Ind. Jn. of Agri. Econ.
Vol. 54, No. 1, Jan.-March 1999

Estimates of Fertiliser Demand and Private Investment Functions in Indian Agriculture - Some Comments

M.P. Wagle*

I

INTRODUCTION

During the period of the last three decades since the publication of papers by Parikh (1965) and by Tara Shukla (1968), a good number of scholars have attempted to estimate the aggregate functions of demand for fertilisers and private investment in agriculture in India. They have yielded varied estimates of elasticities, particularly with respect to the key variables such as price of fertilisers in the fertiliser demand function, or terms of trade or government investment in the private investment function[1] (Annexures 1 and 2). While the past studies have certainly helped in enhancing our understanding of the factors influencing the demand for fertilisers and private investment in agriculture, multiplicity of the functions estimated so far has raised a few additional issues too. The issues as examined in the present paper relate to: (i) econometric properties of the past estimates, (ii) basis for the selection of an appropriate model, and (iii) choice of the most relevant variables and their measurement. These three are not mutually exclusive. But for convenience, they are discussed in three separate sections that follow. Our comments regarding the above mentioned issues are supported by the comparisons of regressions based on the alternative models or choices of variables for the functions under study. Variables used in these regression exercises are specified below for easy reference.

(a) *Demand for Fertilisers*

In this exercise, demand for fertilisers (measured by the total plant nutrients N, P and K in thousand tonnes) is considered to be the function of per cent of area under irrigation and also high-yielding variety (HYV) seeds, rainfall, real price of fertilisers, real price of non-fertiliser farm inputs other than water and HYV seeds, and the lagged dependent variables.[2] The analysis covers the period of 27 years, i.e., from 1962-63 to 1988-89.

(b) *Private Agricultural Investment*

In the second exercise, private agricultural investment (measured by gross fixed capital formation at current prices in Rs. crores) is considered to be the function of relative price of agricultural vis-a-vis manufactured products, government investment and institutional credit (both at current prices in Rs. crores) during the current year, per cent of area under HYV seeds lagged by a year, and the lagged dependent variable.[3] The analysis undertaken covers the period of 28 years from 1961-62 to 1988-89.

* Director, Mangesh International Services, Dadar (West), Mumbai-400 028.
The author is grateful to a referee of the Journal for valuable comments which helped a great deal in improving the paper.

II

CHOICE BETWEEN ALTERNATIVE MODELS

The majority of the past studies referred in the present paper (Annexures 1 and 2) are based on the time-series data with the exception of Dhawan and Yadav (1995, all the models). Hence, the choice of alternative models such as linear vs. log-linear model or static vs. dynamic model is a crucial issue. Whatever may be the alternative, justification of the initial choice of the model has to be with reference to the economic rationale provided by the theory underlying it. In any case, it should not be left entirely to be determined by the criterion of the 'best fit' to the data.

(a) *Choice between Linear and Double-Log Models*

Most of the estimates in the fertiliser and investment functions are based on double-log form with the exception of Desai (1982, models: A to C), Gandhi (1990, models: A and B), Dhawan and Yadav (1995, the models), Misra and Hazell (1996), and Misra (1998), who used linear models.[4]

The linear model presupposes a constant absolute increment per unit of time int he dependent variable. This assumption is inconsistent with reality. Generally, as all the economic series grow with the ever widening base from time to time, the double-log model (alternatively known as a log-linear model) is preferable to a linear model on an *a priori* ground. Moreover, there is an additional reason for preferring the double-log model to the linear model. The former helps in reducing heteroscedasticity (Gujarati, 1995, p. 386). In other words, when the time-series data are taken into consideration, it is advisable to use a double-log model, unless theoretical considerations point to the other clearly superior alternative.

(b) *Choice between Static and Dynamic Models*

Yet another most important issue relating to the choice of a model pertains to the selection of the static versus dynamic model, when the analysis is based on the time-series. It is highly relevant in the present context because with the singular exception of a study by Dhawan and Yadav (1995), all the estimates listed in Annexures 1 and 2 are based on the time-series data.

Theoretically, a dynamic model is more suited when the adjustment process is underway owing to psychological, technological and institutional reasons (Gujarati, 1995, pp. 589-590). The long-run price elasticity, which reveals the farmers' overall response to the real/relative price changes, exceeds its short-run magnitude because the farmers adjust to changing profitability only gradually, with the adjustment process spread over several years owing to the factors mentioned above. The use of a static model, which estimates only the short-run price elasticity, does not help in revealing the true role played by the real/relative prices, or the other relevant variables in the farmers' decision-making.

Demand for Fertilisers

Theoretically, a dynamic model is more suited to the study of the demand for fertilisers in a developing country because of two reasons. One, there is a continuous process of learning over time involved in the application of fertilisers. The farmers reach the optimum level of use only after a certain period of time, and not instantaneously. Another reason for the adjustment period for the full adoption level of technology being larger than one year is the poor state of infrastructural development in many rural areas of India. Many a time, it puts constraints on the farmers' access to availability of fertilisers, as also that of crop loans from the rural credit institutions.

