RESOURCE PRODUCTIVITY, RETURNS TO SCALE AND FARM SIZE IN INDIAN AGRICULTURE: SOME RECENT EVIDENCE*

UMA K. SRIVASTAVA, VISHNUPRASAD NAGADEVARA and EARL O. HEADY**

Iowa State University

A perceptible technological transformation has been under way in India during the last few years. The output of total foodgrains increased sharply between 1967-68 and 1970-71 over previous years. There is enough evidence to show that the technological change has resulted in an upward shift in production functions for major crops, especially for wheat.

Recent studies have attempted to estimate the contribution of technology to the growth of foodgrain production [3, 4]. These studies have implicitly assumed the parameter of scale of returns to be constant. If verification indicates scale returns to be either increasing or decreasing, the previous studies would have inaccurately stated the contribution of technology in the growth of output [17].

Further, some studies suggest that Indian agriculture is characterized by an inverse relationship between output per hectare and farm size[1] and also between farm business income[2] per hectare and farm size. Net profits[3] per hectare, however, have been found to be positively correlated with farm size [1]. These relationships have direct bearing on a number of policy issues, one of them being income disparity among the farm size groups. The inverse relationship of farm size with output and farm business income per hectare would reduce the relative income disparities that exist because of land ownership pattern being skewed in favour of large farms [5].

Previous investigations of these relationships were made with data from the middle of 1950s decade. Unless these relationships also hold true for post-technological change data, their effect on interfarm income disparities may also have changed. For instance, if new data reveal that the relationship between farm size and productivity is positive, new technology may have a neutral or accentuating influence on interfarm *income disparity. A recent study [4] based on one year of post-technological* change data (cross-section) for Punjab (Ferozepur 1967-68)

* Journal Paper No. J-7185 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa; Project No. 1558.

** Uma K. Srivastava is a Post-doctoral Research Associate, Vishnuprasad Nagadevara is a Graduate Assistant and Earl O. Heady is Curtiss Distinguished Professor of Economics and Director of the Center for Agricultural and Rural Development, Department of Economics, Iowa State University.

[1] Farm size is defined as the operational holding in hectares.

[2] Farm business income is defined as value of total output less actual incurred cost.

[3] Net profit is defined as value of total output minus total cost (both actual and imputed cost).

and Uttar Pradesh (Muzzaffer Nagar (1966-67), has concluded that there was no evidence of such a change (Appendix Table 2). The conclusion for Punjab, however, seems to be based on a misinterpretation of a statistical result.[4] Furthermore, the results are based on only one year of data from each of the two regions and only on farm operations in the wheatgrowing region.

Objectives, Data and Framework

The objectives of this paper are twofold: (i) to test the hypothesis of constant returns to scale in Indian agriculture with evidence available for the post-green-revolution period and (ii) to test the hypothesis that farm size is inversely related to both output and farm business income per hectare and positively related to the net profits per hectare. Also, the paper examines the validity of some of the major arguments advanced to explain the inverse relationship between farm size and productivity.

Cross-section data from the national cost accounting sample has been used for the analysis. These data were collected from three regions in India: (a) Tamil Nadu (Thanjavur), (b) Uttar Pradesh (Muzzaffer Nagar), and (c) Punjab (Ferozepur). The data pertain to the production years 1967-68 and 1968-69. The period covered by these data shows definite evidence of an onset of a process of technological change.

Thanjavur, Muzzaffer Nagar and Ferozepur regions have contrasting demographic, economic and agricultural characteristics. More importantly, while Muzzaffer Nagar and Ferozepur are predominantly wheat producing areas, rice cultivation dominated Thanjavur. It has been found that technological change, particularly the use of high-yielding varieties, has rapidly increased the absolute and also the relative profitability per hectare in the wheatgrowing regions (see Appendix Table 4). Hence, the two sets of areas should reflect differential effects of technological change as they relate to wheat and rice as we progress on the main objectives of the study.

