AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

1. SUBJECT CLASSIFICATION

A. PRIMARY: Agriculture — AE10-0000-G635

B. SECONDARY: Agricultural economics--India

2. TITLE AND SUBTITLE

Differential rates of adoption of the new seed varieties in India: the problem of the small farm

3. AUTHOR(S)

Schluter,M.G.G.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1971	69p.	ARC IN631.5.S346

7. REFERENCE ORGANIZATION NAME AND ADDRESS

Cornell

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

(In Occasional paper no.47)

9. ABSTRACT

10. CONTROL NUMBER

PN-RAA- 331

11. PRICE OF DOCUMENT

12. DESCRIPTORS

India
Innovations
Varieties
Farms,small
Grain crops

13. PROJECT NUMBER

14. CONTRACT NUMBER

CSD-2805 Res.

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

August, 1971

Differential Rates of Adoption of the New Seed Varieties in India; The Problem of the Small Farm

by

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Occasional Paper No. 47
Department of Agricultural Economics
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USAID-Employment and Income Distribution Project

ACKNOWLEDGEMENTS

I would like to thank sincerely Professor John W. Mellor who provided the initial stimulus to tackle this subject. His deep insight into the problems of Indian agriculture was invaluable in interpretation of the results.

Special thanks are due also to Professor Timothy D. Mount, who gave constant guidance in the formulation of the model, and throughout the course of the analysis.

I am grateful to Bhupat M. Desai for his comments on an earlier draft of this paper.

I am responsible, of course, for any errors remaining in the analysis.

I would also like to thank USAID for providing the financial support for this study.

PREFACE

There is controversy as to whether or not the new high yielding crop varieties increase income disparities between small and large farmers. On the one hand the new technologies appear to be technically neutral to scale. On the other hand, economic and political factors affecting access to inputs and credit, and different attitudes toward uncertainty may all inhibit spread of cost decreasing innovation to small farms.

Michael Schluter attacks one facet of this controversy by reviewing the now copious body of research results flowing from India which measure the extent to which small cultivators lag in adoption of the high yielding varieties, and the nature of potential causal factors. This study is useful in its own right and seminal for future study of this problem. An intensive study of behavior of small farmers with respect to uncertainty is being initiated on the basis of the findings of this study.

This study would not have been possible without the wealth of carefully collected data and analysis available from India. The various Agro-Economic Research Centres have published a series of in depth studies analyzing farmers' response to the High-Yielding Varieties Programme. The reports contain detailed information about the problems encountered in diffusion of the new varieties, and about factors influencing adoption behavior. A second series of studies, sponsored by the Planning Commission, was undertaken by Programme Evaluation Organisation; these give a clear picture of overall trends in the diffusion pattern over time throughout India. Schluter's study brings together the data from these reports relating to differential rates of adoption between farm size groups and causal factors underlying the relationship between adoption and farm size. An overview of these studies is particularly useful in demonstrating the considerable variability among regions and crops in the relative adoption rate of small and large farmers.

This study is one in a series being carried out at Cornell University as part of a USAID-financed contract for research on the relation between technological change in agriculture and income distribution. We are grateful for the assistance provided by the Agriculture and Fisheries Division of USAID, and, in particular to Arthur Coutu of that Division.

The intellectual framework for these studies of the relation between technological change in agriculture and income distribution is provided by two previous publications in this series as follows:

OccasionalPaper #42 by Uma J. Lele and John W. Mellor, "The Political Economy of Employment Oriented Development" and Occasional Paper #43 by John W. Mellor and Uma J. Lele, " A Labor Supply Theory of Economic Development." Several studies are now underway dealing with various aspects of these processes.

A basic objective of the contract with USAID for the conduct of this research is not only to produce useful research results but also to provide a structure research experience so as to enlarge the pool of trained manpower for the analysis of such problems. For this purpose, the research in this project is accomplished primarily by Ph.D. candidates at Cornell University who use the specific studies conducted as Ph.D. dissertations. The definition of the over-all project has purposefully been kept broad and flexible to facilitate the attainment of this additional objective. This study by Michael Schluter is part of that program and is drawn from his M.Sc. dissertation, completed at Cornell University in 1971, and provides the basis for a much more intensive study to be pursued as a Ph.D. dissertation.

John W. Mellor

Ithaca, New York
August, 1971

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CHAPTER I

INTRODUCTION

The small farm has received considerable attention in recent discussion of agricultural policy in India for two reasons. First, it is thought that rates of adoption of the new varieties differ between farm size groups, resulting in widening income disparities in rural areas. Secondly, small farms occupy a large number of people and contribute significantly to total agricultural production. In 1960-61, there were over 135,000,000 people, constituting 27,000,000 families, living on farms with between half an acre and five acres.[1] This group operated 64,000,000 acres, about 20 percent of the total area operated, and generated about 25 percent of total output prior to the introduction of the new varieties.[2]

The objective of this study is to examine whether there are differences in rates of adoption of the new varieties between farm size groups, and if so, the reasons for the differences.

In this analysis, a farmer is defined to have adopted if he has put any part of his acreage under the new varieties. We also consider on what proportion of acreage under the crop he uses the new varieties. Level of use of variable inputs may have more of an influence on the income of adopters than the proportion of acreage under the new varieties,[3] but unfortunately, comparative data were not available for a study based on a package of improved practices.

In Chapter 2, we consider a priori reasons for expecting some relationship between farm size and adoption of the new varieties.

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[1] National Sample Survey, No. 176, p. 49.

[2] D. Narain, Distribution of the Marketed Surplus of Agricultural Produce by Size-Level of Holding in India, 1950-51, Occasional Paper No. 2, Institute of Economic Growth, Delhi, 1961.

[3] V. S. Vyas, D. S. Tyagi, and V. N. Misra, Significance of the New Strategy of Agricultural Development for Small Farmers, Agro-Economic Research Centre, Sardar Patel University, 1968.

In Chapter 3, we examine two hypotheses:

1. That a positive relationship exists between adoption of the new varieties and farm size.

2. That acreage under the new varieties, as a proportion of total acreage under the crop, is unrelated to size of farm.

Also, differences in the diffusion pattern with respect to size of farm between regions, crops, years and seasons are analyzed.

Two sources of data are used in this study. The first is a series of studies undertaken by the Agro-Economic Research Centres, which cover paddy, wheat, maize and bajra in the period 1966-67 to 1968-69. The aim of these studies is to evaluate the response to the High-Yielding Varieties Programme in a limited area, generally four villages in a district, and to examine closely factors affecting the adoption behavior of about 100 farmers. The villages were selected because they showed relatively high levels of adoption, so that results based on these studies alone might be biased.

The reports of the Programme Evaluation Organisation of the Planning Commission give an over-all view of the response to the High-Yielding Varieties Programme. Thus, for the kharif season of 1967, a sample of 1,487 farmers was taken from 44 Development Blocks. These reports consider all five of the main foodgrain crops--paddy, wheat, maize, bajra and jowar from the rabi crop of 1966-67 to the kharif crop of 1968-69.[1] For each crop, they include all those states growing the crop to any significant extent.

The main limitation of both sets of data for our purposes is the aggregation of individual farm observations into between five and eight farm size groups. With so few degrees of freedom, a multiple regression framework is unsatisfactory, so we use a linear regression model relating adoption only to farm size. A linear regression model is unsatisfactory when the dependent variable is a proportion, so the main results are confirmed using a logit mode.[2]

---

[1] A list of all the reports used in the Analysis is given in Section I of the Bibliography.

[2] For a full discussion of the statistical method of analysis, see Appendix B.

The validity of using farm size as the only independent variable in the regression model is tested in Chapter 4. Studies by the Agro-Economic Research Centres contain data by size of farm group relating to irrigation and credit availability, and the extent to which land is leased-in. Using a linear regression model, we see if there are any differences between adopters and non-adopters with respect to these factors, and if there is any relationship between these factors and farm size. This is supplemented by analysis of data from the Programme Evaluation Organisation reports, showing co-operative membership in relation to size of farm.

The conclusions are summarized in Chapter 5, and we indicate the major implications of the analysis for agricultural policy.

CHAPTER II

REASONS FOR EXPECTING A RELATIONSHIP BETWEEN ADOPTION AND FARM SIZE

In this chapter, we examine a priori reasons for expecting a relationship between the proportion of farmers using the new seeds on any part of their acreage and farm size, and between proportion of acreage put under the new varieties and farm size.

Physical Inputs

Seed, fertilizer and pesticides are almost perfectly divisible in physical terms. However, between 1966 and 1968, the period under study, small farms may have found it difficult to obtain fertilizer since there was a shortage of supply, and political factors may have entered into its allocation. Human labor may be hired in small units, but there may be diseconomies of farm size arising from the high costs of supervising a large labor force. Since the new varieties require additional labor, the problem of supervision may be an important disincentive to adoption for large farms. Bullock and tractor labor are perfectly divisible as long as their services may be hired-in and there is competition between those hiring out these services. In the case of irrigation water, there may be significant economies of size in areas suited to tube-well irrigation.

Capital

The level of cash expenditure determines the level of increase in profitability from adoption of the new varieties. For example, at a low level of fertilizer use, yields of the new wheat varieties are little different from those of the traditional varieties, whereas at high levels the difference is considerable.[1]

Timely irrigation is important in the context of the new varieties both to reduce yield variability and increase average yield.[2] Thus,

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[1] R. W. Cummings, Jr., R. W. Herdt, and S. K. Ray, "New Agricultural Strategy Revisited", Economic and Political Weekly, Vol. III, No. 43, p. A-15.

[2] See, T. V. Moorti, A Comparative Study of Well Irrigation in Aligarh District, India, Occasional Paper No. 29, Department of Agricultural Economics, Cornell University, USAID Prices Research Project, p. 23.

increased expenditure on this input may be a necessary condition for adoption. Additional cash expenditure has been shown to give very high returns on the new varieties relative to traditional varieties in many areas.[1]

The nature of this credit requirement may differ between crops. Desai has shown, for example, that nitrogen should be increased by a greater margin to reach optimal yields for wheat than for rice.[2] But new rice varieties may respond more highly to improvements in irrigation control.

There are four main sources of credit available to the cultivator. The availability of "own funds" or wealth is closely related to farm size. Wealth is related to cash income in preceding years, which is higher for large farms. Availability of credit from money-lenders or commercial banks is also related to farm size since size of loan is limited by the amount of collateral a farmer can provide, and the main form of collateral is land. The maximum loan a co-operative can give is related both to the value of share capital held, and the amount of collateral the farm can provide. The small farm is at an additional disadvantage to the extent that political factors enter into the allocation of funds. Finally, the possibility of borrowing from relatives is probably related to farm size.

Fixed Costs

Adoption of the new varieties involves certain fixed costs. Time must be spent in obtaining variable inputs, and in obtaining information about methods of cultivation. Time has an opportunity cost in terms of production or leisure. Also, the farmer may require some minimum level of remuneration to overcome inertia. The small farmer may be unable to spread the fixed costs over a

---

[1] V. P. Shukla, An Economic Analysis of Farm Resource Use, Jabalapur District, Madhya Pradesh, India, 1967-68, Occasional Paper No. 26, Department of Agricultural Economics, Cornell University, USAID Prices Research Project, p. 68.

[2] G. M. Desai, Growth of Fertilizer Use in Indian Agriculture - Past Trends and Future Demand, Occasional Paper No. 24, Department of Agricultural Economics, Cornell University, USAID Prices Research Project.

larger output by using variable inputs intensively, since he lacks credit. Thus, he must put a relatively high proportion of his acreage under the new varieties in order to reach the level of output at which it becomes profitable to adopt.

Tenancy

If the tenant must meet the fixed costs, he is less likely to innovate than the owner-operator. For example, the level of output necessary to cover fixed costs is twice as great for the sharecropper who pays 50 percent of his crop to the landlord as for the owner-operator. The level of output at which it becomes profitable to adopt for a tenant paying a lump sum rent is also higher than for the owner-operator, since the rent increases the tenant's fixed costs.

Secondly, the sharecropper will be at a disadvantage relative to the owner-operator if the landlord pays for a lower proportion of the inputs than he receives of the crop. In such a case, the tenant receives a lower return in proportional terms than the owner-operator for any input level.

Uncertainty

Farmers probably consider that use of the new varieties involves uncertainty. This may be due to variability of yields of the new varieties being greater, inexperience in methods of cultivation, or bad experience with previous recommendations of the Extension Service.

If the new varieties lower production in a given year, a large farmer is unlikely to experience a deficit in terms of the basic consumption needs of the family. But a small farmer markets only sufficient to cover essential cash needs,[1] so that the household is unable to lower the quantity marketed to meet essential consumption requirements. The farmer must therefore lower his level of consumption, which is probably already close to subsistence, or obtain a loan, which will involve high interest rates and may even result in the rights to his land being affected. For these reasons, a small farmer may be less willing to accept an increase in uncertainty than a large farmer, and therefore may be less willing to adopt the new varieties.