Empirically too, the dynamic model fits better to data than the static model. This is evident from the comparison of data in column (2) with column (3) in Table 1. While the Chow test for structural stability turns out to be significant at 5 per cent level of confidence in respect of the static model, it is not so for the dynamic model. Moreover, the value of the D-W test statistic for the static model falls in the zone of indecision, indicating the existence of autocorrelation. In addition, the long-run fertiliser price elasticity, i.e., -0.95 exceeds significantly its short-run elasticity of -0.37 [regression B, column (3) of Table 3]. This establishes the relative superiority of the dynamic model over the static one in the study of growth in the demand for fertilisers.

Private Agricultural Investment

The dynamic model also appears to be more appropriate in the study of determinants of private agricultural investment. This is not surprising. The farmers cannot exploit profitable options of investment instantaneously. The risks associated with agricultural investment are usually higher owing to instability in production arising out of the vagaries of the monsoon and erratic changes in the other weather parameters. Again, as mentioned above, the absence of timely and efficient access to institutional credit might be yet another constraint under which the farmers operate in many parts of India. For these reasons, the farmers cannot reach the optimum profitable level instantaneously. They are cautious and adjust gradually. The process is usually spread over more than a year.

Empirically too, the dynamic model turns out to be superior for the study of growth in private agricultural investment. While the Chow test for structural stability is significant at 5 per cent level of confidence in respect of the static model, it is not so for all the alternative specifications of the dynamic model (Table 2). Similarly, autocorrelation is present in the static model as the estimated value of the D-W test falls in the zone of indecision. Moreover, the value of the long-run price elasticity being greater (1.803), which is a true measure of the farmers' response to price, than its short-run estimate (0.649) [regression B, column (3) of Table 4] further supports the superiority of the dynamic model over the static model.

TABLE 1. ALTERNATIVE ESTIMATES OF COEFFICIENTS OF VARIABLES INFLUENCING DEMAND FOR FERTILISERS MODEL: (A) STATIC MODEL AND (B) DYNAMIC MODEL

Variable	Estimates of coefficients of				
	Static model	Dynamic model (B)			
	Including irrigation and rainfall (A)	Including irrigation and rainfall		Excluding	
				Rainfall	Rainfall and irrigation
(1)	(2)	(3)@	(4)	(5)	(6)
Lagged dependent variable	-	0.613* (7.511) [-1.113]	0.616* (7.167) [-1.018]	0.554* (4.443) [-0.534]	0.906* (25.606) [0.999]
Real price of fertilisers	-0.572* (3.547) [-1.638]	-0.369* (4.100) [1.449]	0.369* (4.002) [1.529]	-0.290** (2.113) [-0.725]	-0.177 (1.168) [-0.769]
Real price of other inputs#	-	-	0.034 (0.149 [0.788]	-	-
HYV seeds	0.029* (5.754) [-0.531]	0.010** (2.697) [1.256]	0.010** (2.561) [-1.022]	0.013** (2.799) [-0.681]	0.004 (0.747) [-1.206]
Irrigation	4.053* (23.949) [-0.451]	1.344* (3.616) [1.149]	1.332* (3.419)	1.648* (2.906) [-0.668]'	
Rainfall	0.414** (2.493) [-0.662]	0.499* (5.598) [0.599]	0.502* (5.409) [0.355]	-	
$\overline{R}^2$	0.9868	0.9962	0.9963	0.9907	0.9871
D-W 'd' statistic	1.645	-	-	-	-
J.Durbin 'h' statistic	-	0.205	-0.263	-0.511	0.609
Chow 'F' statistic	3.597** /5,17/	1.432 /6,15/	1.523 /7,14/	4.183** /5,17/	8.603* /4,19/

Notes: @ Wagle (1994), Table II, p. 60. However, the above estimates differ from Wagle's (1994) previous estimates marginally owing to updated data.

* and ** Significant at 1 per cent and 5 per cent level of confidence respectively.

\# Inputs other than fertilisers, seeds and water.

Figures in parentheses are 't' values estimated for ascertaining the statistical significance of variables and those in square brackets are the values of 't' (based on Spearman's rank correlation test) estimated for ascertaining the presence of heteroscedasticity.

III

EXAMINATION OF THE ECONOMETRIC BASIS OF THE PAST ESTIMATES

Given the *a priori* selection of the model, four econometric criteria need to be satisfied simultaneously, so that the resulting estimates would have desirable econometric properties. These four criteria, as explained by Johnston (1984, pp. 504-508), are (i) minimum residual variance, (ii) consistency of the signs of the individual variables with the underlying theoretical propositions and their statistical significance, (iii) homoscedastic non-autocorrelated disturbance term and (iv) stability of parameters over various data sets as implied by the Chow test.

