30	2312.90	581.70	2467.14	485.44
31	2617.50	552.00	2804.51	438.68
32	3521.00	480.90	3636.65	385.84
33	5602.00	1037.80	5660.61	1015.97

Table 2. Crop combinations along the E-M frontier for the representative unirrigated farm

Real Income	Mean Absolute Deviation	Area Under					
		Rice 1	Rice 2[b/]	Jowar	Cotton 1	Cotton 2[b/]	Groundnuts[a/]
1530.50	138.90	0.90		4.37	1.63		
1580.50	150.90	0.90		4.42	1.10	0.08	0.40
1630.50	181.90	0.90		4.73	0.23	0.61	0.43
1680.50	223.90	0.45	0.45	4.75		1.19	0.06
1730.50	274.90	0.45	0.45	3.97		1.49	0.54
1780.50	327.00		0.90	3.82		2.18	
1830.60	389.10		0.90	3.31		2.69	
1880.70	456.40		0.90	2.54		3.00	0.46
1930.90	567.60		0.90	0.83		3.00	2.17
1948.40	629.40		0.90			3.00	3.00

a/ This is the low labor-intensive groundnuts activity. The high labor-intensive activity does not enter any of the solutions for this farmer. At low levels of income, groundnuts enter as part of a groundnuts-jowar rotation; at high income levels, it enters as part of a groundnuts-cotton rotation.

b/ These are the activities involving fertilizer use.

The model also provides an explanation of an apparent major misallocation of labor resources. Groundnuts is a highly labor-intensive crop, and consequently, if the man-land ratio is high it should be cultivated. However, the observed man-land ratio of groundnut growers is lower than for those growing cotton, the alternative cash crop. This may readily be understood in terms of risk aversion. Groundnuts tends to enter the E-M solutions at higher levels of income and risk than unfertilized cotton. Farmers with large families and small farms prefer the low risk crop although it is ill-suited to their resource endowments.

The E-M Frontier for a Representative Irrigated Farm

To analyze the impact of irrigation on the E-M frontier of a representative irrigated farm, we assume that resource endowments are the same except that unirrigated land is changed to irrigated land. The only growing activities included in the model are improved and high-yielding rice and wheat varieties, and sugarcane. Cropping combinations along the estimated E-M frontier are shown in Table 3. As incomes and risk increase, high-yielding rice replaces traditional rice varieties, and sugarcane replaces high-yielding wheat varieties.

As income rises, the associated increase of risk is less on the irrigated farm than on the unirrigated farm. A Rs. 100 increase in income results in approximately a Rs. 25 and Rs. 100 increase in the mean absolute deviation on the irrigated and unirrigated farm, respectively. However, the capital requirements increase more rapidly on the irrigated farm, a Rs. 100 increase of income requires approximately an additional Rs. 50 increase in capital expenditures compared to Rs. 20 on the unirrigated farm. These results are illustrated in Figures 2 and 3, and they suggest

Table 3. Crop combinations along the E-M frontier for the representative irrigated farm.

Real Income	Mean Absolute Deviation	Acres Under				
		Kollam	Masuri	Wheat	Wheat HYV	Sugarcane
5568.20	888.40	6.00			5.48	0.52
5644.50	895.10	6.00			5.29	0.71
5744.50	903.90	6.00			5.03	0.97
5844.50	912.80	6.00			4.78	1.22
5944.50	921.60	6.00			4.52	1.47
6044.50	930.40	6.00			4.27	1.73
6144.50	939.70	6.00			4.00	2.00
6244.50	949.60	6.00			3.71	2.28
6344.50	959.40	6.00			3.43	2.57
6444.50	969.30	6.00			3.14	2.86
6544.50	979.20	6.00			2.86	3.14
6644.50	989.10	6.00			2.57	3.43
6744.50	999.00	6.00			2.29	3.71
6844.50	1008.90	6.00			2.00	4.00
6944.50	1024.60	6.00			1.54	4.46
7044.30	1046.80	5.73	0.27		1.34	4.66
7145.50	1074.50	5.53	0.47		1.05	4.95
7248.70	1102.60	5.53	0.47		0.59	5.41
7349.80	1130.60	5.53	0.47		0.12	5.88
7450.40	1165.20	4.07	1.93			6.00
7508.00	1186.50	2.93	3.07			6.00