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[1] D. Narain, op. cit., p. 8.

Conclusions

Three factors lead to the hypothesis that as farm size increases, the proportion of farmers adopting the new varieties also increases. Small farmers have less credit available, and in the period under study may have found it relatively difficult to obtain physical inputs. Also, small farmers may be unable to accept the uncertainty involved in adoption.

Small farmers may try and overcome the credit shortage and uncertainty by experimenting with the new varieties on a small part of their acreage. This suggests the hypothesis that the proportion of acreage under the new varieties increases as farm size increases. However, with fixed costs it is not profitable to put a very small acreage under the new varieties, which suggests the opposite hypothesis, that there is an inverse relationship between the proportion of acreage put under the new varieties and farm size.

CHAPTER III

THE RELATIONSHIP BETWEEN ADOPTION OF THE NEW VARIETIES AND FARM SIZE

In this chapter, we examine the relationship between adoption and farm size, and consider differences in the relationship between regions, crops, years and seasons. We look at a total of 75 areas, 25 of which were studied by the Agro-Economic Research Centres, and 50 by the Programme Evaluation Organisation. Secondly, we analyze differences in the proportion of acreage adopters put under the new varieties.

Adoption and Farm Size: Analysis of Data from the Agro-Economic Research Centres

Hypothesis 1: That the proportion of farmers adopting the new varieties is unrelated to size of farm. Table 1 summarizes the results from the linear regression model for 20 areas studied by the Agro-Economic Research Centres.[1] In 17 of the 20 areas, there is a significant positive relationship between adoption and farm size, indicating that adoption levels increase with farm size.

Then the regions are grouped on the basis of crop, to test the hypothesis for each crop separately.[2] Wheat is the only crop for which the relationship is not significant, and this conclusion is based on a single area. We argue later in the chapter that this area is not representative of wheat-growing areas in general.

Next we tested the hypothesis that all the regions showed the same relationship between adoption and farm size. The hypothesis was rejected at the 0.5 percent level.[3]

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[1] The data are also tested with the logit model. The results, which confirm those from the linear model, are given in Table 10, Appendix A.

[2] The results are given in Table 11, Appendix A.

[3] See Table 22, Appendix A.

TABLE 1. ESTIMATED LINEAR REGRESSION FOR ADOPTION AGAINST FARM SIZE USING AGRO-ECONOMIC RESEARCH CENTRE DATA

				UNRESTRICTED MODEL				RESTRICTED MODEL	
Area By Crop	Crop Year	Season	No. Obs.	Estimated Intercept	Estimated Slope	Estimated t Ratio	Sum of Squared Residuals	Estimated Intercept	Sum of Squared Residuals
Paddy									
W. Bengal 1	67	K	8	13.28	2.83	4.37*	11003.48	33.71	46103.80
W. Bengal 2	67	K	7	52.40	4.61	2.87*	25258.20	69.85	66991.04
W. Bengal 1	68	K	8	38.06	2.75	4.07*	12277.14	58.70	46100.47
W. Bengal 2	68	K	7	86.29	0.97	3.57*	1161.32	90.34	4117.78
Andhra Pradesh 1	68	K	5	9.26	1.42	6.07*	16067.54	23.79	213239.3
Andhra Pradesh 2	68	K	5	14.33	1.04	2.90*	13041.97	20.79	49561.35
Andhra Pradesh 1	68	R	5	58.78	1.61	2.02	14919.48	69.36	35179.14
Andhra Pradesh 2	68	R	5	37.22	1.82	3.38*	29526.27	49.27	141711.4
Orissa	66	K	5	-4.17	4.81	3.87*	13988.19	12.82	83757.80
Bajra									
Gujarat 1	67	K	6	20.43	4.96	3.63*	15397.28	42.91	65994.57
Gujarat 2	67	K	6	-0.20	3.96	4.64*	10323.99	12.51	65882.68
Gujarat 3	67	K	6	6.18	5.43	7.77*	17480.28	28.63	281365.7
Gujarat 1	67	S	6	49.12	5.74	1.67	7203.09	61.86	12253.60
Gujarat 2	67	S	7	38.69	8.07	3.09*	16090.52	49.83	46954.38
Gujarat 3	67	S	7	6.62	4.99	5.71*	2323.536	16.03	17498.66
Gujarat 4	68	K	8	1.64	3.18	9.56*	4720.62	13.64	76683.74
Gujarat 5	68	K	8	11.57	2.85	6.23*	17994.03	44.89	134420.0
Maize									
Bihar 1	68	K	5	16.11	6.99	5.53*	5290.04	48.15	59175.49
Bihar 2	68	K	7	19.70	2.65	1.64	68778.54	28.29	105666.70
Wheat									
Rajhasthan	68	R	8	29.15	0.90	3.54*	31489.80	44.40	97210.65

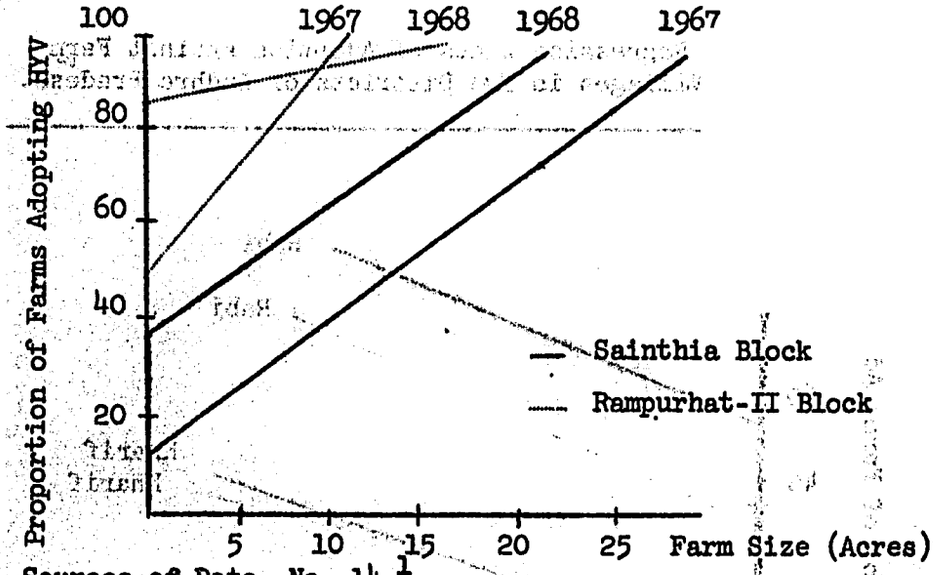
Source: Sources of Data Nos. 2, 3, 6, 7, 9, 10, 11, 12, 14, 15.

*Significant at 5% Level

A more detailed study of the individual regions follows, in order to bring out differences in adoption behavior. Because the regressions were based on such a small number of observations, statistical tests lacked power; so it was not possible to identify with this tool some of the differences within and between regions which might be important from an economic standpoint. For this reason some of the more obvious differences between regions will be discussed, even though a statistical test may show that the difference is not significant.

West Bengal: Surveys were carried out in two development blocks, Sainthia and Rampurhat-II, in the kharif seasons of 1967 and 1968. Both areas are primarily rice-growing. The estimated regression lines from these data are shown in Figure 1.

Figure 1. Estimated Regression Lines of Adoption Against Farm Size for Villages in Two Blocks of West Bengal.



Source: Sources of Data, No. 14.[1]

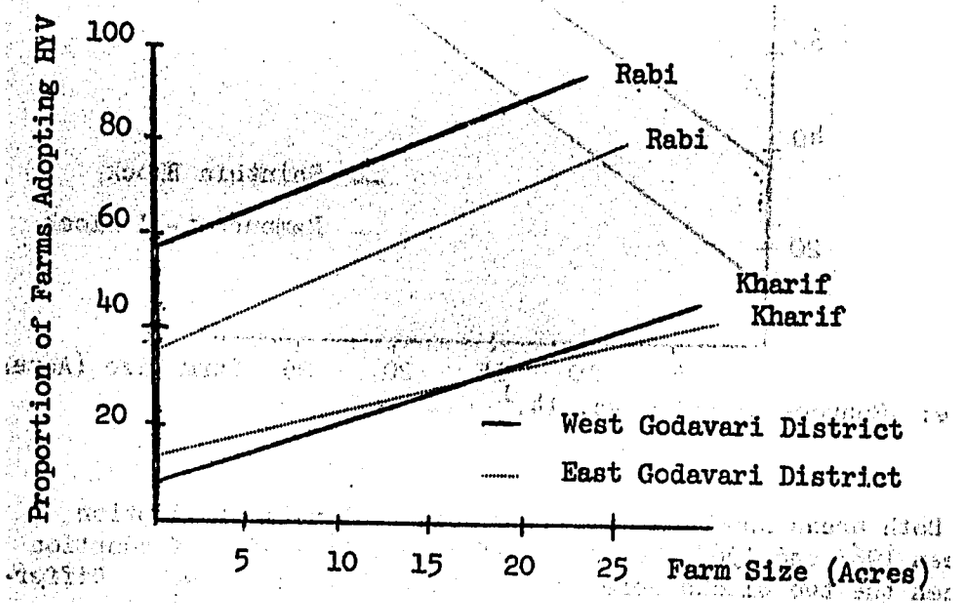
Both areas showed marked increases in levels of adoption between 1967 and 1968, but the differences in levels of adoption between the two blocks were greater in 1968 than in 1967. Differential rates of adoption over time will lead necessarily to widening absolute differences, until the limit of 100 percent adoption on all farms is approached.

[1] A list of the sources of data is given in Section I of the Bibliography.

Adoption differentials between farm size groups were approximately the same between 1967 and 1968 in Sainthia Block, but had narrowed considerably in Rampurhat-II. The reason for the change in the latter lies in the very high levels of adoption in all size of farm groups attained by the kharif season of 1968-69. If adoption ceases to be closely related to farm size only when almost all farms have adopted the new varieties, income differentials resulting from the new varieties will persist longest in areas where the over-all rate of adoption is slowest. Thus, it becomes critical to know what factors lead to a rapid over-all rate of adoption. In this case, the superior availability of irrigation in Rampurhat-II was probably one of the main reasons for the faster rate of adoption in that block.

Andhra Pradesh: Surveys were conducted in two rice-growing areas, East and West Godavari districts, in the kharif and rabi seasons of 1968-69. The estimated regression lines from these data are shown in Figure 2.

Figure 2. Estimated Regression Lines of Adoption Against Farm Size for Villages in Two Districts of Andhra Pradesh.



Source: Sources of Data, Nos. 2 and 3.

Adoption levels are much higher in the rabi than in the kharif season. The main reason is the greater profitability of the new varieties under the weather conditions of the rabi season. For maximum yields, IR-8 requires a high degree of sunlight. Also the low rainfall in the rabi season gives a greater degree of water control to those with irrigation than is present in the kharif season. A second reason may be that the most successful of the new varieties, IR-8, was available for only one kharif season prior to 1968-69, but for two rabi seasons.

Both districts had very low levels of adoption in the kharif season, but in the rabi season, the proportion of farmers who adopted was higher in West Godavari in all farm size groups. A longer period in the package program may have made farmers in West Godavari better equipped to take advantage of IR-8 when it was most profitable.

Differences in adoption levels between farm size groups were similar between the two seasons, although the absolute level of adoption was much higher in the rabi season. This lends support to the hypothesis outlined above, that differences in adoption rates between farm size groups do not diminish until almost all farmers have adopted.

West Bengal and Andhra Pradesh Contrasted: Differences in adoption levels between farm size groups were generally less for the districts studied in Andhra than for those studied in West Bengal. This is probably due to the superior availability of irrigation in Andhra. Irrigation reduces yield variability of the new varieties, so that a greater proportion of small farmers are willing to adopt.

Gujarat: In Piplag, Khadol and Asodar (Gujarat 1, 2 and 3 in Table 1), differences in levels of adoption between size of farm groups were found to be uniformally greater in the summer than in the kharif season.[1] This may be explained in terms of yield variability. Large farmers have greater access to irrigation water, so that they experience lower yield variability than do small farmers. In the summer, there is greater dependence on irrigation, so the difference between farm size groups in their experience of yield variability is greater in the summer, leading to greater disparities in adoption levels.

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[1]The summer season follows the kharif and rabi seasons.

Piplag showed higher levels of adoption in both the kharif and rabi seasons than either Khadol or Asodar. Irrigation is probably again an important factor; Piplag has 56 percent of net sown area irrigated, whereas Asodar has only 37 percent and Khadol 35 percent.