The sample in each district includes 150 farms selected as a stratified random sample. First, fifteen villages are randomly selected in each district. The farms of each village were divided into five groups in such a way that each group cultivated one-fifth of the area under cultivation. Within each of such groups, two farmers were selected at random. As discussed in another paper [2], it is likely that the grouped data presented in the reports suffer from the problem of heteroscedasticity, thereby resulting in less efficient (but yet unbiased) estimates of the regression coefficients. Therefore, we have used disaggregated raw data instead of class-mean observations as presented in the survey reports.

We have fitted the unrestricted form of the Cobb-Douglas production function for the three regions by pooling the two-year data in each case. The pooling procedure will be discussed in the following section. Further, we have fitted an exponential function of the type, $Y = aX^{\beta}$, to verify returns to scale relative to farm size. We also have used the exponential function for verifying the relationship between labour and non-labour inputs with respect to farm size. Because the latter functions

[4] The '*t*' value of deviation of β from unity in the case of Ferozepur 1967-68 [4] is 0·73, which is not significant even at the 10 per cent probability level. Thus, only constant returns to scale relative to farm size can be inferred.

have been fitted on a per-farm basis, we have tested the elasticity coefficients against unity.

Technological Change and Returns to Scale

Technological change in Indian agriculture has been characterized as being of a biological-mechanical type [16]. This change should reveal itself in changed parameters of the partial elasticities of production in a Cobb-Douglas framework. To estimate the contribution of newly available biological inputs of seed and fertilizers and of mechanical inputs of farm machinery and implements, we have specified our production function as:

$$Y = AX_1^{\alpha} X_2^{\beta} X_3^{\gamma} X_4^{\delta} X_5^{\varepsilon} e^{\xi X_6}$$

Where Y = Aggregate crop output (Rupees)
X_1 = Size of farm (hectares)
X_2 = Human labour (adult man days)
X_3 = Bullock labour (bullock pair days)
X_4 = Interest on fixed capital and depreciation on farm machinery and implements (Rupees)
X_5 = Value of seeds (owned and purchased), value of fertilizers and manures (owned and purchased) and irrigation charges (Rupees)
X_6 = Year dummy variable. It takes the value zero for the observations of 1967-68 and value one for the observations of 1968-69 for each of the three regions.

Our specification includes some flow and some stock variables. The inclusion of some stock variables, particularly land, was considered better from the standpoint of accuracy in data collection for these variables. The human labour variable (X_2) combines family labour, permanent hired labour and casual hired labour. The variables X_4 and X_5 are of interest from the standpoint of technological change. Interest on fixed capital and depreciation on farm machinery (X_4) have been used as proxies for mechanical inputs in the flow form. Seed, fertilizers and irrigation (X_5) have been combined to represent a package of biological inputs. Further, a preliminary examination of the data revealed that there was a change in input and output prices between 1968-69 and 1967-68. Hence, direct pooling of data for the two years would result in a bias. We have, therefore, added a year dummy variable (X_6) to incorporate the effects of the price change. The significance level of the coefficient for the X_6 variable would justify inclusion of the dummy variable. We fitted four equations in log form, one for each state and two for Uttar Pradesh. The second equation for Uttar Pradesh excludes the bullock labour since this variable was not found significant even at the 10 percent probability level. The statistical results are presented in Table 1.

The input variables included in the estimated functions explain from 72 to 94 percent of output variance. Further, all coefficients are significant at the 1 per cent probability level (Table 1) except the coefficient γ in the equation I (significant at 5 percent probability level) and coefficient δ in equations II and III (not significant, even at the 10

TABLE 1

Production Functions and Returns to Scale in Indian Agriculture

State	Equation No.	N	Parameters a	α	β	γ	δ	ε	ξ	$\sum_{i=1}^{i=5a}$	R^2
Tamil Nadu	I	300	3·7402	+0·3750*** (0·0386)	+0·4828*** (0·0518)	−0·0704** (0·0299)	+0·0661*** (0·0206)	+0·1396*** (0·0326)	+0·2375*** (0·0337)	0·8920 (0·1390)	·9017
Uttar Pradesh	II	300	5·4915	+0·5004*** (0·0346)	+0·3223*** (0·0596)	−0·0573 (0·0510)	+0·0218 (0·0162)	+0·2502*** (0·0326)	−0·3206*** (0·1112)	1·0376 (0·1604)[b]	·9449
	III	300	5·3694	+0·4893*** (0·0332)	+0·2813*** (0·0473)		+0·0223 (0·0163)	+0·2495*** (0·0326)	−0·1980*** (0·0215)	1·0425 (0·0279)	·9447
Punjab	IV	299	3·4308	+0·3928*** (0·0613)	+0·5097*** (0·0763)	+0·0137*** (0·00062)	+0·1362*** (0·0384)	+0·1417*** (0·0420)	−0·2052** (0·0852)	1·1940* (0·0960)	·7219