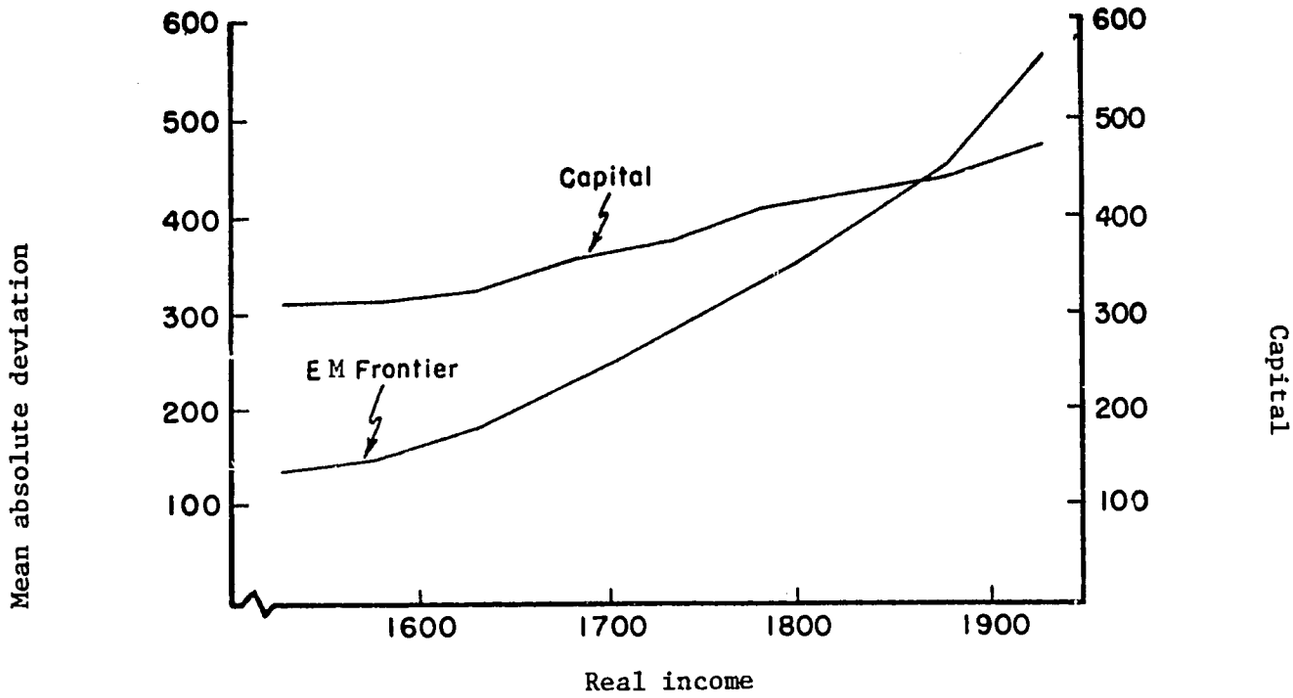

Figure 2. Risk and capital expenditures along the E-M frontier of the representative unirrigated farm.