Next Nadiad and Dehgam Talukas (Gujarat 4 and 5 in Table 1) are contrasted. Nadiad was found to be more progressive, had a higher proportion of irrigable land, but an average size of holding of only 3.71 acres, compared to 12.78 acres in Dehgam. The greater availability of irrigation in Nadiad leads us to expect farmers there to be better able to adopt than in Dehgam, since the level of uncertainty, in terms of yield variability, would be less than in Dehgam. However, the average size of holding was greater in Dehgam, and this region was found to have a higher mean level of adoption, indicating that the irrigation factor was more than offset (in this case) by the influence of farm size.[1]

Bajra and Paddy Contrasted: In general, differences in levels of adoption between size of farm groups are greater in bajra than in paddy-growing areas. A one-acre increase in farm size typically leads to a 5 percent or more increase in the probability of adoption in a bajra-growing area in any given season or year, compared to 2-3 percent in rice-growing areas.

There are probably two main reasons for this. The first is a specification problem. Income per acre is considerably higher in paddy relative to bajra-growing areas. Therefore, credit and uncertainty cease to be constraints to adoption at a smaller farm size. Secondly, the increase in yield variability in moving from traditional to the new varieties may be less in paddy than in bajra-growing areas owing to greater availability of irrigation in the former. For this reason also, uncertainty will cease to be a constraint to adoption at a smaller farm size, and differences in adoption levels between farm size groups will be less.

Adoption and Farm Size: Analysis of Data from the Programme Evaluation Organisation Reports

The data from the Programme Evaluation Organisation Reports are more aggregated than those from the Agro-Economic Research Centres. It is not possible to compare the data for individual

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[1]See, V. S. Vyas, D. S. Tyagi and V. N. Misra, op. cit., p. 22.

regions as no background information on the development blocks sampled is given in the reports, and different development blocks are selected for the studies incorporated in each report. We may only hope to find whether the data support the central and most general findings of the earlier section.

For each crop, the linear and logit models are used to test the hypothesis that adoption is unrelated to size of farm. Tables 11, and 13 to 18, in Appendix A summarize the statistical results.

Paddy, Bajra, Maize: The hypothesis that adoption is unrelated to farm size was rejected at the 0.5 percent level for each of these crops. Positive slope coefficients indicate the familiar result that adoption levels increase as farm size increases, confirming the findings of the studies undertaken by the Agro-Economic Research Centres.

Wheat: The hypothesis that adoption is unrelated to farm size was rejected at the 0.5 percent level, indicating a significant positive relationship exists. Our earlier finding, based on a single district in Rajhasthan, was that there was no significant relationship. Since in the Programme Evaluation Organisation reports, eleven blocks were studied, five of which had regression coefficients significantly positive, there is clearly a positive relationship between adoption and farm size in many wheat growing areas.[1]

Even when 98 percent of all farmers had adopted, as in the rabi season of 1968-69 in the Punjab, the slope coefficient is still positive. This suggests that, at very high levels of adoption, those few who remain outside the fold have small farms.

Jowar: Jowar is the only crop for which the proportion adopting is similar between size of farm groups. This is hardly surprising since hybrid seeds had been introduced relatively late, so that adoption on all farms was generally less than 10 percent.

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[1] The data for this paragraph are to be found in Tables 11 and 15 in Appendix A.

All Areas: Firstly, there is no significant inverse relationship between adoption and farm size among the fifty areas studied. Secondly, it is clear that variation between development blocks in any given state is as great as variation observed between states. Thus, it is not possible to make any useful statements about adoption levels over time in one state relative to another. Thirdly, the slope coefficients are greater in maize, paddy and wheat areas than in bajra areas, showing there are lesser differences in levels of adoption between size of farm groups in the latter. This result conflicts with our earlier finding that there is a more marked relationship in bajra than in paddy-growing areas. However, the earlier finding was based on bajra-growing areas with relatively high levels of adoption, whereas those surveyed by the Programme Evaluation Organisation tend to have such low levels of adoption on all farms that there cannot be such a marked relationship between adoption and farm size.

Proportion of Acreage Under the New Varieties and Farm Size: Analysis of Data from the Agro-Economic Research Centres

Hypothesis 2: The proportion of acreage under a crop which is put under the new varieties is unrelated to size of farm. Table 2 summarizes the results from the linear regression model for eighteen areas studied by the Agro-Economic Research Centres.

Over-All Regions: The hypothesis that the proportion of acreage under the high-yielding varieties is unrelated to size of farm was rejected at the 0.5 percent level (See Table 12, Appendix A). Mostly negative slope coefficients indicate that as farm size increases, the proportion of acreage under the new varieties decreases. The regions will now be examined individually.

Andhra Pradesh: The estimated regression lines for West and East Godavari districts are shown in Figure 3.

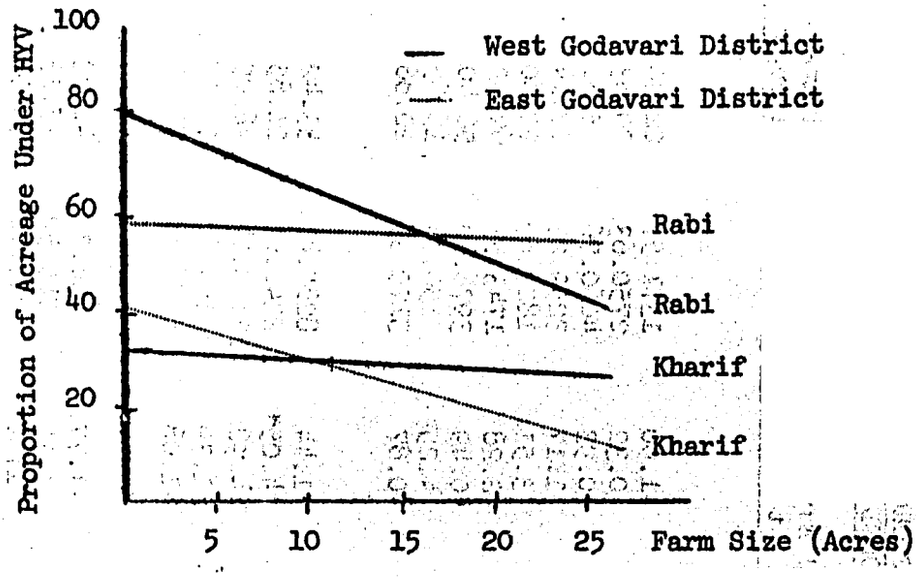
The greater proportion of acreage under the new varieties in both districts in the rabi season probably reflects the conditions better suited to the new varieties of the rabi season. The higher levels in West relative to East Godavari in the rabi season, the reverse of the kharif season, may reflect the greater profitability of the new varieties in West Godavari in the kharif season.

TABLE 2. EXTIMATED LINEAR REGRESSION FOR PROPORTION OF ACREAGE UNDER THE NEW VARIETIES AGAINST FARM SIZE USING AGRO-ECONOMIC RESEARCH CENTRE DATA

Area By Crop	Crop Year	Season	No. Obs.	UNRESTRICTED MODEL: Estimated Intercept	Estimated Slope	Estimated t Ratio	Sum of Squared Residuals	RESTRICTED MODEL: Estimated Intercept	Sum of Squared Residuals
Paddy									
Orissa 1	66	K	5	30.34	-1.35	-1.90	1371.57	22.30	3024.11
W. Bengal (1-2)	67	K	8	21.73	-0.10	-0.32	2750.63	20.83	2797.16
W. Bengal (1-2)	68	K	8	22.23	0.37	0.93	4060.76	25.51	4648.68
Andhra Pradesh 1	68	K	5	34.52	-0.33	-1.17	3259.23	28.14	4752.49
Andhra Pradesh 2	68	K	5	40.82	-0.95	-3.51*	1827.89	29.60	9352.79
Andhra Pradesh 1	68	R	5	81.69	-1.61	-2.28	1743.57	69.62	4765.55
Andhra Pradesh 2	68	R	5	58.75	-0.21	-0.49	3976.20	56.40	4291.18
Uttar Pradesh 1	68	K	6	21.94	-0.25	-4.25*	150.14	16.65	829.65
Punjab 1	68	K	10	24.32	-0.13	-0.87	3179.35	20.86	3479.75
Bajra									
Gujarat 1	67	K	6	26.77	2.17	1.44	8285.41	39.42	12571.88
Gujarat 2	67	K	6	-0.15	3.37	4.05*	2341.65	21.85	11965.64
Gujarat 3	67	K	6	11.58	4.82	4.98*	13180.74	48.05	94998.01
Gujarat (1-3)	67	S	6	66.46	3.81	1.39	19164.68	74.05	28403.97
Gujarat 8	68	K	7	77.50	-0.15	-1.08	6256.88	73.33	7716.09
Maize									
Bihar (1-2)	68	K	7	44.24	-0.39	-1.77	898.35	41.73	1459.41
Gujarat 6	65	K	6	80.62	-0.80	-1.75	585.50	25.13	1036.29
Gujarat 7	65	K	7	49.38	1.36	1.30	802.78	54.54	1073.13
Wheat									
Rajhasthan 1	68	R	8	53.76	-0.39	-1.32	47275.88	44.49	60943.30

Source: Sources of Data. Nos. 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 14, 15. *Significant at 5% Level

Figure 3. Estimated Regression Lines for the Proportion of Acreage Under the New Varieties Against Farm Size for Villages in Two Districts of Andhra Pradesh.



Source: Sources of Data, Nos. 2 and 3.

The most surprising finding from these data is that small farmers have a higher proportion of their acreage under the new varieties than large farmers. The relation is particularly marked in West Godavari district in the rabi season. This suggests that small farmers may be willing to commit themselves further to an innovation in situations where it is clearly profitable to innovate, and uncertainty, in terms of yield variability, has been shown to be small.

All Rice-Growing Areas: Taking all rice growing areas together, we may suggest a more general hypothesis, that after the "experimental period" the new varieties are adopted to a greater extent by small farmers than by large farmers. If the experimental period for a new variety is thought of as three crop seasons, the districts in Andhra were studied in the post "experimental" period with respect to IR-8, the most successful fo the new varieties, whereas the other districts from West Bengal, Uttar Pradesh and Punjab, were studied within the experimental period. In both the experimental and post-experimental periods, large farmers adopted on only about 20-30 percent of their acreage, whereas small farmers adopted on a much higher proportion of their acreage in the latter period (35-80 percent).

The finding that over time small farmers increase their acreage under the new varieties is consistent with the hypothesis that credit is a constraint to adoption on small farms. Having obtained higher yields on acreage under the new varieties in the experimental period, small farmers will be able to purchase a greater quantity of variable inputs in the next period and expand their acreage under the new varieties. A second hypothesis, also consistent with these findings, is that uncertainty is the primary constraint to adoption among small farmers. Once those small farmers who are able to face the uncertainty initially have found that yield variability of the new varieties is reasonably low, they put a greater proportion of their acreage under the new varieties.

The fact that over time small farmers increase their acreage under the new varieties more than large farmers suggests that they have greater incentives, in terms of deriving greater utility from additional income. If this is the case, there must be important factors acting as constraints to adoption among small farmers to explain why relatively few of them adopt.

Bajra-Growing Areas: In bajra-growing areas there is an apparent contradiction in terms of adoption behavior. The three villages in Kaira district, discussed earlier, all have positive regression coefficients, indicating that the proportion under the hybrid varieties increases with farm size. In contrast, the two Talukas sampled from Ahmadabad district have negative regression coefficients, indicating that as farm size increases, the proportion of acreage under the high-yielding varieties decreases. The explanation may lie in the degree of dependence on the crop for income. In Kaira district, the large farmers have a larger acreage under bajra than small farmers; but in Ahmadabad district, large farmers have a smaller acreage under bajra than small farmers, owing to the possibilities of alternative cash crops such as cotton and groundnuts. In both districts, the correlation between acreage under bajra and area under hybrid bajra was significant at the 1 percent level.[1] This suggests that the greater the degree of dependence on a crop for income, the greater the proportion of acreage put under the new varieties.

Maize-Growing Areas: The hypothesis that proportion of acreage under the high-yielding varieties is unrelated to size of farm was

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[1] See sources of data, Nos. 7 and 10.

not rejected at the 5 percent level.[1] We may conclude that the proportion of acreage put under the new varieties is similar in different farm size groups.

The difference in the proportion of acreage under the new varieties between the two villages studied in Gujarat is due to the hybrid varieties having been introduced a year earlier in the village showing the greater extent of adoption.