TABLE 2. ALTERNATIVE ESTIMATES OF COEFFICIENTS OF VARIABLES INFLUENCING PRIVATE AGRICULTURAL INVESTMENT: (A) STATIC MODEL AND (B) DYNAMIC MODEL

Variable	Estimates of coefficients of					
	Static model (A)	Dynamic model (B)				
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lagged dependent variable	-	0.556* (3.156) [1.022]	0.640* (5.104) [0.369]	0.592* (4.440) [0.613]	0.512* (4.176) [0.477]	0.697* (4.083) [1.168]
Relative price (t_0)	0.938* (3.282) [0.559]	0.650** (2.512) [0.621]	0.649** (2.715) [0.696]	0.570* (3.207) [0.070]	0.724* (2.483) [0.762]	0.548 (2.038) [0.003]
Government investment	0.464* (3.415) [0.559]	0.280 (1.962) [0.828]	0.309* (2.849) [0.196]	0.327* (2.387) [0.417]	0.325** (2.750) [0.291]	-
Credit	0.284** (2.297) [1.099]	0.073 (0.587) [0.898]	-	0.019 (0.182) [0.457]	-	0.205 (1.850) [1.063]
HYV seeds	0.011** (2.549) [1.114]	0.003 (0.583) [0.925]	-	-	0.002 (0.408) [0.504]	0.002 (0.408) [1.054]
$\bar{R}^2$	0.9917	0.9838	0.9934	0.9943	0.9937	0.9927
D-W 'd' statistic	1.917	-	-	-	-	-
J.Durbin 'h' statistic	-	0.131	-0.465	0.098	-0.341	0.497
Chow 'F' statistic	3.919** /5.18/	1.439 /6.16/	0.930 /4.20/	1.121 /5.18/	0.667 /5.18/	1.714 /5.18/

Notes: See footnotes to Table 1.

The dependent variable is measured by gross fixed capital formation in all the above regressions.

The variables other than those of relative price and HYV seeds are measured at current prices (for clarifications, refer Wagle, 1994, Note 15, p. 68).

If a model fails to satisfy one or more of the four criteria stated above, such a model needs to be redefined or even rejected. This is because, many a time, the presence of a heteroscedastic/autocorrelated disturbance term and structural instability may imply the omission of one, or more than one, relevant variable, mis-specification of the functional form or serious errors of measurement in the explanatory variables. Alternatively, it may be the outcome of simultaneous presence of more than one of these variables.

One of the major reasons for weaknesses of the past estimates has been that most of them do not satisfy simultaneously all the four econometric criteria necessary for the acceptance of a model. In fact, only one amongst them (Wagle, 1994) examines both the presence of heteroscedasticity and structural stability. Autocorrelation also does not seem to have been assessed in many papers. Some of them [i.e., Desai, 1982, models: B, D, E and F; Subramniyan and Nirmala, 1991 (both models); Sharma, 1993, model: C - all in Annexure 1; and Gandhi, 1990, models: A and C in Annexure 2], who assessed the presence of autocorrelation, reported their findings ignoring its presence. Besides, there are other studies, such as Sharma (1993, models: A, B, D and E), Dholakia and Majumdar (1995, models: A,

TABLE 3. ALTERNATIVE ESTIMATES OF ELASTICITIES OF DEMAND FOR FERTILISERS MODEL WITH THE DEPENDENT VARIABLE 'TONNAGE OF FERTILISERS' DEFLATED/ NOT DEFLATED BY GROSS CROPPED AREA

Model (1)	Lagged dependent variable (2)	Fertiliser price (3)	HYV (4)	Irrigation (5)	Rainfall (6)	$\bar{R}^2$ (7)	'h' (8)	'F' (9)
A. With deflation	0.576* (6.452) [-1.259]	-0.329* (3.428) [1.347] \-0.776\	0.011** (2.705) [1.226] \0.026\	1.445* (3.773) [-1.310] \3.408\	0.326* (3.512) [1.153] \0.769\	0.9955	0.478	1.648 /6.15/
B. Without deflation	0.613* (7.511) [-1.113]	-0.369* (4.110) [1.449] \-0.953\	0.010** (2.697) [1.256] \0.026\	1.344* (3.616) [-1.149] \3.473\	0.499* (5.598) [0.599] \1.289\	0.9959	0.205	1.432 /6.15/

Notes: See footnotes to Table 1. 'h' = J. Durbin 'h' statistic; 'F' = Chow F statistic.
\ \ Figures within this sign are the estimates of the long-run elasticities.

TABLE 4. ALTERNATIVE ESTIMATES OF ELASTICITIES OF PRIVATE AGRICULTURAL INVESTMENT MODEL WITH THE DEPENDENT VARIABLE MEASURED BY GCF/GFCF

Model (1)	Lagged dependent variable (2)	Relative price (3)	Government investment (4)	$\bar{R}^2$ (5)	'h' (6)	'F' (7)
A With measurement by GCF	0.511* (3.420) [-0.162]	0.943* (3.323) [-0.636] \1.928\	0.425* (3.191) [0.363] \0.868\	0.992	-1.091	1.92 /4.20/
B With measurement by GFCF	0.640* (5.104) [0.369]	0.649** (2.715) [0.696] \1.803\	0.309* (2.849) [0.196] \0.858\	0.9934	0.465	0.930 /4.20/

Data sources: Government of India (1989, 1992, 1994, 1996, 1997 a, b, c).
Notes: See footnotes to Tables 1, 2 and 3.

B, C and E) and Gandhi (1990, model: B) where after identifying the existence of autocorrelation, the authors presented modified results by correcting estimates for the existence of autocorrelation. In our opinion, rather than correcting for autocorrelation, the authors should have attempted to remove the source of autocorrelation through re-specification of their models.