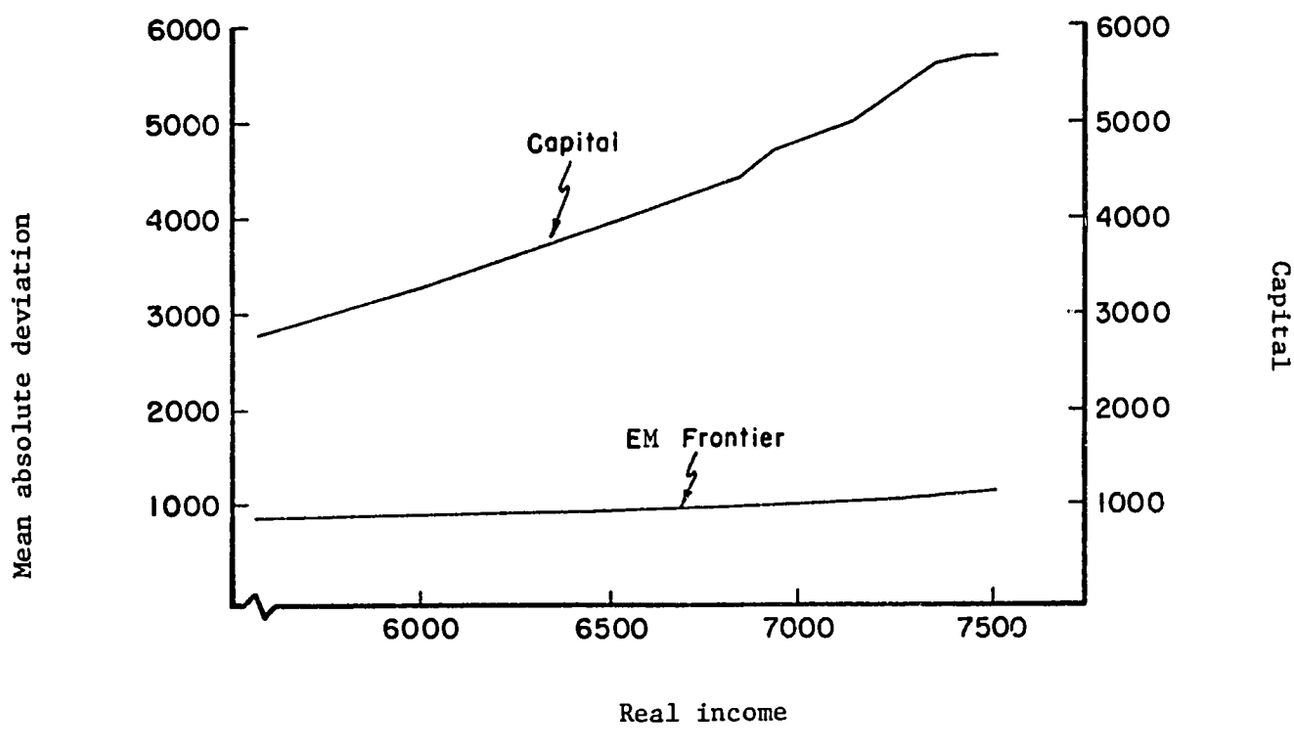

Figure 3. Risk and capital expenditures along the E-M frontier of the representative irrigated farm

that risk may create an effective barrier to increasing income under unirrigated conditions, but under irrigated conditions, difficulty in obtaining capital may be more important.

The risk involved in raising incomes even on irrigated farms may result in small farmers being unwilling to use available capital. The role of the cooperative is critical not only in making credit available but also in allowing more flexibility in the repayment of loans, such as automatically extending the loan in poor years. In contrast, lack of demand for credit is likely to make cooperative credit an ineffective tool to help small farmers in unirrigated zones.

Some Policy Implications

A. Price Stabilization

A price stabilization policy will often exacerbate the problem of risk for small farmers. In general, prices and yields are inversely correlated so that price fluctuations stabilize incomes by offsetting the effects of yield variation. Policies which result in stable prices, however, will benefit producers in situations where yields are relatively stable. For example, in an area with an assured water supply, and for a crop with relatively low disease risks, an agro-processing plant would stabilize farmers' incomes if it offered to buy the crop at a prearranged price. Price stabilization policies also may prove beneficial when prices and yields are positively correlated, as may occur when crop prices are not determined by local yields, but by levels of supply in a wider national or international market.

B. Yield Stabilization

Our results indicate that the main source of risk on unirrigated farms is yield and not price variability; this underlines the importance of policies to stabilize yields. The most obvious means to do this is to lessen the weather effect on yields through irrigation, either directly through canal schemes or indirectly by ensuring adequate and reliable electric power to areas with well-irrigation potential. There may also be scope for increased fertilizer use with deep placement to increase yields in years of poor rainfall. But the primary emphasis again rests on research, to develop high-yielding varieties which will tolerate low rainfall.

C. Raising Yields and Prices

Raising the mean yield or price of a crop will shift the E-M frontier down and to the right. Thus, a farmer can obtain the same mean income with lower risk. The results of our model indicate that the lower risk associated with crop diversification will tend to dampen the shift into more profitable crops after such exogenous yield or price increases. A yield-increasing technology for foodgrain crops will benefit primarily farms with a high proportion of their acreage under these crops (i.e. those with a high man-land ratio). Conversely, farms which use little of their production for home consumption will be the main beneficiaries of a rising price of either a food or a cash crop.