* Significantly different from zero at 10 percent probability level.
** Significantly different from zero at 5 percent probability level.
*** Significantly different from zero at 1 percent probability level.
[a] The coefficient of dummy variable (X_6) has not been included in the sum of elasticity.
[b] Figures refer to $\sum_{i=1}^{i=4}$.

percent probability level). As the correlation matrix presented in the appendix indicates, the intercorrelation problem among the explanatory variables is not beyond the bounds usually accepted in production functions based on cross-section data.[5]

The results in Table I indicate that output is highly responsive to land and labour inputs in all the regions. In fact, there has been a significant upward shift in the partial elasticity with respect to land in Uttar Pradesh and Tamil Nadu as compared to mid-fifties (Appendix Table 3). The partial elasticity of production with respect to seed, fertilizer and irrigation (ε) is significantly higher in Uttar Pradesh as compared to mid-fifties (Appendix Table 3). The partial elasticity coefficient for the variable of farm machinery and implements (δ) is very small in the case of Tamil Nadu and Uttar Pradesh, but fairly large in the case of Punjab (0·1362 in equation IV as compared with 0·0661, 0·0218 and 0·0223 in equations I, II and III), perhaps showing that new or modern mechanical inputs have begun to play a significant role in Punjab agriculture. It is also indicated by the upward shift in the partial elasticity coefficient (δ) as compared to mid-fifties (Appendix Table 3). The sign on the elasticity of production of bullock labour (γ) is negative, indicating that the use of bullock labour has been pushed beyond the optimal level in Tamil Nadu and Uttar Pradesh. The coefficient of bullock labour is, however, not significantly different from zero in Uttar Pradesh.

Scale returns

To test the hypothesis of constant returns to scale, we tested the sum of elasticities against unity. We find that the sums of coefficients in Tamil Nadu and Uttar Pradesh are not statistically different from unity even at the 10 percent probability level. Therefore, we cannot reject the hypothesis of constant returns to scale. This result implies, for the two regions that have not added modern mechanical equipment, that the upward shift in production has been neutral to the scale parameter. But the sum of elasticities is significantly greater than one in the Punjab, signifying increasing returns to scale. This finding is not in conformity with some of the earlier studies [8, 13, 14]. The result could be because some important variables are excluded from the production function in earlier studies.[6] Thus, our mixed evidence suggests that generalization about returns to scale in agriculture sector on all-India basis may not be appropriate.

Returns to Scale Relative to Farm Size

The results of either constant or increasing 'physical returns to scale' do not necessarily imply that 'economic returns to scale'[7] are constant or increasing. Also, this does not imply that constant or increasing

[5] In Equation II for Uttar Pradesh δ and γ could be insignificant because of high intercorrelation.

[6] The estimates of returns to scale become biased unless all the input factors are included in the production function. The production function fitted by Saini [14] has an R^2 of only 0·59, whereas the production function for Punjab in our study has an R^2 of 0·72, which might be the result of including more explanatory variables.

[7] Economic returns to scale include only those variables under control of the entrepreneur [7, p. 232].

returns to scale will hold relative to any one factor; i.e., land, labour or capital items [7]. By and large, technological change in India has been oriented towards modern inputs, raising productivity per hectare. Since there is evidence of a differential rate of adoption and levels of application of new technology among different farm size groups, it can be postulated that the size-productivity relationship may have changed to a positive one in recent years.