As regards statistical significance of the explanatory variables, which helps to decide their relevance, it is expected that in a reasonably realistic model, a majority of the variables should turn out to be significant statistically, hence all such variables should appear in the final specification of the function. Nonetheless, it needs to be emphasised that the key variables, like the price variable, must be retained in the finally selected function despite statistical non-significance of their coefficients.

A review of research papers on the subjects under consideration, however, reveals that many non-significant variables appear in the alternative specifications of the model provided by the authors [refer to figures in parentheses given in column (2) of Annexures 1 and 2]. Only in a few studies, did all the explanatory variables turn out to be statistically significant (for example, estimates by Sharma, 1993, models: A, B, D and E; Wagle, 1994, both estimates; Dholakia and Majumdar, 1995, model: C; Dhawan and Yadav, 1995, models: A to D).

Indeed, an additional point that needs to be stressed here is that listing of all the alternative estimates of the function attempted in the study, and commenting on them is not enough. In addition, the author must indicate his/her final choice of the functional specification, and comment on the relative importance of various determinants of the dependent variable based on the estimates provided by it.

IV

ISSUES RELATING TO THE CHOICE OF VARIABLES

(i) *Demand for Fertilisers*

It is our contention that in respect of the demand for fertilisers model, exclusion of either one or both of the water variables, namely, 'irrigation' and 'rainfall' represents a serious lacuna in specification of the function. Exceptions are only those of Sharma (1993: models C to E, Annexure 1) and Wage (1994).[5] The issue, therefore, calls for a more rigorous scrutiny.

Exclusion of the water variables represents a serious deficiency in the specification of the fertiliser demand function. This is because water is not only a complementary but also an indispensable input in the use of fertilisers. It is available either through irrigation and/or rainfall.[6] The total volume of fertilisers used in any given year not only depends upon the size of the irrigated area, but is also greatly influenced by the performance of the monsoon, especially in the rainfed farming areas of India. That is why, both of them must be included separately in the model. The fact that the exclusion of the water variables distorts the estimates of the fertiliser demand model can be ascertained by comparing its estimates with and without their inclusion [compare column (3) with columns (5) and (6) of Table 1]. Besides, with the exclusion of both the water variables, the Chow test becomes significant at 1 per cent level of confidence for the dynamic model of fertiliser demand, implying thereby an incomplete specification of the model. It is pertinent to note in this context that the HYV and fertiliser price variables become non-significant statistically with the exclusion of both the water variables. They thus demonstrate clearly the adverse impact of the omission of the crucial variables on the statistical significance and magnitudes of the coefficients of the other relevant variables.

As regards the issue of the inclusion of the prices of the non-fertiliser farm inputs, the question of inclusion of the prices of irrigation water and HYV seeds does not arise as these variables get included explicitly in the model. Price indices of the remaining inputs, i.e., farm labour, organic manure, pesticides and insecticides, feed for livestock, besides the cost of market services and the interest for short-term finance (required for working capital), need to be included in the demand function, they being supplementary to the use of fertilisers. But the inclusion of their composite price index neither yields the expected negative sign in the alternative regression, nor affects, to any appreciable extent, the estimates of the coefficients of the other exogenous variables [compare column (3) with column (4) of Table 1]. In other words, the prices of the non-fertiliser farm inputs, other than water and HYV seeds, appear to be superfluous in the fertiliser demand model in India.[7]

There is an additional important problem of specification of the dependent variable. Some studies measure this variable by the tonnage of fertilisers (Parikh, 1965; Rao, 1973; Wagle, 1994), while others deflate the tonnage by gross cropped area (GCA) (Subramaniyan and Nirmala, 1991; Sharma, 1993; Dholakia and Majumdar, 1995). It is out contention that the former specification is more appropriate. This is because the area under fertilisers may expand over a period of time leading to substantial increase in the total use of fertilisers. Yet, the per hectare use of fertilisers may not increase proportionately. Moreover, in the years of above-normal rainfall, the total consumption of fertilisers may go up due to rise in GCA because of adequate availability of water on larger arable land, as also increase in the rainfed area under fertilisers, but not necessarily or only due to increase in the per hectare use of fertilisers. That is why, the larger the weightage of the rainfed area in the GCA, and the more extensive the use of fertilisers on the rainfed area, the more relevant becomes the non-deflated dependent variable that the deflated variable. As a result, the former, i.e., the non-deflated variable, is expected to reflect the effect of the rainfall variable more realistically, and to that extent the model based on it, to provide more realistic estimates of the other variables as well.

Table 3 demonstrates this latter point clearly [see column (6) of Table 3]. While the short-run elasticity of the rainfall variable goes up from 0.326 in the case of the model with deflation, to 0.499 in the case of the model without deflation, its long-run elasticity goes up from 0.769 to 1.289. As a result, and in keeping with our expectations, the short-run fertiliser price elasticity goes up from -0.329 to -0.369 and the long-run relative price elasticity moves up from -0.776 to -0.953.

(ii) *Private Agricultural Investment*

In the discussion that follows, we judge the relevance of government investment and the spread of HYV seeds in the specification of the private agricultural investment function. We believe that in a developing country, these variables are likely to perform crucial roles in fostering private agricultural investment (Dhawan, 1996 b, pp. 530-531).