Conclusions

We conclude that the farmers studied in Surat District, India, make proficient decisions through use of the dual and competing objectives of

increasing income and reducing risk. Our evidence shows they are willing to reduce their incomes substantially from the maximum obtainable to lower the risk. Consequently, these farmers are not economically efficient in the sense that they do not maximize expected profits. Analysis of other decisions made by these farmers, such as levels of fertilizer use, adoption of new varieties, and the number of livestock maintained also suggests that profit maximization alone is not an adequate criterion for explaining farmers' decisions.

The central policy implication of those arguing for allocative efficiency in traditional agriculture has been the need for new technology. The difficulties of increasing small farmers' ability to bear risk lead us to a similar conclusion. However, our conclusions lend a new emphasis to the direction of research and the kind of policy considerations which may be relevant for those least able to bear risk--small farmers.

Footnotes

1/ Levels of rural employment are closely tied to the choice of cropping pattern (see G. M. Desai and M. G. G. Schluter).

2/ A similar conclusion is reached by J. D. Dillon and J. R. Anderson, who state "quantitative information on risk attitudes must be an important element in understanding farmers behavior in underdeveloped agricultures" (Dillon and Anderson, p. 31).

3/ Many applications of this type of procedure are related to selecting investment portfolios (see, for example, H. M. Markowitz).

4/ For example, a suitable statistical model which could be generalized for use with this type of pooled data is described by A. Zellner.

5/ A more detailed discussion of the factors influencing fertilizer use is given in M. G. G. Schluter, Chapter 5.

6/ An initial attempt to include the risk of growing crops for home consumption using the actual yield multiplied by the mean price was unsatisfactory as prices and yields tend to be negatively correlated. Consequently, under these assumptions it is less risky to grow a crop for market than for home consumption; market activities are the only ones selected on the E-M frontier.

7/ The only cost to farmers of storage are storage losses, which are probably small and the interest cost of holding this food. The latter may lead farmers to discount future consumption a little, implying that they consume more than average in years of excess and less in poor years (see U. J. Lele).

8/ All the information necessary for replacing these solutions is summarized in M. G. G. Schluter, Appendix A.

9/ This definition is similar to the more familiar E-V frontier, which is the term given when risk is measured by the variance of income.

10/ The minimum point of the E-M frontier is now shown at the origin as the land used is constrained to equal land available.

11/ Real income is equivalent to net cash income plus the value of all food and fodder purchased or grown for home consumption, and consequently, it is not affected by the home consumption constraints. All money values are given in current rupees.

12/ See M. G. G. Schluter, Chapters 5 and 6.

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Appendix: The Linear Programming Model

The linear programming model for computing points on the E-M frontier of a particular farm may be formally written as follows:

Select levels of $X_1, X_2, \ldots, X_N$ to minimize

$$M = \frac{1}{T} \sum_{t=1}^{T} \left| \sum_{n=1}^{N} (c_{nt} - \bar{c}_n) X_n \right|$$

subject to the constraints

$$\sum_{n=1}^{N} a_{nj} X_n \leq b_j \qquad j = 1,2,\ldots,J$$

$$\sum_{n=1}^{N} \bar{c}_n X_n = d$$

$$X_n \geq 0 \qquad n = 1,2,\ldots,N$$

where X_n is the nth activity representing the number of acres of the nth crop ($n = 1,2,\ldots,N$)

c_{nt} is the observed net cash income per acre for the nth crop in the tth year ($t = 1,2,\ldots,T$)

$\bar{c}_n$ is the mean net cash income per acre for the nth crop over the T years

M is the mean absolute deviation of net cash income over the T years

a_{nj} is the specified coefficient for the jth constraint corresponding to the nth crop ($j = 1,2,\ldots,J$)

b_j is the specified j^{th} constraint level

d is the mean net cash income which is parameterized from zero to the maximum attainable level.

An example of the numerical values used in the model for an unirrigated farm are summarized in the table that follows.