We have tested the size-productivity relationship with two regression equations specified as (a) $Y = aX^{\beta}$, where Y is output per farm and X is farm size in hectares, and (b) $Y = aX_1^{\alpha}X_2^{\beta}$, where Y is defined as before, X_1 is farm size in hectares and X_2 is ratio of irrigated area to farm size. The second equation is expected to correct the size-productivity relationship for irrigation differences in land inputs. The statistical results of these equations are presented in Tables 2 and 3.

TABLE 2

The Relationship Between Output per Farm and Farm Size

State	Year	N	Parameters a	Parameters β	R^2
Tamil Nadu	1967-68	150	2·8250	*** +0·8789 (0·0390)	0·7742
	1968-69	150	2·8730	* +0·9177 (0·0382)	0·7459
Uttar Pradesh	1967-68	150	3·5018	* +0·9588 (0·0202)	0·8263
	1968-69	150	3·6185	*** +0·9193 (0·0303)	0·9384
Punjab	1967-68	149	3·2436	+0·9661 (0·0501)	0·7200
	1968-69	150	2·1737	+0·9730 (0·0583)	0·6257

* Significantly different from unity at 10 percent probability level.
*** Significantly different from unity at 1 percent probability level.

In Table 2, β is significantly different from unity and decreasing only in four of six regressions. The β coefficients for Punjab are not significantly different from unity even at the 10 percent probability level. Furthermore, when the irrigation effect is 'taken out' of the size-productivity relationship (Table 3), α is significantly different from unity only in three of six cases. The output per hectare remains unchanged in Punjab and Tamil Nadu (1967-68) as farm size increases. Thus, the findings in Tables 2 and 3 at best give mixed support to the hypothesis of decreasing returns to scale relative to farm size. It is clear that the evidence, unlike mid-fifties data, does not permit any generalization as to decreasing or constant returns relative to farm size for Indian agriculture. But evidence presented here indicates that there are no increasing returns to scale relative to farm size.[8]

[8] It is noteworthy that scale returns in the production of high-yielding varieties of wheat also are found to be constant (Appendix Table 5).

TABLE 3

The Relationship Between Output per Farm (corrected for irrigated area) and Farm Size

State	Year	N	Parameters a^1	α	β	R^2
Tamil Nadu	1967-68	150	6·7445	+0·9803	+0·3887*	0·8585
				(0·0332)	(0·1918)	
	1968-69	150	6·5483	+0·8876**	+0·3989	0·7482
				(0·0446)	(0·2042)	
Uttar Pradesh	1967-68	150	8·4207	+0·9160***	+0·0718*	0·8652
				(0·0298)	(0·0348)	
	1968-69	150	8·1449	+0·9585*	+0·0042	0·9398
				(0·0204)	(0·0162)	
Punjab	1967-68	149	7·5560	+0·9791	+0·6308***	0·7282
				(0·0769)	(0·1896)	
	1968-69	150	4·9532	+1·0248	+0·8772***	0·7264
				(0·0526)	(0·1397)	

* Significantly different from unity at 10 percent probability level.
** Significantly different from unity at 5 percent probability level.
*** Significantly different from unity at 1 percent probability level.

[1] The intercept is log to the base e.

An Explanation of Observed Farm Size-productivity Relationships

The studies with mid-fifties data found that the higher output per unit of land on small farms was a function of higher inputs of labour and non-labour inputs per unit of land [10, 6]. We have tested these findings as to how far the differences in input allocation can explain our findings with respect to size-productivity relationships. We have fitted three equations where farm size has been made an independent variable in all of the three equations. Equation I uses labour inputs (family, casual and permanent labour valued in rupees) as a dependent variable Equation II uses all inputs, other than the wage bill, as a dependent variable. Equation III uses total value of inputs (imputed or actually incurred) as a dependent variable. The statistical estimates are presented in Table 4.