Proportion of Acreage Under the New Varieties: Analysis of Data from the Programme Evaluation Organisation Reports

Data from the Programme Evaluation Organisation reports are even more aggregated with respect to the proportion of acreage under the new varieties than for the relationship between adoption and farm size. Data for the proportion of acreage under the new varieties by size of farm group are aggregated over all states. For example, for paddy a single figure is given for the proportion under the high-yielding varieties for a given size of farm group, which is a weighted average of the proportions observed in each of the states for that size of farm group. Thus only the most general conclusions are possible.

The intercept coefficients for the restricted model in Table 3 show that large increases in the extent of adoption occurred from season to season and from year to year. This is clearly seen in Figure 4.

For all five crops, adopters put a much higher proportion of their acreage under the new varieties in 1968 than in 1967. In the case of jowar, it is interesting to note that in neither 1967 nor 1968 is there any significant increase in the proportion under the new varieties between the kharif and rabi seasons, in marked contrast to paddy.

For bajra, paddy, maize and jowar, the proportion of acreage under the new varieties is unrelated to size of farm. These results are not in conflict with our earlier findings, since there is not a consistent relationship between proportion of acreage under the new varieties and farm size in the areas studied by the Agro-Economic Research Centres; however, as noted above, the relationship, such as it exists, tends to be an inverse relationship.

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[1] See Table 12, Appendix A.

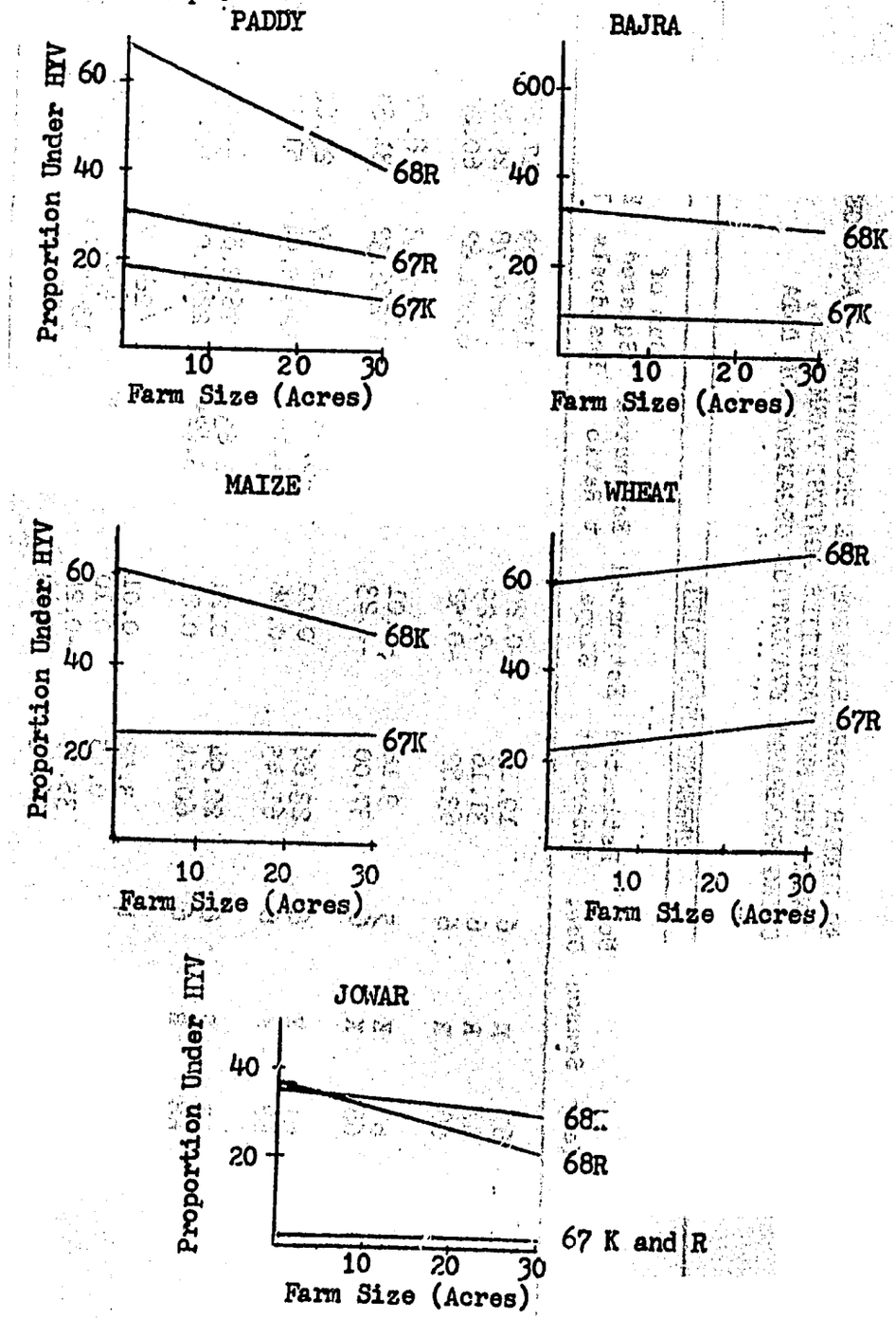
TABLE 3. ESTIMATED LINEAR REGRESSION FOR THE PROPORTION OF ACREAGE UNDER THE NEW VARIETIES AGAINST FARM SIZE, USING PROGRAMME EVALUATION ORGANISATION DATA

				UNRESTRICTED MODEL				RESTRICTED MODEL	
Crop	Year	Season	No. Obs.	Estimated Intercept	Estimated Slope	Estimated t Ratio	Sum of Squared Residuals	Estimated Intercept	Sum of Squared Residuals
Paddy	67	K	6	19.13	-0.20	-1.12	13077.09	17.28	17173.62
Paddy	67	R	6	31.16	-0.29	-0.39	74479.78	29.12	77240.28
Paddy	68	R	6	63.82	-0.52	-0.74	63671.62	60.20	72377.09
Bajra	67	K	5	9.16	-0.01	-0.12	1847.58	8.87	1855.85
Bajra	68	K	6	37.00	-0.23	-0.94	15266.32	31.34	18619.77
Maize	67	K	6	23.66	0.00	-0.02	936.97	23.63	937.03
Maize	68	K	6	61.45	-0.46	-1.59	12925.94	51.71	21090.40
Wheat	67	R	6	22.94	0.21	1.63	7632.85	26.44	12699.50
Wheat	68	R	6	60.04	0.21	3.02*	2202.05	63.52	7226.00
Jowar	67	K	4	3.52	0.01	0.10	266.56	3.69	267.93
Jowar	67	R	5	0.45	0.10	2.76*	150.87	3.15	533.20
Jowar	68	K	5	35.59	-0.24	-0.77	13406.87	28.91	16045.85
Jowar	68	R	6	36.23	-0.44	-1.46	12717.63	25.09	19507.24

Source: Sources of Data, Nos. 16-20

*Significant at 5% Level.

Figure 4. Estimated Regression Lines for the Proportion of Acreage Under the New Varieties Against Farm Size for Five Crops.



K = Kharif
R = Rabi

67 = 1967
68 = 1968

In wheat-growing areas, there is a significant positive relationship between proportion of acreage under the new varieties and farm size, indicating that proportion of acreage under the new varieties increases as farm size increases. The reason why there is not a positive relationship in paddy-growing areas may be that adoption of the new rice varieties involves a change to double-cropping, so that problems of labor supervision may discourage large farms from putting a high proportion of their rice acreage to the new varieties.

CHAPTER IV

CAUSES OF THE RELATIONSHIP OBSERVED BETWEEN ADOPTION OF THE HIGH-YIELDING VARIETIES AND FARM SIZE

In this chapter, we analyze the causes of the relationship observed between adoption and farm size. Three of the main factors which are thought to influence adoption behavior will be considered--the land-holding structure, irrigation availability and credit availability. In order to show that any of these variables is important in explaining the relationship observed, we must show that there is a relationship between the variable and farm size, and that the variable has an influence on adoption.

The Land-Holding Structure

Hypothesis 3: That the proportion of land owned is unrelated to size of farm. Table 4 summarizes the results for eight regions studied by the Agro-Economic Research Centres. For all regions, the hypothesis was not rejected at the 5 percent level, indicating there is no significant relationship between proportion of land owned and farm size in these areas.[1]

Hypothesis 4: That the proportion of land owned is the same for adopters and non-adopters, was rejected at the five percent level for all regions together.[2] This suggests there is a relationship between tenancy and adoption. However, a closer examination of the data reveals this is not a consistent relationship; in the villages of Gujarat studied, adopters owned a greater proportion of their land than non-adopters, whereas in the areas of both Rajasthan and Orissa, the reverse is the case. It is clear that tenancy does affect adoption behavior, but the nature of the relationship is not clearly identified.

[1] For the F ratio, See Table 20, Appendix A.

[2] See Table 21, Appendix A.

TABLE 4. ESTIMATED LINEAR REGRESSION FOR PROPORTION OF LAND OWNED AGAINST FARM SIZE, FOR ADOPTERS AND NON-ADOPTERS[1] USING AGRO-ECONOMIC RESEARCH CENTRE DATA.

Area By Crop	Crop Year	Season	No. Obs.	UNRESTRICTED MODEL Estimated Intercept	Estimated Slope	Estimated t Ratio	Sum of Squared Residuals	RESTRICTED MODEL Estimated Intercept	Sum of Squared Residuals
Paddy									
Orissa 1 A	66	K	5	75.08	1.64	2.03	1767.09	84.82	4194.11
Orissa 1 NA	66	K	4	75.85	3.13	3.83*	511.62	85.61	2133.93
W. Bengal 1 A	67	K	8	87.11	0.56	2.98*	918.43	91.96	2280.67
W. Bengal 1 NA	67	K	5	82.29	0.84	0.64	2012.97	85.12	2291.09
W. Bengal 2 A	68	K	8	84.15	0.49	2.49*	994.07	88.50	2025.17
W. Bengal 2 NA	68	K	5	93.21	-0.19	-0.38	179.75	92.46	188.29
Bajra									
Gujarat 1 A	67	K	5	98.24	0.02	0.02	583.29	98.33	583.33
Gujarat 1 NA	67	K	5	97.49	-0.05	-0.06	213.08	97.33	213.33
Gujarat 2 A	67	K	5	86.78	0.20	0.14	844.20	88.00	850.00
Gujarat 2 NA	67	K	3	89.84	-0.20	-0.03	4092.54	89.33	4096.00
Gujarat 3 A	67	K	5	90.82	0.80	6.65*	8.24	94.60	129.60
Gujarat 3 NA	67	K	3	106.57	-4.18	-1.99	494.99	96.30	2464.20
Maize									
Bihar (1-2) A	68	K	7	89.93	0.26	1.03	1216.37	91.64	1476.07
Bihar (1-2) NA	68	K	4	80.92	3.29	2.34	1280.53	90.31	2392.46
Wheat									
Rajhasthan 1 A	68	R	5	66.09	0.22	0.35	2710.68	68.99	2824.52
Rajhasthan 1 NA	68	R	5	88.23	-0.34	-0.41	4521.58	84.35	4882.18

Source: Sources of Data, Nos. 7, 9, 11, 12, 14, 15.

*Significant at the 5% Level

[1] In the table, A = Adopters, NA = Non-Adopters.

Although there is a relationship between tenancy and adoption, we may conclude that tenancy is not the factor underlying the relationship between adoption and farm size for these areas, since there is no relationship observed between tenancy and farm size.

All-India data are used to analyze the relationship between tenancy and farm size in districts studied by the Programme Evaluation Organisation, since these districts are a random sample of districts in the whole of India. Data for the proportion of land owned by size of farm group is given in Table 5.

Table 5. Area Leased-In as a Proportion of the Total Acreage Operated by Size of Farm Group, 1960-61.

Size of Farm (Acres) 1	Areas Operated '000 Acres 2	Area Owned '000 Acres 3	Proportion Owned 3 + 2
0.1 - 2.5	23320	19312	0.83
2.5 - 5	41991	35990	0.86
5 - 10	69333	61095	0.88
10 - 20	78445	73023	0.93
20 - 50	79931	76624	0.96
50 & Above	36565	34071	0.93

Source: National Sample Survey, No. 176, p. 49.

Clearly, there is some relationship between the proportion of land leased-in and farm size. In Table 6, we examine the proportion of pure tenants by size of farm group, since those who own no land may be expected to have the greatest disadvantage in adoption.

Small farm-size groups have the greatest proportion of pure tenants. If tenants are less likely to innovate, the relationship between tenancy and farm size is a factor underlying the relationship observed between adoption and farm size in areas studied by the Programme Evaluation Organisation.

Table 6. Proportion of Households which are Pure Tenants by Size of Farm Group.