Data to derive time-series estimates of gross returns for each crop are based on three overlapping studies--"Studies into the economics of Farm Management in Surat District 1966-1968," "Changing Farm Production and Organization in Developing Agriculture, 1968-1970" and the senior author's own study which includes data for 1970/71 and 1971/72 and farmer's expected and actual cropping pattern for 1972/73; yield data for Surat District from the Office of the Director of Agriculture for Gujarat State, and price data from the Bureau of Economics and Statistics, Gujarat State, are used in the absence of alternative sources. The authors are grateful to the following for making these data available: Directorate of Economics and Statistics, Government of India; Department of Agricultural Economics, Baroda University; Office of the Director of Agriculture; State Income Unit, Bureau of Economics and Statistics, Government of Gujarat.

Appendix Table: The linear programming matrix for unirrigated farms.[a]

	Rice for home consumption		Rice for sale		Jowar for home consumption		Jowar for sale		Groundnuts (with jowar)		Groundnuts (with cotton)	
	Low fertilizer	High fertilizer	Low fertilizer	High fertilizer	No rotation	With cotton or groundnuts	No rotation	With cotton or groundnuts	Low labor	High labor	Low labor	High labor
Objective function												
Rice land	1	1	1	1								
Land other					1	1	1	1	1	1	1	1
Transplanting labor	21	21	21	21								
Family labor for transplanting	- 2	- 2	- 2	- 2								
Weeding labor	35	35	35	35	18	18	18	18	15	40	15	40
Harvesting labor rice	25	30	25	30								
Family labor harvesting rice	- 2	- 2	- 2	- 2								
Harvesting labor groundnuts									27	40	27	40
Family labor harvesting groundnuts									- 4	- 5	- 4	- 5
Harvesting labor jowar					5	5	5	5				
Family labor harvesting jowar					- 1	- 1	- 1	- 1				
Harvesting labor cotton												
Family labor harvesting cotton												
Capital requirement	28	70	28	70	10	10	10	10	35	35	35	35
Savings												
Borrow co-operative												
Borrow moneylender												
Home consumption rice	20.6	25.65			3.74	3.74						
Home consumption jowar					11.7	11.7						
Dry fodder value	49.6	61.9	49.6	61.9	21.2	21.2	21.2	21.2	25.8	30.8	25.8	30.8
Rotation 1						1		1	- 1	- 1		
Rotation 2											- 1	- 1
Maximum groundnut (acres)									1	1	1	1
Maximum jowar (acres)					1	1	1	1				
Maximum cotton (acres)												
Deviation 1966			-166.2	-197.6			-124.3	-124.3	-121.3	-121.3	-121.3	-121.3
Deviation 1967			-52.2	-64.2			70.0	70.0	-11.2	-11.2	-11.2	-11.2
Deviation 1968			6.2	-26.6			52.6	52.6	36.9	36.9	36.9	36.9
Deviation 1969			108.4	136.8			95.8	95.8	240.8	240.8	240.8	240.8
Deviation 1970			55.2	104.1			-40.6	-40.6	-38.5	-38.5	-38.5	-38.5
Deviation 1971			48.6	47.5			-53.5	-53.5	-106.7	-106.7	-106.7	-106.7
Real income	321.4	400.4	321.4	400.4	273.2	273.2	273.2	273.2	340.2	422.1	340.2	422.1
Cash income			271.8	338.5			252.0	252.0	314.4	391.3	314.4	391.3

a/ All labor coefficients are measured in man days, land in acres, capital and deviations in Rs., and home consumption in maunds (1 maund = 20 kg. in Gujarat).

b/ These coefficients change from farmer to farmer, reflecting different numbers of family members, different interest rates from moneylenders for credit or different constraint levels.

c/ Parameterized from zero to maximum attainable level.