The coefficients, α, β and γ (Table 4), are significantly different from unity, except for 1968-69 in equation II, at 10 percent or less probability levels. Hence, we can interpret the inverse of direct relationship between farm size and inputs per hectare according to the values of the coefficients. The results of the equation III show that total inputs per hectare are inversely related with farm size in all the years and all the regions except in the Punjab for the year 1968-69. The decrease in inputs per hectare also is seen both in labour and non-labour inputs (equation II), except in the Punjab (1968-69) when non-labour inputs per hectare increase as the farm size increases. Total inputs per hectare

TABLE 4

The Relationship Between Inputs per Farm and Farm Size

State	Year	N	Equation I Parameters a^1	Equation I Parameters α	R^2	Equation II Parameters a	Equation II Parameters β	R^2	Equation III Parameters a	Equation III Parameters γ	R^2
Tamil Nadu	1967-68	150	5·5541	+0·8094*** (0·0476)	0·6609	6·1046	+0·9078* (0·0426)	0·7540	6·5698	+0·8789*** (0·0390)	0·7742
	1968-69	150	5·6078	+0·8610*** (0·0376)	0·7796	6·2378	+0·9473 (0·0413)	0·7799	6·6815	+0·9177* (0·0382)	0·7959
Uttar Pradesh	1967-68	150	5·9742	+0·7015*** (0·0315)	0·7696	7·5889	+0·8347*** (0·0350)	0·7933	7·7735	+0·8204*** (0·0245)	0·8871
	1968-69	150	5·8715	+0·7719*** (0·0262)	0·8541	6·9563	+0·7481*** (0·0330)	0·7770	7·2606	+0·7516*** (0·0280)	0·8297
Punjab	1967-68	149	6·4753	+0·7639*** (0·0631)	0·4950	7·3158	+0·8661*** (0·0400)	0·7614	7·6970	+0·8296*** (0·0410)	0·7352
	1968-69	150	6·5117	+0·7337*** (0·0542)	0·5535	5·0295	+1·3090** (0·1204)	0·4122	6·7099	+0·9495 (0·0670)	0·5751

* Significantly different from unity at 10 percent level of probability.
** Significantly different from unity at 5 percent level of probability.
*** Significantly different from unity at 1 percent level of probability.
[1] the intercept is in log to the base e.

are not significantly different from unity however, indicating that the decrease in labour inputs per hectare offsets the increases in non-labour inputs as farm size increases. The inverse relationship between farm size and productivity observed in Tamil Nadu and Uttar Pradesh evidently is explained by lower inputs per hectare as farm size increases (Table 4). Again, the constant returns relative to farm size in the Punjab for the year 1968-69 result from a statistically constant level of total (labour and non-labour) inputs per hectare irrespective of farm size.

Profit per hectare and farm size

The hypothesis of a diiect relationship between farm size and profit per hectare has been investigated with the new data by fitting the regression equation $Y=aX^{\beta}$, where Y is net profit per farm in rupees and X is farm size in hectares. The statistical results show that in only one of six cases is profit per hectare significantly different from unity with farm size (Table 5). In all other cases, profit per hectare is constant as farm size

TABLE 5

The Relationship Between Profits per Farm and Farm Size

State	Year	N	Parameters a	Parameters β	R^2
Tamil Nadu	1967-68	150	2·6279	+1·0051 (0·0519)	0·7163
	1968-69	150	2·8427	+1·0444 (0·0271)	0·9091
Uttar Pradesh	1967-68	150	3·1521	+1·1693*** (0·0299)	0·6781
	1968-69	150	3·2278	+1·0530 (0·0604)	0·9115
Punjab	1967-68	149	2·1588	+1·1878 (0·1763)	0·2371
	1968-69	150	1·3836	+0·9362 (0·1465)	0·2161

*** Significantly different from unity at 1 percent level of probability.

increases. These results lead us to reject the hypothesis that, as farm size increases, at least within the bounds of our sample and data, profit per hectare goes up. The reasons for this constant-profit-size relationship can be traced back to the proportional changes in inputs and outputs (Tables 2 and 4), which leave profits per hectare unaffected.