As regards government investment, we find that its inclusion receives the support of empirical justification too. This was because it turned out to be statistically significant in all the dynamic model regressions when the other three crucial variables, namely, relative price, lagged dependent variable and HYV seeds were present singly [columns (4) and (6) in Table 2]. Only in the presence of both the credit and HYV seeds variables, it lost its statistical significance [column (3) in Table 2]. More importantly, its inclusion improved the statistical significance of the relative price variable too [compare columns (3) and (7) of Table 2].

In our opinion, HYV variable lagged by one year, as used in the present exercise, rather than the current HYV variable, is more relevant in determining the level of current investment. This is because last year's proportion of area under HYV influences crucially last year's (net) agricultural income, and thereby the farmers' capacity to invest in the current year. But this variable turned out to be significant only in the static model [columns (2), (3), (6) and (7) of Table 2]. This demonstrates that its indirect impact through the last year's income is more important than its direct impact on current investment.

Another explanatory variable used in many past studies of private agricultural investment function is institutional credit.[8] To evaluate its importance, we included it in all the alternative regressions. However, like the HYV variable, this variable too was found to be statistically significant only in the static model [column (2) of Table 2] and not so in the regressions under the dynamic model. Its non-significance may be, again, the result of its high multicollinearity ($r = 0.9897$) with the lagged dependent variable. But as concluded in Section II, the dynamic model is found to be superior to the static model due to statistical significance of the Chow test statistic in the latter.

Ultimately, therefore, the version of the model provided in column (4) of Table 2, i.e., the one which omits both the HYV and credit variables appears to be a better option to all the alternative specifications of the private agricultural investment function. It demonstrates that the relative price is the most crucial variable influencing the farmers' decision-making. Next in importance is the government agricultural investment which plays the role of fostering private investment in agriculture. Besides, as the model hypothesises lags in adjustment behaviour of the farmers, to a certain extent it takes care of the impact of HYV and credit variables too, at least indirectly.

Finally, the issue of specification of the dependent variable, i.e., agricultural investment deserves attention. According to us, private gross fixed capital formation (GFCF),[9] if available, should be preferred to private gross capital formation (GCF) as a measure of private investment in agriculture. This is because GCF includes change in stock of livestock and plantation crops such as tea, coffee and rubber and these are not capital goods by nature and hence should, in fact, be excluded from investment.[10] Empirically too, replacement of GCF by GFCF leads to improvement in the econometric properties of the investment function. Durbin 'h' statistic comes closer to its statistically desired value of zero, i.e., from -1.091 to -0.465 (Table 4). Likewise, the estimated value of the Chow statistic declines from 1.92 to 0.930. Interestingly, the adjustment coefficient goes down from 0.489 to 0.360, indicating a longer time lag.

A reference to the criticism of GCF, it being an under-estimate of farm investment in agriculture, is in order in this context. Under-estimation has been attributed to exclusion of stocks of foodgrains and inventories of cash crops from GCF (Mishra and Chand, 1995; Mishra, 1996, p. 194). As per the methodology followed by the Central Statistical Organisation, the stocks of foodgrains are included in the trade sector and inventories of cash crops are assumed to be negligible and both are not included in GCF. In our opinion, their non-inclusion in GCF is, indeed, desirable for the study of private agricultural investment. The crops, by nature, are not investment goods, hence their stocks/inventories, measured by their changes in a year, have to be excluded from the purview of private agricultural investment.