Appendix Table: The linear programming matrix for unirrigated farms.[a]

	Cotton (with jowar)		Cotton (with groundnuts)													
	Low fertilizer	High fertilizer	Low fertilizer	High fertilizer	Savings	Co-operative	Moneylender	Buy rice	Buy jowar	Buy fodder	Sell fodder	Hire labor weeding	Hire labor planting and harvesting rice	Hire labor harvesting other crops	Family labor planting rice
Objective function															
Rice land															
Land other	1	1	1	1											
Transplanting labor													- 1		- 3[b]
Family labor for transplanting															1
Weeding labor	21	21	21	21								- 1			
Harvesting labor rice													- 1		
Family labor harvesting rice															
Harvesting labor groundnuts														- 1	
Family labor harvesting groundnuts															
Harvesting labor jowar														- 1	
Family labor harvesting jowar															
Harvesting labor cotton	9	12	9	12											- 1
Family labor harvesting cotton	- 2	- 2	- 2	- 2											
Capital requirement	9	33	9	33	- 1	- 1	- 1					1.5	2.0		
Savings					1										
Borrow co-operative						1									
Borrow moneylender							1								
Home consumption rice								1							
Home consumption jowar									1						
Dry fodder value										1	- 1				
Rotation 1	- 1	- 1													
Rotation 2			1	1											
Maximum groundnut (acres)															
Maximum jowar (acres)															
Maximum cotton (acres)	1	1	1	1											
Deviation 1966	-152.7	-278.3	-152.7	-278.3				- 1.47	1.78						
Deviation 1967	-11.9	-60.6	-11.9	-60.6				0.62	- 0.25						
Deviation 1968	95.4	111.3	95.4	111.3				- 1.71	1.88						
Deviation 1969	40.5	247.6	40.5	247.6				0.88	- 4.27						
Deviation 1970	50.3	48.1	50.3	48.1				1.00	1.26						
Deviation 1971	-21.6	-68.1	-21.6	-68.1				0.68	- 0.4						
Real income	286.4	414.9	286.4	414.9	- 1.0	- 1.09	- 1.25[b]							- 2.0	
Cash income	286.4	414.9	286.4	414.9	- 1.0	- 1.09	- 1.25[b]	-13.20	-17.33	- 1.0	1.0			- 2.0	

a/ All labor coefficients are measured in man days, land in acres, capital and deviations in Rs., and home consumption in maunds (1 maund = 20 kg. in Gujarat).

b/ These coefficients change from farmer to farmer, reflecting different numbers of family members, different interest rates from moneylenders for credit or different constraint levels.

c/ Parameterized from zero to maximum attainable level.

Appendix Table: The linear programming matrix for unirrigated farms.[a]

	Family labor harvesting rice	Family labor harvesting groundnuts	Family labor harvesting jowar	Family labor harvesting cotton	Real income	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Constraints
Objective function						- 0.33	- 0.33	- 0.33	- 0.33	- 0.33	- 0.33	MAX
Rice land												= 0.9[b]
Land other												= 6.0[b]
Transplanting labor												≤ 0
Family labor for transplanting												≤ 0
Weeding labor												≤ 60[b]
Harvesting labor rice	- 3[b]											≤ 0
Family labor harvesting rice	1											≤ 0
Harvesting labor groundnuts		- 3[b]										≤ 0
Family labor harvesting groundnuts		1										≤ 0
Harvesting labor jowar			- 3[b]									≤ 0
Family labor harvesting jowar			1									≤ 0
Harvesting labor cotton				- 3[b]								≤ 0
Family labor harvesting cotton				1								≤ 0
Capital requirement												≤ 0
Savings												≤ 0[b]
Borrow co-operative												≤ 0[b]
Borrow moneylender												≤ 500[b]
Home consumption rice												= 26[b]
Home consumption jowar												= 45[b]
Dry fodder value												≥ 152[b]
Rotation 1												= 0
Rotation 2												= 0
Maximum groundnut (acres)												≤ 6.0[b]
Maximum jowar (acres)												≤ 6.0[b]
Maximum cotton (acres)												≤ 6.0[b]
Deviation 1966						1						≤ 0
Deviation 1967							1					≤ 0
Deviation 1968								1				≤ 0
Deviation 1969									1			≤ 0
Deviation 1970										1		≤ 0
Deviation 1971											1	≤ 0
Real income					- 1							= 0
Cash income												= d[c]

a/ All labor coefficients are measured in man days, land in acres, capital and deviations in Rs., and home consumption in maunds (1 maund = 20 kg. in Gujarat).

b/ These coefficients change from farmer to farmer, reflecting different numbers of family members, different interest rates from moneylenders for credit or different constraint levels.

c/ Parameterized from zero to maximum attainable level.