Farm business income and farm size

In the estimates for the fifties, the large farmers were earning less family income per hectare than were small farmers because the latter had the advantage of more family labour (which is not a purchased input in their case) as compared to large farmers. This relationship has been tested with the new data by fitting the equation $Y = aX^{\beta}$ where Y is net farm business income per farm and X now is farm size. The statistical results are presented in Table 6. Of the six equations presented, β is significantly different from unity in only two. In the remaining four, it is not significantly different from unity and signifies constant farm business income per hectare as farm size increases. For the two cases where β is significantly different from

TABLE 6

The Relationship Between Farm Business Income per Farm and Farm Size

State	Year	N	Parameters a	Parameters β	R^2
Tamil Nadu	1967-68	150	2·5053	+0·7621** (0·0875)	0·3387
	1968-69	150	2·6776	+0·9737 (0·0500)	0·7192
Uttar Pradesh	1967-68	150	3·2455	+1·0929*** (0·0262)	0·8424
	1968-69	150	3·4706	+0·9768 (0·0352)	0·9213
Punjab	1967-68	149	2·8558	+1·0658 (0·0783)	0·5591
	1968-69	150	4·2747	+0·9398 (0·1428)	0·2261

** Significantly different from unity at 5 percent probability level.
*** Significantly different from unity at 1 percent probability level.

unity, farm-business income per hectare increases as farm size increases only for Uttar Pradesh (1967-68). In the equation for Tamil Nadu (1967-68), farm-business income per hectare decreases as farm size increases. Hence, we do not have results that conform to those generalizations based on mid-fifties data. This difference likely results because purchased inputs (used here in the sense of nonfamily labour inputs) have acquired a dominant role in total inputs of even the small farmers.

Concluding Remarks

Our results for Tamil Nadu and Uttar Pradesh show that there has been no change in the returns to scale. But the results for Punjab show an increasing return to scale. This possibly might exist through a shift to tractors and other modern mechanical inputs. Hence, our analysis of current data leads us to believe that no generalizations about returns to scale can be made for Indian agriculture as a whole.

On the whole, we find that changes in output per hectare relative to farm size are explained by changes in inputs. Thus, one can postulate that, in successive production cycles, large farmers will use more of the purchased inputs per hectare and that will augment problems of income disparity among farms.

The finding of higher output per hectare on smaller farms from data of the mid-fifties has been interpreted to mean that the small farmers are more efficient *vis-a-vis* large farmers. However, our results throw doubt on this finding as a generalization, and more tests of the hypothesis of relative efficiency must be made. One such attempt has been made in testing an UOP profit function [11]. This test did support the widely held view that the small farmers were more efficient as compared with large farmers in the 1950s. But when we fitted this function to the recent data, the results suggested no difference in the the relative efficiency among various farm size groups [2].

References

[1] Bhagwati, Jagdish N., and Chakravorty, Sukhamoy, 'Contributions to Indian Economic Analysis: A Survey', *American Economic Review (Supplement)*, 59: 1-73, September 1969.

[2] Crown, Robert W., and Srivastava, Uma K., 'A Test of Relative Efficiency and Application to Indian Agriculture: A Comment'. To be published.

[3] Cummings, Ralph W., Jr., and Ray, S. K., 'The New Agricultural Strategy —Its Contribution to 1967-68 Production', *Economic and Political Weekly, Review of Agriculture*, 3: A7-A16, March 1969.

[4] Cummings, Ralph W., Jr., Herdt, Robert W., and Ray, S. K., 'New Agricultural Strategy Revisited', *Economic and Political Weekly, Review of Agriculture*, 3: A15-23, October 1968.

[5] Government of India, Tables With Notes on Some Aspects of Land Holdings in Rural India—States and all-India Estimates, National Sample Survey 17th Round, 1961-62, Report No. 144, Central Secretariat, New Delhi, 1968.

[6] Hanumantha Rao, C. H., 'Alternative Explanations of the Inverse Relationship Between Farm Size and Output Per Acre in India', *Indian Economic Review*, 1: 1-12, October 1966.

[7] Heady, Earl O., and Dillon, John L., *Agricultural Production Functions*, Iowa State University Press, Ames, 1961.

[8] Kahlon, A. S., and Others, Studies in Economics of Farm Management Ferozepur District (Punjab), Department of Economics and Sociology, Punjab Agricultural University, Ludhiana, 1969-70 (Mimeographed).

[9] Khusro, A. M., 'Returns to Scale in Indian Agriculture', *Indian Journal of Agricultural Economics*, 19: 51-80, July-December 1964.