Size of Farm (Acres) 1	No. of Households as Pure Tenants 2	Total No. of Households 3	Proportion of Pure Tenants 2 + 3
0 - 0.99	1067588	157334	0.15
1.0 - 2.49	2263120	248069	0.11
2.5 - 4.99	2191492	165817	0.08
5.0 - 9.99	2023088	105806	0.05
10.0 - 14.99	838661	35775	0.04
15.0 - 29.99	822069	27270	0.03
30.0 - 49.99	260089	6325	0.02
Over 50	130013	5240	0.04

Source: Census of India 1961, Vol. I, Part III (ii), p. 18-19.

Irrigation Availability

Hypothesis 5: That the proportion of land irrigated is unrelated to size of farm. Table 7 summarizes the results for eight regions studied by the Agro-Economic Research Centres. For all regions, the hypothesis was rejected at the 5 percent level, indicating there is no significant relationship between the proportion of land irrigated and farm size in these regions.[1]

Hypothesis 6: That the proportion of land irrigated is the same for adopters and non-adopters, was also tested over all regions. The hypothesis was rejected at the 0.5 percent level, indicating that adopters have a greater proportion of their land irrigated than non-adopters.[2]

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[1]See Table 20, Appendix A.

[2]See Table 21, Appendix A.

TABLE 7. ESTIMATED LINEAR REGRESSION FOR THE PROPORTION OF LAND IRRIGATED AGAINST FARM SIZE, FOR ADOPTERS AND NON-ADOPTERS[1] USING THE AGRO-ECONOMIC RESEARCH CENTRE DATA

Area By Crop	Crop Year	Season	No. Obs.	UNRESTRICTED MODEL Estimated Intercept	Estimated Slope	Estimated t Ratio	Sum of Squared Residuals	RESTRICTED MODEL Estimated Intercept	Sum of Squared Residuals
Paddy									
Orissa 1 A	66	K	5	80.99	0.45	0.84	780.24	83.68	965.35
Orissa 1 NA	66	K	4	78.31	-0.51	-0.47	460.38	76.71	510.59
W. Bengal 1 A	67	K	8	93.53	-0.49	-0.18	1987.31	93.10	1997.69
W. Bengal 1 NA	67	K	5	83.29	1.72	2.73	469.18	89.09	1636.92
W. Bengal 2 A	68	K	8	87.43	0.54	2.81	978.59	92.29	2263.11
W. Bengal 2 NA	68	K	5	86.09	0.42	0.34	1077.86	87.75	1119.39
Andhra Pradesh 1 A	68	K	5	100.00	0.00	0.00	0.00	100.00	0.00
Andhra Pradesh 1 NA	68	K	5	100.00	0.00	0.00	0.00	100.00	0.00
Andhra Pradesh 2 A	68	K	5	99.95	0.00	-0.27	4.46	99.91	4.57
Andhra Pradesh 2 NA	68	K	5	98.81	-0.32	-3.31	144.19	96.08	670.29
Andhra Pradesh 1 A	68	R	5	100.06	-0.15	-0.13	74.73	98.97	99.29
Andhra Pradesh 1 NA	68	R	4	96.47	0.16	2.21	4.99	97.25	17.19
Andhra Pradesh 2 A	68	R	5	100.00	0.95	0.11	0.15	100.00	0.12
Andhra Pradesh 2 NA	68	R	4	100.13	-0.01	2.25	0.77	99.96	2.72
Maize									
Bihar (1-2) A	68	K	7	35.22	0.75	1.05	9674.72	40.11	11806.09
Bihar (1-2) NA	68	K	4	23.01	2.15	4.66*	68.97	29.15	818.6198

Source: Sources of Data, Nos. 2, 3, 11, 12, 14, 15.

*Significant at the 5% Level

[1] In the table, A = Adopters, NA = Non-Adopters

In East and West Godavari districts, almost the entire acreage on all farm size groups is irrigated. However, differential rates of adoption are observed between farm size groups, as well as high rates of non-adoption in all groups.

These results suggest that a high degree of irrigation availability is a necessary but not a sufficient condition for adoption, nor a sufficient condition to equalize rates of adoption between farm size groups. We may conclude that irrigation availability is not a factor underlying the relationship between adoption and farm size in these areas, since we do not find a positive relationship between irrigation availability and farm size.

Water control may be a factor in the relationship between adoption and farm size. Moorti has shown that the degree of water control has an important influence on adoption behavior.[1] If there is also a relationship between water control and farm size, then water control is a factor explaining the relationship between adoption and farm size. Unfortunately, data showing the degree of water control in these areas were not available for this study.

To analyze the importance of irrigation availability in the areas studied by the Programme Evaluation Organisation, we examine in Table 8 data for the relationship between irrigation availability and farm size in India as a whole.

Table 8. Irrigation Availability and Farm Size in India.

Farm Size Group (acres)	Ratio of Farms with Irrigation to the Total No. of farms in Group	Ratio of Irrig. Acreage, per farm with Irrigation to average size of holding
0 - 1	0.38	0.89
1 - 5	0.48	0.63
5 - 10	0.48	0.54
10 - 15	0.46	0.46
15 - 25	0.45	0.39
25 - 50	0.44	0.29
50 & above	0.39	0.22

Source: Derived from the Sixteenth and Seventeenth Rounds Estimates of the National Sample Survey, 1959-61.

[1] T. V. Moorti. op. cit., p. 22.

In 1961, the proportion of farms with irrigation is similar between size of farm groups, excluding the extremely small and extremely large farms, but as farm size increases, the proportion of land irrigated on farms with irrigation tends to decline. However, since 1961, irrigation availability has increased considerably, notably by the installation of a large number of tube-wells. This has occurred mainly on the larger farms,[1] which will have narrowed the differentials between size of farm groups noted above.

In the period 1966-68, irrigation availability probably decreased with farm size, despite the investment in tube-wells on large farms. Therefore, irrigation availability is probably not a factor underlying the positive relationship between adoption and farm size in the areas studied by the Programme Evaluation Organisation.

The Availability of Co-operative Credit

Hypothesis 7: That the proportion of cash expenditure met by the co-operative is unrelated to size of farm. Table 9 summarizes the results for eight regions studied by the Agro-Economic Research Centres. In only three of the regions is the slope coefficient significantly different from zero at the 5 percent level. All three coefficients are negative, indicating that as farm size increases, the proportion of cash expenditure met by the co-operatives decreases. Such a result indicates that large farmers meet cash expenditure from other sources; other empirical studies have suggested that the greater part of total cash expenditure is met from farmer's own funds.[1]

To the extent that small farmers use co-operative credit when large farmers use their own funds, they pay a higher price for credit. If the cost of credit is important in adoption, the relationship between cost of credit and farm size is a factor in the relationship between adoption and farm size.

Next we tested hypothesis 8, that the proportion of cash expenditure met by the co-operatives is the same for adopters and non-adopters. This was rejected at the 0.5 percent level for all regions, indicating that adopters meet a greater part of their cash expenditure from this source than non-adopters.

The following figures indicate the proportion of cast expenditure met by the co-operatives for adopters and non-adopt in four of the areas studied.[2]

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[1] Programme Evaluation Organisation, Report for the Kharif Season, 1968, Planning Commission, Government of India, 1969, p. 67.

[2] See data for the restricted model in Table 9.

TABLE 9

ESTIMATED LINEAR REGRESSION FOR THE PROPORTION OF CASH EXPENDITURE MET BY THE CO-OPERATIVES AGIANST FARM SIZE, FOR ADOPTERS AND NON-ADOPTERS,[1] USING AGRO-ECONOMIC RESEARCH CENTRE DATA

	UNRESTRICTED MODEL							RESTRICTED MODEL	
Area By Crop	Crop Year	Season	No. Obs.	Estimated Intercept	Estimated Slope	Estimated t Ratio	Sum of Squared Residuals	Estimated Intercept	Sum of Squared Residuals
Paddy									
Orissa 1 A	66	K	5	59.78	-2.03	-2.10	2523.90	47.71	6245.21
Orissa 1 NA	66	K	4	4.96	-0.53	2.02	26.69	5.71	190.42
W. Bengal 1 A	67	K	8	18.05	-0.60	-2.77*	1416.79	12.47	3223.64
W. Bengal 1 NA	67	K	5	8.76	1.01	0.76	2090.88	12.16	2492.60
W. Bengal 2 A	68	K	8	88.38	-3.11	-4.47*	12585.35	60.62	54537.87
W. Bengal 2 NA	68	K	5	47.25	-3.24	-1.57	3018.84	34.45	5393.40
Andhra Pradesh 1 A	68	K	5	20.81	-0.16	-0.46	4852.25	17.78	5188.05
Andhra Pradesh 1 NA	68	K	5	22.19	-0.85	-1.55	3467.55	14.44	6261.27
Andhra Pradesh 2 A	68	K	5	13.39	-0.22	-1.62	438.44	10.85	821.61
Andhra Pradesh 2 NA	68	K	5	5.82	-0.08	-0.36	769.23	5.12	803.19
Andhra Pradesh 1 A	68	R	5	1.32	0.59	1.18	877.57	5.74	1282.34
Andhra Pradesh 1 NA	68	R	4	6.50	-0.27	-0.41	426.09	8.95	533.80
Andhra Pradesh 2 A	68	R	5	37.69	-0.41	-0.71	7047.78	33.16	8222.06
Andhra Pradesh 2 NA	68	R	4	2.11	0.23	0.34	999.55	5.25	1176.09
Maize									
Bihar (1-2) A	68	K	7	89.93	0.26	1.03	1216.37	91.64	1476.07
Bihar (1-2) NA	68	K	4	19.69	-1.76	4.75*	44.25	25.42	1543.37

Source: Sources of Data, Nos. 2, 3, 11, 12, 14, 15.

*Significant at the 5% Level

[1] In the table, A = Adopters, NA = Non-Adopters

	Adopters	Non-Adopters
Bihar	92%	25%
Orissa	48%	6%
W. Bengal (in 1968)	61%	34%
Andhra Pradesh[1]	33%	5%

These data indicate a close relationship between use of co-operative credit and adoption. However, the line of causality is not clear. All farms may want co-operative credit, but owing to a shortage of supply, mismanagement, or political factors entering into loan disbursement, only a small proportion of farms are able to obtain loans.[2]

An alternative explanation of the relationship between co-operative credit and adoption is that all farms which are willing to adopt the new varieties are able to obtain as much credit as they require. The district administrations, being anxious to increase acreage under the new varieties, may have encouraged the co-operatives to give loans to those willing to adopt the new varieties. If this explanation is correct, the problem remains as to why some farms are willing to adopt while others are not.

Next, we examined the relationship between co-operative membership and farm size, using Programme Evaluation Organisation data.

Hypothesis 9: That the proportion of farmers who are members of the co-operatives is unrelated to size of farm, was tested for each crop. In three out of eight cases, the slope coefficients were significantly different from zero at the 5 percent level, indicating a positive relationship between the proportion of farmers who are members of the co-operatives and farm size.[3] However, since the slope coefficients were very small, we tested hypothesis 10, that the proportion of farmers who are co-operative members is the same for adopters and non-adopters. The hypothesis was rejected at the 0.5 percent level, indicating that a higher

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[1] East Godavari district in the rabi season.

[2] Programme Evaluation Organisation, op. cit., p. 64.

[3] See Table 19, Appendix A.

proportion of adopters are co-operative members than non-adopters.[1] This confirms our earlier finding that adopters use co-operative credit more than non-adopters.

In combination, these data suggest that a relatively small proportion of those with small farms are members of the co-operatives, but those who are members meet a relatively high proportion of their cash expenditure from this source. These are the small farmers who adopt the new varieties.

If there is a significant relationship between any of the variables considered in this chapter and farm size, the estimated coefficients of Chapter III between adoption and farm size are biased. Also the standard errors used in testing the significance of coefficients in Chapter III are too large unless the coefficients of the excluded variables are equal to zero.

We have found no relationship between the proportion of land irrigated and farm size, but a positive relationship between the proportion of land owned and farm size, and an inverse relationship between the proportion of cash expenditure met by the co-operatives and farm size. However, these relationships were not significant in many of the regions taken individually, and the regression coefficients in most cases were extremely small, so that we may still regard the estimates of the relationship between adoption and farm size as unbiased.

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[1] See Table 21, Appendix A.

CHAPTER V

SUMMARY AND IMPLICATIONS FOR POLICY

Summary of Main Findings

1. Adoption and Farm Size. As farm size increases, the proportion of farms which have adopted the new varieties also increases. This relationship is statistically significant in 45 of the 70 areas studied.

2. Variability in the Relationship Between Adoption and Farm Size. The nature of the relationship between adoption and farm size varies considerably between crops, regions, seasons and over time.