Received September 1997. *Revision accepted February 1999.*

ANNEXURE I

PREVIOUS ESTIMATES OF COEFFICIENTS OF VARIABLES INFLUENCING DEMAND FOR FERTILISERS IN INDIA

Author	Model	Lagged dependent variable	Relative price of fertilisers	Irrigation	HYV seeds	Rainfall	One of the other specified variable	$R^2/\bar{R}^2$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Parikh	(A)	-	-0.264	6.265*	-	-	0.004 T	0.765
(1965)	[1/3]		(0.316)	(4.537)			(0.432)	
	(B)	-	-0.241	6.546*	-	-	-	0.801
	[1/2]		(0.311)	(5.772)				
Rao	(A)	0.08	-0.31	7.15*	-	-	-	0.99
(1973)	[1/3]	(0.320)	(1.292)	(3.438)				
	(B)	0.92*	-0.53	-	-	-	-	0.98
	[1/2]	(13.143)	(1.656)					
Desai	(A)#	-	-5.5†*	174.7*	34.0*	-	0.02 q†	0.98
(1982)	[3/4]		(3.88)	(4.68)	(2.28)		(0.01)	
	(B)#	-	-18.3 Z1*	134.4*	22.0	-	-9.4 q	0.97
	[2/4]		(3.33)	(2.27)	(0.91)		(0.73)	
	(C)#	-	-13.2*	88.5	41.4	-	-	0.97
	[1/3]		(3.03)	(1.62)	(1.89)			
	(D)	-	-1.055†*	3.58*	0.142	-	0.926 q*	0.97
	[3/4]'		(5.153)	(2.46)	(1.427)		(2.912)	
	(E)	-	-1.078 Z1*	3.090*	0.157	-	0.880 Z1q	0.97
	[2/4]		(3.286)	(3.087)	(1.584)		(1.074)	
	(F)	-	-1.029*	3.135*	0.153	-	-	0.98
	[2/3]		(5.492)	(3.372)	(1.652)			
Subrama-	(A)	-	-0.426*	1.438*	0.093*	-	0.067 T	0.9943
niyan and	[5/6]	0.164**	(3.036)	(2.637)	(7.363)		(1.757)	
Nirmala	(B)	(3.09)	-1.296	-				0.65
(1991)	[1/2]		(1.53)					
Sharma	(A)@	0.681*	-0.382*	-	-	-	-	0.9900
(1993)	[2/2]	(9.503)	(3.421)					
	(B)@	-	-0.410†	-	-	-	0.316 T	0.9843
	[2/2]		(2.611)				(7.524)	
	(C)	-	-0.433	-1.671	0.106	-0.523	0.857 n*	0.9757
	[1/8]		(1.995)	(1.001)	(1.106)	(1.038)	(3.271)	
	(D)@	-	-0.258*	0.671*	0.103*	0.395*	0.113 n*	0.9775
	[8/8]		(516.4)	(478.9)	(171.2)	(79.0)	(141.6)	
	(E)@	0.155*	-0.268*	0.696*	0.107*	0.444*	0.118 n*	0.9796
	[8/8]	(310.4)	(893.0)	(994.3)	(267.0)	(143.2)	(196.5)	
Wagle‡	(A)	0.613*	-0.369*	1.344*	0.010*	0.499*	-	0.9962
(1994)	[5/5]	(7.511)	(4.110)	(3.616)	(2.693)	(5.598)		
Dholakia	(A)@	-	-0.277†*	0.510	0.270*	-	-0.037 †r	0.9916
and	[2/B]		(2.35)	(1.16)	(4.31)		(0.86)	
Majumdar	(B)@	-	-0.328†*	-	0.653*	-	0.316†q	0.990
(1995)	[2/4]		(2.78)		(2.78)		(1.57)	
	(C)@	-	-0.338*	-	0.055*	-	0.349*q	0.989
	[3/3]		(2.97)		(5.47)		(3.00)	
	(D)	0.708*	0.059	-	0.014	-	-0.007q	0.952
	[1/4]	(4.08)	(0.68)		(1.41)		(0.08)	
	(E)@	0.466*	-0.185	-	0.027*	-	0.199q	0.993
	[2/4]	(2.89)	(1.79)		(2.66)		(1.99)	

Notes: Only 1 per cent and 5 per cent significance levels are considered, and both such variables are marked by * and ** respectively.

All the models are based on time-series.

Figures in square brackets show the number of significant variables against the total explanatory variables.

Figures in parentheses are 't' values estimated for ascertaining statistical significance of a variable.

‡ = These estimates are based on updated data.

= Linear model. The others are the double-log form except the trend variable, if included, is measured in the absolute scale.

@ = Corrected for autocorrelation; t = Trend; Z1 = Deflated by the index of wholesale prices of all commodities; n = Credit; r = Cost of capital; † = Undeflated price; q = Price of agricultural output.

ANNEXURE 2

PREVIOUS ESTIMATES OF COEFFICIENTS OF VARIABLES INFLUENCING PRIVATE AGRICULTURAL INVESTMENT IN INDIA

Author	Model	Lagged dependent variable	Relative price of agri-cultural products'	Governme nt investm ent	Credit	Other two specified varaibles		$R^2/\bar{R}^2$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Shetty	(A)	-	-	0.661*	-	-	-	N.A.
(1990)	[1/1]			(3.915)				
Gandhi	(A) #	-	4.338 q†*	-	0.467 $*	0.482 $$*	0.625 RS*	0.957
(1990)	[5/10]		(2.04)		(2.28)	(2.23)		
	(B) #@	-	4.723 q†*	-	0.459 $*	0.516 $$*	0.562 RS*	0.93
	[5/10]		(2.36)		(2.12)	(2.31)	(4.10)	
	(C)	-	0.066 q†	-	0.982 $*	0.721 $$*	0.510 RS*	N.A.
	[5/10]		(1.05)		(3.43)	(3.50)	(3.61)	
Gandhi	(A) #	-	-0.387 q†	-	0.190 $	0.671 $$*	0.050 RS*	N.A.
(1996)	[2/11]		(0.481)		(1.270)	(2.669)	(4.168)	
	(B) #@	-	4.723 q†*	-	0.459 $*	0.516 $$*	0.562 RS*	N.A.
	[5/10]		(2.36)		(2.12)	(2.31)	(4.10)	
	(C)	-	0.066 q†	-	0.982 $*	0.721 $$*	0.510 RS*	N.A.
	[5/10]		(1.05)		(3.43)	(3.50)	(3.61)	
Wagle	(A)	0.511*	0.943*	0.425*	-	-	-	0.992
(1994)	[3/3]	(3.420)	(3.323)	(3.191)				
Krishna-murty and	(A)	-	0.297 k	0.981	-	0.044*Y	-	N.A.
Pandit (1994) (see Dhawan, 1996 a, p. 211)	[2/3]		(1.51)	(2.57)		(3.18)		
Dhawan	(A) #, @@	N.R.	-	-	0.38*	5.96 L*	32.76 ml*	0.9513
and Yadav	[3/3]				(7.47)	(3.50)	(2.13)	
(1995)	(B) #, @@	N.R.	-	-	3.32*	7.21 L*	1.68 m2*	0.9625
	[3/3]				(6.10)	(5.18)	(3.12)	
	(C) #, @@	N.R.	-	-	0.33*	6.47 L*	39.57 m3*	0.960
	[3/3]				(6.65)	(4.81)	(3.48)	
	(D) #, @@	N.R.	-	-	0.35*	7.60 L*	4.62 m4*	0.966
	[3/3]				(7.10)	(5.30)	(2.92)	
	(E) #, @@	N.R.	-	-	0.23 m5*	8.06 L*	5.00 m2*	0.949
	[3/4]				(5.68)	(4.85)	(2.66)	
	(F) #, @@	N.R.	-	-	0.21 m5*	7.65 L*	1.81 m4*	0.951
	[3/4]				(4.68)	(4.70)	(2.79)	
Misra and	(A) #	-	10.63*	0.47	-	39.67 m6*	-	0.80
Hazell (1966)	[2/3]		(5.75)	(0.30)		(10.97)		
Bhide *et al.*	(A)	-	0.231 k	0.260	0.359*	-	-	0.86
(1996)	[1/3]		(0.42)	(2.04)	(2.89)			
Misra	(A) #	-	6.01*	0.14	-	42.77 m6*	11.50 m7	0.932
(1998)	[2/4]		(4.09)	(0.22)		(42.77)	(1.84)	