[10] Mazumdar, Dipak, 'Farm Size and Productivity', *Economics*, (New Series), 32: 163-73, May 1965.

[11] Lau, Lawrence J., and Yotopoulos, Pan A., 'A Test for Relative Efficiency and Application to Indian Agriculture', *American Economic Review*, 61: 94-109, March 1970.

[12] Saini, G. R., 'Resource-Use Efficiency in Agriculture', *Indian Journal of Agricultural Economics*, 24: 1-18, April-June 1969.

[13] Saini, G. R., 'Farm Size, Productivity and Returns to Scale', *Economic and Political Weekly, Review of Agriculture*, 4: A19-A22, June 28 1969.

[14] Saini, G. R., 'Holding Size, Productivity and Some Related Aspects of Indian Agriculture', *Economic and Political Weekly, Review of Agriculture*, 6: A79-A85, June 1971.

[15] Srivastava, Uma K., Crown, Robert W., and Heady, Earl O., 'The Green Revolution and Farm Income Distribution in India: A Theoretical Analysis', *Economic and Political Weekly, Review of Agriculture*, 6: A163-A172, December 1971.

[16] Srivastava, Uma K., and Nagadevara, Vishnuprasad, 'On the Allocative Efficiency Under Risk in Transforming Traditional Agriculture', *Economic and Political Weekly, Review of Agriculture*, 7: A73-A78, June 1972.

[17] Walters, A. A., 'A Note on Economies of Scale', *Review of Economics and Statistics*, 45: 425-427, November 1963.

APPENDIX—TABLE 1

Simple Correlation Coefficients Between Independent Variables (excluding dummy) (1967-68 and 1968-69)

	X_5	X_4	X_3	X_2	X_1
Tamil Nadu					
X_5	1·000	0·640	0·298	0·468	0·515
X_4		1·000	0·732	0·780	0·706
X_3			1·000	0·742	0·704
X_2				1·000	0·767
X_1					1·000
Punjab					
X_5	1·000	0·314	0·071	0·407	0·487
X_4		1·000	0·071	0·429	0·419
X_3			1·000	0·331	0·314
X_2				1·000	0·670
X_1					1·000
Uttar Pradesh					
X_5	1·000	0·526	0·229	0·520	0·566
X_4		1.000	0·371	0·835	0·839
X_3			1·000	0·465	0·413
X_2				1·000	0·842
X_1					1·000

APPENDIX—TABLE 2

Statistics Relating to 'Inverse Relationship'

State	Year	N	Constant log C	β Coeffi-cient	S E of	t-value of deviation of β from unity	R^2	F-Value
Andhra Pradesh	1957-58	104	2·59	0·90	0·05	2·11	0·78	367·10
Andhra Pradesh	1958-59	97	2·60	0·80	0·06	3·25	0·65	179.24
Andhra Pradesh	1959-60	84	2·60	0·85	0·10	1·49*	0·48	74·56
Bihar	1958-59	98	2·55	0·71	0·08	3·77	0·46	83·32
Madras	1954-55	198	2·08	0·69	0·10	3·14	0·21	51·14
Madras	1955-56	181	2·22	0·63	0·09	4·24	0·23	52·81
Maharashtra	1955-56	160	2·06	0·70	0·07	4·31	0·39	102·74
Maharashtra	1956-57	160	2·15	0·66	0·07	5·10	0·38	98·35
Madhya Pradesh	1955-56	159	1·71	1·03	0·05	0·51*	0·70	372·25
Madhya Pradesh	1956-57	159	2·12	0·86	0·04	3·37	0·74	443·75
Orissa	1957-58	98	2·15	0·96	0·06	0·72*	0·76	303·15
Orissa	1958-59	100	2·12	0·92	0·03	2·35	0·88	748·89
Orissa	1959-60	99	2·05	0·90	0·04	2·53	0·83	485·52
Punjab	1955-56	200	2·28	0·90	0·04	2·28	0·70	451·58
Punjab	1956-57	200	2·45	0·85	0·04	3·88	0·69	448·22
UP	1955-56	147	2·55	0·78	0·05	5·05	0·68	304·26
UP	1956-57	196	2·52	0·85	0·04	3·38	0·66	381·20
West Bengal	1955-56	190	2·13	1·08	0·08	0·99*	0·50	184·93
West Bengal	1956-57	192	2·33	1·10	0·06	1·79*	0·67	382·32
UP (Muzaffar Nagar)	1955-56	97	2·56	0·76	0·05	4·85	0·71	228·54
UP (Muzaffar Nagar)	1956-57	96	2·57	0·82	0·05	3·44	0·71	232·23
UP (Muzaffar Nagar)	1966-67	150	3·55	0·84	0·04	3·69	0·71	367·73
Punjab (Ferozepore)	1955-56	100	2·19	0·95	0·06	0·81*	0·70	228·99
Punjab (Ferozepore)	1956-57	100	2·45	0·84	0·06	2·66	0·65	180·92
Punjab (Ferozepore)	1967-68	150	3·28	0·94	0·08	0·73	0·49	143·48