Crops. The relationship between adoption and farm size is more marked in bajra than in paddy-growing areas. This is due in part to a specification problem. Income per acre is considerably higher in paddy relative to bajra-growing areas. Therefore, size of farm related factors such as credit and uncertainty may cease to be constraints to adoption at a smaller farm size. Secondly, the increase in yield variability in moving from traditional to new varieties may be less in paddy than in bajra-growing areas owing to greater availability of irrigation in the former. For this reason also, uncertainty will cease to be a constraint to adoption at a smaller farm size, and differences in adoption levels between farm size groups will be less.

Wheat-growing areas show a significant relationship between adoption and farm size less often than bajra- and rice-growing areas. In jowar-growing areas, there is little relationship evident between adoption and farm size because so few farms in any size of farm group had adopted hybrid varieties.

Regions. There is a less marked relationship between adoption and farm size in villages studied in Andhra than in those of West Bengal. Both are paddy-growing areas. We attribute this to the higher proportion of land irrigated in the former. In general, we found that the higher the proportion of land irrigated in a region, the higher the over-all level of adoption. However, even when a very high proportion of the acreage on all farm size groups is irrigated, as in the two districts of Andhra, differences in the levels of adoption between farm size groups persist.

Seasons. In Andhra, levels of adoption are much higher in the rabi than in the kharif season, but differences in levels of adoption between farm size groups remain the same. A greater amount of sunshine in the rabi season increases the profitability of the new varieties, especially IR-8.

Over Time. Absolute differences in levels of adoption between farm size groups do not diminish as the mean level of adoption rises, until the limit of 100 percent adoption on all farm size groups is approached. This means that income differentials resulting from the new varieties will persist longest in areas where the over-all rate of adoption is slowest.

3. Causes of the Relationship between Adoption and Farm Size

Irrigation. In the areas studied by the Agro-Economic Research Centres, adopters have a higher proportion of their land irrigated than non-adopters, indicating that the irrigation factor has an important influence on adoption behavior. However, since there is no relationship between proportion of land irrigated and farm size, the availability of irrigation is not a factor underlying the relationship between adoption and farm size. Degree of water control may explain in part the relationship between adoption and farm size, but data were not available to study this.

Tenancy. There is not a systematic relationship between the proportion of land owned and adoption; in some cases a greater proportion owned leads to greater adoption of the new varieties, and in other cases the reverse is the case. Thus, although there is a relationship between the proportion of land owned and farm size, we may not conclude this underlies the relationship between adoption and farm size. Since in all these areas, in all farm size groups, the proportion of land owned is greater than 50%, we have been unable to isolate the effect of pure tenancy on adoption.

Co-operative Credit. In the areas studied by the Agro-Economic Research Centres, there is not a marked relationship between the proportion of cash expenditure met by the co-operatives and farm size, but the relationship such as it exists tends to be an inverse relationship. This indicates that small farms are relatively dependent on this form of credit. If large farms meet their cash expenditure from their own funds, small farms have a disadvantage since co-operative credit has a higher cost than 'own funds'. This may then be a factor underlying the relationship between adoption and farm size. If large farms meet their cash expenditure from the relatively high-cost moneylender, we would have expected an inverse relationship between adoption and farm size.

Adopters on all farm size groups meet a far greater proportion of their cash expenditure from co-operatives than non-adopters. But the line of causality between dependence on co-operative credit and adoption is not clear. All farms may want co-operative credit, but owing to a shortage of supply, mismanagement, or political factors entering into loan disbursement, only a small proportion of farms are able to obtain loans. An alternative explanation is that all farms willing to adopt the new varieties had credit made available to them by the co-operatives, but if this is the case, the problem remains as to why some farms were willing to adopt while others were not.

In areas studied by the Programme Evaluation Organisation, there is a positive relationship between the proportion of farmers who are members of the co-operatives and farm size. It is probable that a relatively small number of small farms obtain co-operative credit.

In combination, these results suggest that few of those with small farms obtain co-operative credit, but those who do meet a high proportion of their cash expenditure from this source. It is these farms that adopt the new varieties.

Farm Size. Probably farm size itself to some extent determines adoption. Acreage in a given region is some measure of income and wealth, and thus may act as a proxy variable both for the farm's ability to bear uncertainty, and the amount of 'own funds' available for the purchase of variable inputs. Acreage may also determine the availability of credit from institutional sources, since land is an important form of collateral. A more detailed analysis would be necessary to determine whether it is the ability of large farms to face uncertainty, or the greater availability of credit for the purchase of variable inputs, which results in their greater willingness to adopt.

4. Proportion of Acreage Under the New Varieties and Farm Size. There is not a marked relationship between the proportion of acreage under the new varieties and farm size, but the relationship, such as it exists, tends to be an inverse relationship. This is the case for paddy, bajra, maize and jowar. We have suggested that small farmers lack credit. Inability to face uncertainty is probably also a difficulty. Thus we would expect small farmers to experiment by putting a small part of their acreage under the new varieties. Such is the case in wheat-growing areas. But for all other crops, small farmers which adopt do so on a greater proportion of their acreage than large farmers. We may only conclude that in many cases small farmers have greater incentives to adopt the new varieties, in that they rely relatively heavily on foodgrains for income, but that they face constraints to initial adoption. There may be some "discontinuity" present which prevents small farmers from

"experimenting" with the new varieties. The "fixed costs" of innovating, in terms of overcoming inertia and obtaining variable inputs may make it necessary to put some minimum acreage under the new varieties before it becomes profitable to adopt. There may also be some discontinuity in credit availability to small farms. Either a small farmer is a member of the co-operative and meets a high proportion of his cash expenditure from this source, or he is not a member and receives no credit at all from this source. A third explanation may be that small farmers have taken the new "inferior" grain varieties into their diet, whereas large farmers can afford to continue to eat only the traditional varieties.

5. Proportion of Acreage Under the New Varieties Over Time. The greater the time period from the introduction of the new varieties, the greater the proportion of acreage put under the new varieties in all farm size groups. This is true for all crops. There is also a tendency over time for the development of a more strongly inverse relationship between the proportion of acreage under the new varieties and farm size. This suggests that when small farmers have assessed the uncertainty arising from yield variability, their greater dependence on the foodgrain crops for income causes them to put a higher proportion of their acreage under the new varieties.

Limitations of This Study for Policy

This study is only a partial analysis of the problem of raising incomes on small farms. We have been concerned here only with the introduction of the new varieties.[1] There are a number of alternative possibilities to raise incomes on small farms such as encouraging dairy enterprise and vegetable-growing. Thus, to formulate an optimal policy to raise incomes on small farms, it would be necessary to study the factor requirements for, and constraints to, adoption of these alternatives. The interrelationships between the new varieties and these alternatives is also highly relevant. For example, introduction of the new varieties may release land for alternative crops on small farms, because essential consumption requirements of the family can be met from a smaller acreage. On the other hand, expenditure on variable inputs for the new varieties is likely to intensify the problems of obtaining the credit required to utilize the released acreage in a profitable alternative.

The analysis has also been partial in the sense that it considers only that part of a farmer's income which is derived from his function as a land-owner. Changes in levels of employment of agricultural labor, which also may provide a source of income to a farmer with a small holding, or in income derived from non-agricultural rural employment, resulting from the introduction of the new varieties, are not considered here.

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[1] For a detailed study of the effects of the new varieties on income, see: V. S. Vyas, D. S. Tyagi, V. M. Misra, op. cit.

Bearing in mind these limitations, we turn to the implications of the preceding analysis for policy.

Facilitating Adoption of the New Varieties on Small Farms

Credit. This analysis has shown that small farmers who adopt rely heavily on co-operative credit. Credit is required for the purchase of variable inputs; to a great extent, the level of use of variable inputs determines the level of profitability of the new varieties. Secondly, credit may be used as a form of crop insurance, so that in the event of a lower production the farm can meet essential consumption requirements without recourse to the moneylender. We have been unable to determine which of these is the predominant factor underlying small farmers' demand for co-operative credit. If the problem centers on uncertainty, a crop insurance program might be the most effective means of facilitating adoption of the new varieties. But if small farms require variable inputs, credit supplied in the form of physical inputs such as fertilizers might be a more effective policy.

The line of causality between credit availability and adoption is also unclear. All small farmers may want co-operative credit in order to adopt, but only a few may be able to obtain this credit. Co-operatives may discriminate in the allocation of the credit supply, in which case some reform of the institutional structure is required. Alternatively, few small farmers may want co-operative credit in order to adopt. Adequate credit may already be available, or some other factor, such as uncertainty, may make them unwilling to adopt. In this case, further analysis is needed of factors underlying both adoption and demand for co-operative credit.

Irrigation. This study has shown that the proportion of land irrigated is an important factor determining whether a farmer adopts the new varieties. Another study has shown the importance of the degree of water control in adoption behavior.[1] The availability of irrigation water and the degree of control are important not only because they increase the level of yields of the new varieties relative to local varieties, but also because they reduce variability of yields. Yield variability is of particular concern to the small farmer, who has a relative inability to face uncertainty.

If both small and large farms rely on the same irrigation source, as may occur when a canal or state tube-well is the

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[1] T. V. Moorti, op. cit.

source, small farmers may be at a disadvantage since they are least able to ensure an adequate supply of water in a period of shortage. Ideally, some form of irrigation is required which is cheap, allows a high degree of water control, and allows the farm to be independent. A tube-well meets these specifications, but a farm with less than five acres may be too small to absorb the total discharge of water. If tube-wells were installed to cater for a medium-sized and a small farm, or two or more small farms, the dependence of small farmers on those with greater economic and political power would be minimized. We suggest that medium-term credit be made available for such investment. Also, research might be directed toward the development of an irrigation technology suited to the needs of the small farm.

Uncertainty. If uncertainty is the central problem facing the small farm, increasing credit and irrigation availability may not be the only means of facilitating adoption. It may be possible to develop strains which provide not only a higher average yield, but also lower the variability of yields. Provision of a steady source of nonfarm income may also increase dramatically a farmer's ability to face uncertainty. Further analysis is needed of the weight assigned to uncertainty in the objective function of the small farmer. Specifically, it is necessary to determine the extent to which the farmer is willing to accept a lower level of income in order to reduce the variability of his income. Such analysis may indicate not only the reasons why credit and irrigation availability influence adoption behavior, but also what alternative policy measures would be appropriate to raise incomes on small farms.

APPENDIX A

STATISTICAL TABLES

The districts have been numbered as follows:[1]

W. Bengal 1: Sainthia Block, Birbhum District.
W. Bengal 2: Rampurhat Block II, Birbhum District.

Andhra Pradesh 1: West Godavari District.
Andhra Pradesh 2: East Godavari District.

Gujarat 1: Piplag Village, Nadiad Taluka, Kaira District.
Gujarat 2: Khadol Village, Borsad Taluka, Kaira District.
Gujarat 3: Asodar Village, Borsad Taluka, Kaira District.
Gujarat 4: Nadiad Taluka, Kaira District.
Gujarat 5: Dehgam Taluka, Ahmadabad District.
Gujarat 6: Jambua Village, Dohad Taluka, Panchmahals District.
Gujarat 7: Gangarda Village, Dohad Taluka, Panchmahals District.
Gujarat 8: Ahmadabad District.

Bihar 1: Baniapur Block, Saran District.
Bihar 2: Hawthwa Block, Saran District.

Rajhasthan 1: Kota District.

Punjab 1: Amritsar District.

Orissa 1: Cuttack District.

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[1] The different levels of aggregation reflect different levels of aggregation of the data in the reports.

TABLE 10. ESTIMATED LOGIT REGRESSION FOR ADOPTION AGAINST FARM SIZE USING AGRO-ECONOMIC RESEARCH CENTRE DATA

Area By Crop	Crop Year	Season	No. Obs.	UNRESTRICTED MODEL Estimated Intercept	Estimated Slope	Estimated t Ratio	Sum of Squared Residuals	RESTRICTED MODEL Estimated Intercept	Sum of Squared Residuals
Paddy									
W. Bengal 1	67	K	5	-1.21	0.03	0.61	5.49	-0.14	35.96
W. Bengal 2	67	K	3	-1.07	0.64	11.34*	1.29	0.36	42.01
W. Bengal 1	68	K	5	-1.21	0.25	7.17*	2.91	0.09	31.86
W. Bengal 2	68	K	3	1.59	0.18	1.32	9.08	0.60	113.49
Andhra Pradesh 1	68	K	5	-2.10	0.07	3.87*	105.86	-0.02	1998.28
Andhra Pradesh 2	68	K	5	-1.72	0.05	2.80*	36.23	-0.06	1124.79
Andhra Pradesh 1	68	R	5	-0.32	0.09	1.59	84.39	0.12	94.99
Andhra Pradesh 2	68	R	5	-0.56	0.09	3.66*	60.21	0.06	152.90
Orissa	66	K	4	-4.11	0.47	2.21	189.52	-0.40	2382.70
Bajra									
Gujarat 1	67	K	6	-1.33	0.22	3.54*	31.73	0.03	145.99
Gujarat 2	67	K	6	-3.64	0.34	3.40*	141.91	-0.22	2390.50
Gujarat 3	67	K	6	-2.23	0.27	7.41*	46.46	0.01	1307.98
Gujarat 1	67	S	5	-0.05	0.19	1.03	11.48	0.21	11.53
Gujarat 2	67	S	6	-0.49	0.37	2.77*	28.03	0.17	57.29
Gujarat 3	67	S	6	-2.27	0.28	8.17*	3.62	-0.35	465.93
Gujarat 4	68	K	8	-3.37	0.28	3.02*	358.27	-0.17	3227.23
Gujarat 5	68	K	7	-1.75	0.13	5.38*	38.34	0.02	260.08
Maize									
Bihar 1	68	K	5	-1.54	0.32	4.71*	15.69	0.10	99.11
Bihar 2	68	K	5	-1.93	0.26	1.58	126.98	-0.12	519.25
Wheat									
Rajhasthan	68	R	7	-0.90	0.04	2.43*	57.47	0.00	155.28

Source: Sources of Data Nos. 2, 3, 6, 7, 9, 10, 11, 12, 14, 15.