Notes: See footnote to Annexure 1.

@@ = Based on cross-sectional analysis; the other models are based on time-series. N.A. = Not available.

N.R. = Not relevant; L = Preference; $ = Commercial bank credit; $$ = Co-operative credit; RS = Rural savings; K = Price lagged by a year; Y = Permanent income; ml = Technical progress; m2 = Gross irrigated area as per cent of net sown area in 1980-81; m3 = Annual rate of growth of crop sector during 1960-80 (per cent); m4 = Net canal irrigated area as per cent of net sown area in 1980-81; m5 = Loan including credit; m6 = Per cent of area under HYV seeds; and m7 = Dummy for policy reforms.

NOTES

1. The estimates of the elasticity of the fertiliser price in the demand for fertilisers model varies between 0.06 (Dholakia and Majumdar, 1995) and 1.07 (Desai, 1982). Similarly, the relative price elasticity in the private agricultural investment model varies between 0.07 (Gandhi, 1990) and 0.94 (Wagle, 1994).

2. For definitions of rainfall and real price of fertilisers, refer Wagle, 1994, pp. 57-59, and note 9, p. 68.

3. For further clarifications, see Wagle, 1994, notes 11 to 15, p. 68.

4. The models of Gandhi (1990, model: C; 1996, models: A, B and C), though non-linear, are not strictly double log-models.

5. However, a subtle difference in the rainfall variable as defined by Sharma and the present author can be noted. In the paper by the former, "Rainfall has been measured as annual rainfall in millimeters. The rainfall has been taken as the national average and it does not take into account the regional variation" (Sharma, 1993, p. 511). In the latter case, the rainfall variable is defined as the ratio of actual rainfall to normal rainfall during the twelve months from March to February. For the country as a whole, the ratio is a weighted average, weights being equal to nutrients consumed in each of the 35 meteorological sub-divisions in the base year (Wagle, 1994, equation 4, pp. 58-59).

6. In the first model of the paper by Dholakia and Majumdar (1995), rainfall is included implicitly as a part of the weather variable. However, this variable finds a place in their model as it affects farm output, and not fertiliser demand directly as such.

7. For theoretical explanation regarding the superfluous variables, refer Koutsoyiannis, 1977, p. 239.

8. Both medium- and long-term credit together is considered as farm investment.

9. GFCF also includes incompleted construction works (Government of India, 1989, p. 231).

10. In any case, the use of GCF instead of GFCF as a measure of Government investment is unlikely to affect our analysis. The available evidence shows that the stocks (of tea, coffee, etc.) account for a marginal share, ranging between 0.01 per cent and 1.8 per cent of Government's GCF (Government of India, 1997 c, pp. 108-120).

REFERENCES

Bhide, S.; A. Sinha, S. Purohit, D. Joshi and K. Anwar (1996), *Macro Economic Modelling for Forecasting and Analysis: Final Report*, National Council of Applied Economic Research, New Delhi and Conference Board of Canada, Ottawa, March (mimeo.).

Desai, Gunvant M. (1982), *Sustaining Rapid Growth in India's Fertiliser Consumption: A Perspective Based on Composition of Use*, International Food Policy Research Institute, Washington, D.C., U.S.A., October. Reproduced by the Centre for Monitoring Indian Economy, Mumbai.

Dhawan, B.D. (1996 a), "Relationship between Public and Private Investments in Indian Agriculture with Special Reference to Public Canals", *Indian Journal of Agricultural Economics*, Vol. 51, Nos. 1 and 2, January-June, pp. 209-219.

Dhawan, B.D. (1996 b), "Trends and Determinants of Capital Formation in Indian Agriculture", *Indian Journal of Agricultural Economics*, Vol. 51, No. 4, October-December, pp. 529-542.