Source: [14, pp. A79-A85].

Notes: The estimating equation is as follows: $\text{Log } Q = \log C + \beta \log A$
where Q = gross value of output of crops (Rs.)
A = size of the operational holdings

* Deviation not significant at the 5 percent level.

APPENDIX—TABLE 3

Production Functions and Returns to Scale in Indian Agriculture in Mid-fifties

State	Year	a	α	β	γ	δ	ε	$\sum_{i=1}^{5} \beta_i$	R^2	N
Tamil Nadu	1955-56	1·9667	0·1488*** (0·0576)	0·4338*** (0·1040)	—0·0094** (0·0732)	0·0971** (0·0385)	0·3131** (0·1521)	0·9835 (0·2384)	0·9905	168
Uttar Pradesh	1955-56	2·8823	0·2656** (0·1032)	0·2799** (0·1018)	0·2116** (0·1038)	0·0799 (0·0733)	0·1311 (0·0958)	0·9680 (0·3792)	0·9962	139
Punjab	1955-56	2·9871	0·3764*** (0·0648)	0·7871*** (0·1898)	—0·3641*** (0·0898)	0·0057 (0·0408)	0·1525*** (0·0076)	0·9577 (0·2353)	0·9982	197

Note: The estimated equation and definition of variables are the same as used in Table 1, except the year dummy varibale X_6.

APPENDIX—TABLE 4

Changes in Total Cost and Total Revenues in Wheat Production of Major Producing States in India

States	Total Cost I / Total Cost II	Total Revenue I / Total Revenue II
Uttar Pradesh	1·73	2·49
Punjab	2·93	5·79
Maharashtra	0·66	4·54
Rajasthan	1·98	8·51

Notes: Cost I stands for the cost of production of hybrid wheat with new array of inputs made available by new technology.
Cost II stands for the cost of production of indigenous wheat with irrigation and old array of inputs.
Total Revenue I and II stands for the same as the costs respectively.

Source: [15, pp. A163-A172].

APPENDIX—TABLE 5

Production Functions for Mexican Varieties of Wheat

Year	Estimated equation	R^2	df	$\Sigma\beta_i$	F
1967-68	$\ln Y_1 = 5{\cdot}0808 + 0{\cdot}4608^{***} \ln X_{11}$ (0·0913) $+ 0{\cdot}1070^{*} \ln X_{21} + 0{\cdot}4099^{***} \ln X_{51}$ (0·0893) (0·1013)	0·9064	106	0·9777 (0·0316)	342·5
1968-69	$\ln Y_2 = 3{\cdot}7062 + 0{\cdot}2162^{***} \ln X_{12}$ (0·0862) $+ 0{\cdot}6929^{***} \ln X_{22} + 0{\cdot}1320^{***} \ln X_{52}$ (0·0918) (0·0332)	0·8912	135	1·0413 (0·0316)	368·5

Source: [16, pp. A74-75].

Note: where Y_j = crop output (rupees)
X_{1j} = area under crop production (hectares)
X_{2j} = human labour (man days)
X_{5j} = value of seeds (rupees)
j = 1 for 1967-68
2 for 1968-69