*Significant at 5% Level

TABLE 11. F STATISTIC TO TEST THE HYPOTHESIS THAT ADOPTION IS UNRELATED TO FARM SIZE

Crop	No. of Areas	No. of Obs.	Observed F Statistic
Agro-Economic Research Centre Data			
Linear Model			
Paddy	9	55	13.46**
Bajra	8	50	36.81**
Maize	2	12	49.02**
Logit Model			
Paddy	9	55	27.07**
Bajra	8	50	46.42**
Maize	2	10	10.00**
Programme Evaluation Organisation Data			
Linear Model			
Paddy	16	82	6.91**
Bajra	8	39	44.16**
Maize	9	46	21.17**
Wheat	11	53	7.02**
Jowar	6	30	0.95
Logit Model			
Paddy	16	82	4.7**
Bajra	8	39	16.77**
Maize	9	46	13.21**
Wheat	11	53	7.14**
Jowar	6	30	0.64

** Significant at 0.5% level

TABLE 12. F STATISTICS TO TEST THE HYPOTHESIS THAT THE PROPORTION OF ACREAGE UNDER THE NEW VARIETIES IS UNRELATED TO FARM SIZE

Crop	No. of Areas	No of. Obs.	Observed F Statistics
Agro-Economic Research Centre Data			
Paddy	9	57	3.03*
Bajra	5	31	9.08**
Maize	3	20	2.62*
Programme Evaluation Organisation Data[1]			
Paddy	3	18	0.41
Bajra	2	11	0.69
Maize	2	12	2.36
Wheat	2	12	4.10*
Jowar	4	20	1.11

* Significant at 5% level.

** Significant at 0.5% level.

1 The data given in these reports for the proportion of acreage under the New Varieties by Farm Size is aggregated across regions. We have, therefore, only one regression for each season, so the figure in the No. of Areas column refers to the number of seasons for which data were available.

TABLE 13. ESTIMATED LINEAR REGRESSION FOR ADOPTION OF NEW RICE VARIETIES AGAINST FARM SIZE, USING PROGRAMME EVALUATION ORGANISATION DATA

				UNRESTRICTED MODEL				RESTRICTED MODEL	
Area By Crop	Crop Year	Season	No. Obs.	Estimated Intercept	Estimated Slope	Estimated t Ratio	Sum of Squared Residuals	Estimated Intercept	Sum of Squared Residuals
Andhra Pradesh	67	K	6	4.32	0.55	3.64*	2036.11	14.59	8788.98
Bihar	67	K	6	44.81	1.63	2.22*	11085.87	61.67	29263.76
Kerala	67	K	4	-0.96	-0.39	-0.73	87.27	5.41	110.78
Madras	67	K	5	52.78	2.03	2.57*	3587.75	61.83	11505.86
Maharastra	67	K	6	15.62	0.38	1.68	1895.60	19.09	3228.89
Mysore	67	K	5	8.53	1.08	2.93*	1079.32	22.92	4172.62
Orissa	67	K	5	8.19	2.07	6.02*	497.12	22.22	6267.56
Punjab	67	K	5	0.40	0.78	6.14*	219.78	21.91	2979.32
Uttar Pradesh	67	K	5	19.65	1.77	4.98*	2062.37	39.52	19107.02
W. Bengal	67	K	5	16.56	0.58	0.89	4352.98	20.56	5505.53
Andhra Pradesh	68	K	6	6.39	0.45	4.36*	1116.13	14.77	6418.93
Assam	68	K	4	43.93	1.73	1.11	1847.17	52.69	2986.6[illegible]
Bihar	68	K	5	21.64	0.97	1.99	4868.44	32.66	11291.16
Kerala	68	K	5	24.67	1.06	1.45	3395.71	31.53	5787.96
Madras	68	K	5	67.75	0.81	7.07*	318.99	73.59	5633.21
Maharashtra	68	K	5	6.21	0.59	2.96*	498.11	10.54	1956.40

Source: Sources of Data, Nos. 16, 19

*Significant at 5% Level

TABLE 14. ESTIMATED LINEAR REGRESSION FOR ADOPTION OF HYBRID, BAJRA AND MAIZE VARIETIES AGAINST FARM SIZE, USING PROGRAMME EVALUATION ORGANISATION DATA

	UNRESTRICTED MODEL							RESTRICTED MODEL	
Area By Crop	Crop Year	Season	No. Obs.	Estimated Intercept	Estimated Slope	Estimated t Ratio	Sum of Squared Residuals	Estimated Intercept	Sum of Squared Residuals
Bajra									
Gujurat	68	K	6	12.64	0.78	10.61*	517.80	29.32	15092.72
Haryana	68	K	4	-7.85	0.58	1.98	643.38	8.26	1901.04
Maharashtra	68	K	6	5.60	0.12	6.13*	31.32	8.62	325.75
Rajhasthan	68	K	4	-0.39	0.01	1.77	321.46	-0.04	583.51
Uttar Pradesh	68	K	3	0.05	0.13	6.26*	0.20	2.09	8.20
Gujurat	67	K	6	12.95	0.26	3.58*	655.53	18.37	2752.47
Maharashtra	67	K	6	5.63	1.00	14.08*	396.15	27.62	20024.82
Uttar Pradesh	67	K	4	3.82	0.90	9.12*	49.03	16.18	2087.87
Maize									
Bihar	67	K	4	2.96	4.26	5.67*	418.26	28.27	7148.13
Madhya Pradesh	67	K	5	3.10	1.69	4.10*	812.74	20.79	5361.52
Punjab	67	K	3	57.01	0.30	0.54	417.66	63.33	566.28
Uttar Pradesh	67	K	5	7.71	1.11	7.36*	302.39	19.16	5768.60
Maharashtra	67	K	5	16.75	2.53	5.00*	340.87	44. 4	3182.77
Uttar Pradesh	68	K	6	-0.07	0.89	28.08*	15.44	11.19	4072.95
Bihar	68	K	6	-1.77	0.58	28.53*	18.95	13.57	3876.48
Madhya Pradesh	68	K	5	7.07	0.39	4.83*	109.15	14.74	959.24
Punjab	68	K	4	3.23	1.32	2.37	2608.46	42.83	8426.18

Source: Sources of Data, Nos. 16 and 19.

*Significant at the 5% Level

TABLE 15. ESTIMATED LINEAR REGRESSION OF ADOPTION OF HIGH-YIELDING WHEAT AND HYBRID JOWAR VARIETIES AGAINST FARM SIZE, USING THE PROGRAMME EVALUATION ORGANISATION DATA

				UNRESTRICTED MODEL				RESTRICTED MODEL	
Area By Crop	Crop Year	Season	No. Obs.	Estimated Intercept	Estimated Slope	Estimated t Ratio	Sum of Squared Residuals	Estimated Intercept	Sum of Squared Residuals
Wheat									
Bihar	67	R	4	43.26	3.11	3.32	1323.84	62.27	8629.01
Haryana	67	R	5	7.52	0.50	3.09	1169.76	20.73	4884.28
Punjab	67	R	5	67.75	0.80	2.53	3548.98	81.30	11119.55
Rajasthan	67	R	5	20.99	0.49	2.58	1748.59	39.78	5616.77
Uttar Pradesh	67	R	6	33.53	1.31	2.90*	15655.14	46.83	48530.64
Bihar	68	R	5	61.26	-0.87	-1.71	3436.66	50.80	6776.13
Haryana	68	R	5	31.38	1.14	15.10*	159.01	53.85	12241.70
Maharashtra	68	R	4	16.88	1.18	2.35	1278.01	40.84	4799.47
Punjab	68	R	5	98.10	0.01	0.71	17.46	98.34	20.38
Rajhasthan	68	R	3	-4.45	2.18	111.72*	1.14	54.42	14227.89
Uttar Pradesh	68	R	6	69.24	0.93	1.95	11669.02	77.05	22771.73
Jowar									
Maharashtra	67	K	6	17.21	0.47	8.17*	294.53	28.42	5204.41
Madhya Pradesh	67	K	5	10.24	0.22	2.46	164.34	16.22	495.45
Mysore	67	K	4	4.56	0.12	0.29	11.56	4.89	12.00
Madhya Pradesh	68	K	3	-0.23	0.20	2.32	48.73	6.98	310.58
Maharashtra	68	K	6	17.70	0.41	3.81*	1085.61	26.29	5032.57
Maharashtra	68	R	6	37.38	-0.41	-0.65	42332.95	27.44	46764.75

Source: Sources of Data, Nos. 18 and 20.

*Significant at 5% Level

TABLE 16.

ESTIMATED LOGIT REGRESSION FOR ADOPTION OF NEW RICE VARIETIES AGAINST FARM SIZE, USING PROGRAMME EVALUATION ORGANISATION DATA

				UNRESTRICTED MODEL				RESTRICTED MODEL	
Area By Crop	Crop Year	Season	No. Obs.	Estimated Intercept	Estimated Slope	Estimated t Ratio	Sum of Squared Residuals	Estimated Intercept	Sum of Squared Residuals
Andhra Pradesh	67	K	6	-3.33	0.06	2.12	63.28	-2.28	134.24
Bihar	67	K	6	-0.29	0.09	3.00*	17.72	0.62	70.69
Kerala	67	K	4	-2.78	-0.13	-0.42	4.98	-3.00	5.42
Madras	67	K	5	0.06	0.10	3.44*	5.19	0.52	25.69
Maharashtra	67	K	6	-1.74	0.02	1.44	9.89	-1.52	15.02
Mysore	67	K	5	-2.15	0.06	1.91	7.68	-1.36	17.06
Orissa	67	K	5	-2.20	0.11	3.63*	3.95	-1.43	21.28
Punjab	67	K	5	-3.72	0.07	2.60	9.93	-1.79	32.24
Uttar Pradesh	67	K	5	-1.47	0.08	3.49*	9.52	-0.53	48.23
W. Bengal	67	K	5	-1.77	0.04	0.92	22.66	-1.47	29.04
Andhra Pradesh	68	K	6	-2.79	0.04	2.26	33.21	-2.04	75.58
Assam	68	K	4	-0.25	0.71	1.11	3.13	0.11	5.05
Bihar	68	K	5	-1.49	0.05	1.51	25.88	-0.88	45.55
Kerala	68	K	5	-1.16	0.05	1.41	8.43	-0.83	14.05
Madras	68	K	5	0.64	0.06	9.64*	1.11	1.11	35.58
Maharashtra	68	K	5	-2.76	0.06	1.72	14.09	-2.34	27.94

Source: Sources of Data, Nos. 16, 19

* Significant at 5% Level

TABLE 17. ESTIMATED LOGIT REGRESSION FOR ADOPTION OF HYBRID, BAJRA AND MAIZE VARIETIES AGAINST FARM SIZE, USING PROGRAMME EVALUATION ORGANISATION DATA

Area By Crop	Crop Year	Season	No. Obs.	UNRESTRICTED MODEL Estimated Intercept	Estimated Slope	Estimated t Ratio	Sum of Squared Residuals	RESTRICTED MODEL Estimated Intercept	Sum of Squared Residuals
Bajra									
Gujarat	68	K	6	-1.80	0.04	5.91*	4.18	-0.96	40.74
Haryana	68	K	4	-3.91	0.04	2.04	2.81	-2.81	8.64
Maharashtra	68	K	6	-2.77	0.14	4.22*	0.97	-2.40	5.26
Rajhasthan	68	K	4	-0.39	0.92	1.77	0.54	-0.04	1.38
Uttar Pradesh	68	K	3	-4.88	0.52	17.91*	0.00	-4.04	1.38
Gujarat	67	K	6	-1.90	0.02	2.75	4.89	-1.54	14.10
Maharashtra	67	K	6	-2.30	0.05	5.54*	7.06	-1.15	61.19
Uttar Pradesh	67	K	4	-2.55	0.57	9.47*	0.18	-1.77	8.25
Maize									
Bihar	67	K	4	-2.42	0.22	4.56*	1.69	-1.13	19.33
Uttar Pradesh	67	K	5	-2.55	0.09	2.63	5.68	-1.60	18.82
Punjab	67	K	3	0.29	0.12	0.59	0.71	0.55	0.96
Uttar Pradesh	67	K	5	-2.36	0.07	2.77	8.94	-1.62	31.82
Maharashtra	67	K	5	-1.71	0.14	6.45*	0.58	-0.20	8.69
Uttar Pradesh	68	K	6	-3.41	0.08	5.42*	3.50	-2.37	37.67
Bihar	68	K	6	-4.02	0.06	4.98*	5.99	-2.52	43.10
Uttar Pradesh	68	K	6	-2.42	0.03	3.42*	1.07	-1.88	5.22
Punjab	68	K	4	-2.60	-7.71	2.15	9.17	-0.47	30.26

Source: Sources of Data, Nos. 16 and 19. *Significant at 5% Level

TABLE 18.