Dhawan, B.D. and S.S. Yadav (1995), "Private Fixed Capital Formation in Agriculture: Some Aspects of Indian Farmers' Investment Behaviour", *Economic and Political Weekly*, Vol. 30, No. 39, September 30, pp. A-103-A-109.

Dholakia, Ravindra H. and Jagdip Majumdar (1995), "Estimation of Price Elasticity of Fertiliser Demand at Macro Level in India", *Indian Journal of Agricultural Economics*, Vol. 50, No. 1, January-March, pp. 36-46.

Gandhi, Vasant P. (1990), "Investment Behaviour in Developing Countries: The Case of Agriculture in India", *Food Research Institute Studies*, Vol. 22, No. 1.

Gandhi, Vasant P. (1996), "Investment Behaviour in Indian Agriculture ", *Indian Journal of Agricultural Economics*, Vol. 51, No. 4, October-December, pp. 543-559.

Government of India (1989), *National Accounts Statistics: Sources and Methods*, Central Statistical Organisation, New Delhi.

Government of India (1992), *National Accounts Statistics: Disaggregated Statements, 1950-51-1979-80*, Central Statistical Organisation, New Delhi.

Government of India (1994), *National Accounts Statistics: Factor Incomes (New Series), 1980-81-1989-90*, Central Statistical Organisation, New Delhi.

Government of India (1996), *National Accounts Statistics: 1996*, Central Statistical Organisation, New Delhi.

Government of India (1997 a), *Economic Survey 1996-97*, Economic Division, Ministry of Finance, New Delhi.

Government of India (1997 b), "Government Subsidies in India: Discussion Paper", Economic Division, Ministry of Finance, New Delhi.

Government of India (1997 c), *National Accounts Statistics, 1997*, Central Statistical Organisation, New Delhi.

Gujarati, Damodar N. (1995), *Basic Econometrics*, Third Edition, McGraw-Hill Book Company, Singapore.

Johnston, J. (1984), *Econometrics Methods*, Third Edition, International Edition, McGraw-Hill Book Company, Singapore.

Koutsoyiannis, A. (1977), *Theory of Econometrics*, Second Edition, Macmillan Education Ltd., London.

Krishnamurty, K. and V.N. Pandit (1994), *A New Econometric Model for India*, Institute of Economic Growth and Delhi School of Economics Research Team, Delhi (Preliminary).

Mishra, S.N. and Ramesh Chand (1995), "Public and Private Capital Formation in Indian Agriculture: Comments on Complementary Hypothesis and Others", *Economic and Political Weekly*, Vol. 30, No. 25, June 24, pp. A-64-A-79.

Mishra, S.N. (1996), "Capital Formation and Accumulation in Indian Agriculture Since Independence", *Indian Journal of Agricultural Economics*, Vol. 51, Nos. 1 and 2, January-June, pp. 193-208.

Misra, V.N. (1998), "Economic Reforms, Terms of Trade, Aggregate Supply and Private Investment in Agriculture: Indian Experience", *Economic and Political Weekly*, Vol. 33, No. 31, August 1, pp. 2105-2109.

Misra, V.N. and P.B.R. Hazell (1996 a), "Terms of Trade, Rural Poverty, Technology and Investment: The Indian Experience, 1952-53, to 1990-91", *Economic and Political Weekly*, Vol. 31, No. 13, March 30, pp. A-2-A-12.

Misra, V.N. and P.B.R. Hazell (1996 b), "Price and Non-Price Factors in Agricultural Investments", *Economic and Political Weekly*, Vol. 31, No. 43, October 26, pp. 2891-2892.

Parikh, Ashok K. (1965), "Demand for Nitrogenous Fertilisers: An Econometric Study", *Indian Journal of Agricultural Economics*, Vol. 20, No. 3, July-September, pp. 13-19.

Rao, M.S. (1973), *Protection to Fertiliser Industry and Its Impact on Indian Agriculture*, Ph.D. Dissertation, University of Chicago, Chicago, U.S.A. (Unpublished). This is as stated in the paper by Peter C. Timmer (1974), "The Demand for Fertiliser in Developing Countries", *Food Research Institute Studies*, Vol. 13, No. 3, pp. 197-224.

Sharma, Anil Kumar (1993), "Price and Non-Price Factors in the Growth of Fertiliser Use After Green Revolution", *Journal of Indian School of Political Economy*, Vol. 5, July-September, pp. 507-518.

Shetty, S.L. (1990), "Investment in Agriculture: Brief Review of Recent Trends", *Economic and Political Weekly*, Vol. 25, Nos. 7 and 8, February 17-24, pp. 389-398.

Shukla, Tara (1968), "Investment in Agriculture", *Economic and Political Weekly*, Vol. 3, No. 45, November 9, pp. 1729, 1731-1732.

Subramaniyan, G. and V. Nirmala (1991), "A Macro Analysis of Fertiliser Demand in India, 1966-67 to 1985-86", *Indian Journal of Agricultural Economics*, Vol. 49, No. 1, January-March, pp. 12-19.

Wagle, M.P. (1994), "Estimates of Aggregate Functions for Demand for Fertilisers and Private Investment in Indian Agriculture", *Indian Journal of Agricultural Economics*, Vol. 49, No. 1, January-March, pp. 56-69.