ESTIMATED LOGIT REGRESSION OF ADOPTION OF HIGH-YIELDING WHEAT AND HYBRID JOWAR VARIETIES AGAINST FARM SIZE, USING THE PROGRAMME EVALUATION ORGANISATION DATA

Area By Crop	Crop Year	Season Season	No. Obs.	UNRESTRICTED MODEL Estimated Intercept	Estimated Slope	Estimated t Ratio	Sum of Squared Residuals	RESTRICTED MODEL Estimated Intercept	Sum of Squared Residuals
Wheat									
Bihar	67	R	4	-0.38	0.16	4.04*	2.48	0.62	22.70
Haryana	67	R	5	-2.36	0.03	2.73	7.12	-1.45	24.76
Punjab	67	R	5	0.61	0.06	3.77*	8.43	1.60	48.29
Rajasthan	67	R	5	-1.42	0.02	2.02	7.04	-0.48	16.64
Uttar Pradesh	67	R	6	-0.70	0.06	2.94*	27.98	-0.13	88.40
Bihar	68	R	5	0.47	-0.04	-1.75	5.89	0.03	11.89
Haryana	68	R	5	-0.78	0.04	14.31*	0.32	0.17	21.90
Maharashtra	68	R	4	-1.68	0.59	1.86	5.07	-0.47	13.99
Punjab	68	R	5	3.99	0.01	0.61	5.68	4.11	6.39
Rajhasthan	68	R	3	-2.48	0.98	15.56*	0.12	0.16	28.81
Uttar Pradesh	68	R	6	0.74	0.07	2.60	42.28	1.37	113.52
Jowar									
Maharashtra	67	K	6	-1.52	0.02	5.28*	1.67	-0.97	13.29
Madhya Pradesh	67	K	5	-2.11	0.02	1.94	1.29	-1.70	2.91
Mysore	67	K	4	-3.10	0.00	0.36	0.65	-3.00	0.70
Madhya Pradesh	68	K	3	-3.70	0.25	2.10	0.93	-2.79	5.04
Maharashtra	68	K	6	-1.47	0.19	3.30*	3.12	-1.07	11.61
Maharashtra	68	R	6	0.81	-0.15	-0.46	110.67	-1.18	116.79

Source: Sources of Data, Nos. 18 and 20.

* Significant at 5% Level

TABLE 19.

ESTIMATED LINEAR REGRESSION FOR THE PROPORTION OF FARMERS WHO ARE MEMBERS OF THE CO-OPERATIVES AGAINST FARM SIZE, USING PROGRAMME EVALUATION ORGANISATION DATA

Crop	Year	Season	UNRESTRICTED MODEL No. Obs.	Estimated Intercept	Estimated Slope	Estimated t Ratio	Sum of Squared Residuals	RESTRICED MODEL Estimated Intercept	Sum of Squared Residuals
Paddy A	67	K	6	54.47	0.31	2.00	9218.43	58.00	18406.84
Paddy HA	67	K	6	32.90	1.22	1.95	24200.16	38.49	47211.28
Maize A	67	K	6	47.72	0.63	2.30	5374.67	56.29	12476.51
Maize HA	67	K	5	26.69	1.50	3.80*	3078.81	39.46	17880.84
Bajra A	67	K	6	35.98	0.18	1.28	5738.27	40.11	8089.06
Bajra HA	67	K	6	49.20	0.72	2.88*	5418.11	60.07	16633.94
Jowar A	67	K	6	49.42	0.17	1.64	1348.07	53.61	2249.14
Jowar HA	67	K	6	42.50	0.88	3.70*	5017.46	58.53	22190.94

Source: Sources of Data, No. 16.

*Significant at 5% Level.

TABLE 20. F STATISTICS TO TEST THE HYPOTHESIS THAT CERTAIN VARIABLES ARE UNRELATED TO FARM SIZE

Name of Variable[1]	No. of Regression	No. of Obs.	Observed F Statistic
Proportion of land owned	16	50	1.47
Proportion of land irrigated	16	52	1.28
Proportion of cash expenditure met by the co-operatives	16	52	4.48**
Proportion of farmers who are members of the co-operatives	8	47	11.36**

TABLE 21. F STATISTICS TO TEST THE HYPOTHESIS THAT CERTAIN VARIABLES ARE THE SAME FOR ADOPTERS AND NON-ADOPTERS

Name of Variables	No. of Regression	No. of Obs.	Observed F Statistic
The proportion of land owned	16	82	2.11*
The proportion of land irrigated	16	52	22.71**
The proportion of cash expenditure met by the co-operatives	16	52	10.56**
The proportion of farmers who are members of the co-operatives	8	47	13.26**

* Significant at the 5% level.

** Significant at the 0.5% level.

1 The first three variables were tested using Agro-Economic Research Cent Data. (See Tables 4, 7, and 9). The fourth variable was tes using data from the Programme Evaluation Organisation (See Table 19).

TABLE 22

ESTIMATED LINEAR REGRESSION FOR ADOPTION AGAINST FARM SIZE IN DIFFERENT REGIONS[1] USING AGRO-ECONOMIC RESEARCH CENTRE DATA

				UNRESTRICTED MODEL				RESTRICTED MODEL	
REGION	Crop Year	Season	No. Obs.	Estimated Intercept	Estimated Slope	Estimated t Ratio	Sum of Squared Residuals	Estimated Intercept	Sum of Squared Residuals
Northeast	66	K	5	-4.17	4.81	3.87*	13988.19	12.82	83757.8
Northwest	67	K	42	16.52	3.26	4.22*	1349160.	33.42	1949267.
Northeast	67	K	15	49.22	1.95	1.45	116467.3	58.68	193433.3
Northwest	67	R	27	29.01	4.24	1.85	244550.4	36.65	278145.9
Northeast	68	K	27	40.74	2.89	2.44*	531793.	55.32	658889.2
Southeast	68	K	10	11.49	1.30	7.33*	34498.52	22.46	265966.7
Southeast	68	R	10	44.13	1.78	3.11*	108941.9	55.87	240595.3
Northwest	68	R	8	29.15	0.90	3.54*	31489.8	44.89	134420.0

Source: Sources of Data, Nos. 2, 3, 6, 7, 9, 10, 11, 12, 14, 15. *Significant at 5% Level

1 The data is aggregated over all crops in each region

Appendix B: Statistical Methods of Analysis

The linear regression for a single farm is

$$P_f = \alpha + \beta X_f + \epsilon_f \qquad f = \text{farm}$$

where P is the probability of adoption, X is farm size, α and β are unknown parameters, ϵ is the error term and

$$E(\epsilon_f) = 0$$

$$E(\epsilon_f \epsilon_{f'}) = \sigma^2 \text{ if } f = f'$$

$$= 0 \text{ if } f \neq f'$$

The outcome of whether or not a single farm adopts may be observed, but the probability of a single farm adopting may not be observed. It is possible to aggregate farms into groups, and the model for farm means becomes:

$$1/n_j \sum_{f \text{ in } j} P_f = 1/n_j \sum_{f \text{ in } j} (\alpha + \beta X_f + \epsilon_j)$$

where $j = 1,2,\ldots,J$ is the farm group, grouped by size in this analysis, and n_j is the number of farms in the jth farm group.

This model may be rewritten as follows:

$$\bar{P} = \alpha + \beta \bar{X}_j + \bar{\epsilon}_j$$

Since all residual covariances are zero, it follows that

$$E(\bar{\epsilon}_j) = 0$$

$$E(\bar{\epsilon}_j \bar{\epsilon}_{j'}) = \sigma^2/n_j \text{ if } j = j'$$

$$= 0 \qquad \text{if } j \neq j'$$

Hence, the residual means are heteroscedastic - i.e. the matrix of variances and covariances of residuals is as follows:

$$\sigma^2 \begin{bmatrix} 1/n_1 & 0 & \cdots & 0 \\ 0 & 1/n_2 & & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1/n_J \end{bmatrix}$$

We, therefore, weighted each group mean by $\sqrt{n}$ so that the transformed residuals are homoscedastic. Ordinary least squares estimates are unbiased, but do not exhibit minimum variance if residuals are heteroscedastic.[1]

An additional source of variation in the error term is introduced when we deal with a sample instead of the entire population. With a sample of n out of a population N_j, the model becomes

$$\pi_j = \alpha + \beta \bar{X}_j + (\bar{\epsilon}_j + \bar{\pi}_j - \bar{P}_j)$$

where π_j is the sample estimate of the mean probability. Hence, the residual contains a stocastic component $\bar{\epsilon}_j$, and a second term due to estimation error $(\bar{\pi}_j - \bar{P}_j)$.

The residual variance may be rewritten as follows[2]

$$\mathrm{Var}\,(\bar{\epsilon}_j + \bar{\pi}_j - \bar{P}_j) = \frac{\sigma^2}{n_j} + \frac{\bar{P}_j\,(1 - \bar{P}_j)}{n_j} - \sum_{f \text{ in } j} \frac{(P_f - \bar{P}_j)^2}{n_j}$$

All covariances terms are zero. The second term on the right hand side of this equation is the variance of the binomial probability estimate, and the last term is the variance of the true probability around the mean within each group j. In this analysis, we assume either that the second and third terms on the right hand side are approximately constant for all j, or that the first term dominates. Clearly, when the whole population is used, both the last two terms are equal to zero.

1/ See J. Johnston, Econometric Methods, McGraw Hill, 1963, pp. 107-108.

2/ The variance of the sampling error is given by N. S. Kendall and A. Stuart, Advanced Theory of Statistics, Vol. I, Gritten, London 1958, p. 127.

An alternative to the simple linear model is the "logit" model. The model is

$$\log\left(\frac{\bar{P}_j}{1-\bar{P}_j}\right) = \alpha + \beta\bar{X}_j + \bar{\epsilon}_j \quad \text{and } j = \text{farm group}$$

and

$$E(\bar{\epsilon}_j) = 0$$

$$E(\bar{\epsilon}_j\bar{\epsilon}_{j'}) = \sigma^2/n_j \quad \text{if } j = j'$$

$$= 0 \quad \text{if } j \neq j'$$

The problem with respect to the sampling error is similar to that considered in the preceding paragraphs.[1/] The essential difference between this and the earlier model lies in the shape of the function due to the transformation of the dependent variable in the latter. In the simple linear model, probabilities may be predicted which are smaller than zero or greater than one. In the logit model all probabilities are constrained to lie between zero and one.

Ideally, iterative techniques should be used to obtain the least squares estimate of the unknown parameters. However, the absence of a suitable program to obtain these estimates by iteration, it was necessary to assume that the weighted residuals were well-behaved. It should also be added that if the model is used for each farm, $\bar{P}_j$ should be the geometric mean rather than the arithmetic mean.

To calculate the F statistic for testing the hypothesis that all the slopes are zero in M regressions, the following formula was used

$$Fo = \frac{\dfrac{SSRr - SSRu}{M}}{\dfrac{SSRu}{N-2M}}$$

where

SSRr is the sum of squared residuals for the restricted model.
SSRu is the sum of squared residuals for the unrestricted model.
M is the number of regressions.
N is the number of observations.

If the slopes are zero, Fo has an F distribution with $j_1 = M$ and $j_2 = N - 2M$ degrees of freedom. The hypothesis is rejected if Fo is larger than the initial F value.

1/ For a detailed discussion of sampling error in the logit model, see Henri Theil, Economics and Information Theory, Rand McNally and Company, Chicago, 1967, pp. 71-87.

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