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By

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Discussion Paper No. 7

THE IMPACT OF THE NEW RICE TECHNOLOGY ON FERTILISER CONSUMPTION

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THE IMPACT OF THE NEW RICE TECHNOLOGY ON FERTILIZER CONSUMPTION*

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The resource paper analyzes the effects of modern varieties on fertilizer consumption in the Asian rice economy by examining response functions of modern and traditional rice varieties as well as by estimating fertilizer demand functions. Date base of the paper is enormous. The response functions are based on several years' data from a number of experiment stations in the Philippines and India, and cross-section data at farm level in the Philippines. The fertilizer demand functions are estimated from: (i) time series observations (1950-1972) for 12 Asian rice growing countries, (ii) cross-section data of the Asian farm survey covering about 2,000 rice farmers in 36 villages of 6 Asian countries in 1971-72, and (iii) continuous cross-section data of the Laguna (Philippines) survey of about 150 farmers from 1966 to 1971. With the help of the analysis based such varied and vast data, Dr. David and Dr. Barker have made an important contribution on the subject. In Section I we summarize the major conclusions of the resource paper. Section II focuses on certain methodological issues and conclusions of the paper.

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Section I

Major Conclusions of the Resource Paper

Analysis of Response Functions

Yield response of the modern varieties to nitrogen is greater than that of the traditional varieties in both wet and dry seasons. Yields in the dry season exceed those in the wet season throughout the entire range of the response functions. Under farm conditions, however, the difference between the responses in the two seasons may not necessarily be as great because of the inadequacy of irrigation during the dry season. Maximum yield of the modern varieties is about 1 to 2 tons per hectare, higher than that of the traditional varieties, except in eastern India during the wet season. Fertilizer required to obtain maximum yield of modern varieties is about 80 kg of N per hectare in the Philippines in the wet season, but about twice as high in India. In the dry season also, maximum yield is achieved in India at a much higher level of nitrogen. The modern varieties do not seem to perform well in eastern India during the wet season. Even under the more favorable experiment station environment, their superiority over the traditional ones appears to be very slight. Consequently, Mashuri which was originally developed and released in Malaysia around 1965, and which performs well at low levels of nitrogen use, has become popular in some parts of India, Bangladesh and Malaysia. Though the values of the intercepts indicate that the modern varieties do as well or somewhat better than traditional ones at zero level of nitrogen, under many conditions this may not be true. There is great year to year variability in fertilizer response even under "controlled" experimental conditions.

The analysis based on farm level data from Philippines also shows superior nitrogen response of the modern varieties under both irrigated and rainfed conditions. Consequently, replacement of the traditional varieties by the modern varieties has substantially increased fertilizer use, both at optimum and sub-optimum levels. This, in turn, accounts for most of the increase in the average rice yield after 1962-64. Finally, even with existing technology, irrigation facilities and price situation, there is a considerable scope to increase nitrogen use because the prevailing rates of nitrogen application are much below the economic optimum rates derived from response functions based on farm level data.

Fertilizer Demand Functions

The authors have estimated two demand models with the three sets of data described above.[1] The major conclusions derived from this analysis are as follows.

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[1]In Model I, fertilizer use per hectare is a function of, (i) relative price of fertilizer to rice, (ii) proportion of area planted to modern varieties, (iii) value of production, and (iv) two parameters of the underlying production function, namely, intercept and production elasticity. The parameters of the production function are estimated by fitting a Cobb-Douglas production function to the same set of data in which total rice production is considered a function of crop area and fertilizer use. In estimating this production function, dummy variables

Relative price of fertilizer to rice, modern varieties and variables representing shifts in fertilizer response functions are highly significant factors in explaining variations in the rate of fertilizer application in the Asian rice economy. Variables representing shifts in fertilizer response functions improve R^2 of most equations dramatically, and the generally higher t-values of these variables indicate their greater precision of fit relative to price in the regressions. Most of the shift in the fertilizer response function is explained by the spread of modern varieties. The results strongly support the hypothesis that rice farmers' demand for fertilizer responds to changes in the relative price of fertilizer to rice. The "long-run price elasticity," derived from the relationship between fertilizer use per hectare and fertilizer-rice price ratio, is -0.8 to -0.9 and remarkably stable across the three sets of data. The estimated

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are used for intercept and slope to distinguish inter-country, inter-village and inter-year differences in the productivity of fertilizers. An alternative model (Model II) is specified to overcome the statistical problem arising from estimating the fertilizer demand function and the production function from the same set of data. Model II is specified in two different ways depending on the availability of data. In one formulation of Model II, variations in fertilizer response functions are assumed to be reflected in the differences in the intercept levels and price elasticity of the fertilizer demand function, and the same demand function as in Model I is estimated by using dummy variables to distinguish inter-country or inter-year differences in the level and price elasticity of fertilizer demand. In the other formulation of Model II, four "instrumental" variables are substituted for the estimates of fertilizer response parameters.

"short-run price elasticity," which takes into account shifts in fertilizer response functions, is lower than the long-run elasticity, -0.3 to -0.7. Inclusion of the variable "value of output" in the demand equation does not contribute much to the R^2, thus indicating that either financing of fertilizer purchase is not a constraint to farmers' effective demand for fertilizer or value of output is not an appropriate proxy variable for farmers' liquidity position.

Model II fits better to the data than Model I. It reveals that demand for fertilizer is more sensitive to price changes in countries with high levels of fertilizer use such as Japan, Taiwan and South Korea as compared to the Philippines and Indonesia where the level of fertilizer use is quite low. The analysis of continuous cross-section data of Laguna farm survey shows a rightward shift in the demand function through time, and a decline in the price elasticity of demand for fertilizer from -0.9 to -0.6. Finally, the analysis reveals that differences in the fertilizer response functions provide the major explanation for the wide gap in fertilizer application between the "average" and "heaviest" fertilizer user.

Section II

Methodological Issues Concerning Certain Conclusions

Demand for fertilizer is governed by returns from its use, and these are significantly influenced by yield response of crops to fertilizer use. Therefore, to study effects of the modern varieties on fertilizer consumption, one should compare response functions of the modern varieties with those of the traditional ones as well as examine the evidence on actual fertilizer consumption. But such studies are quite rare. Hence, the resource paper, which covers both these aspects by analyzing vast data, is an important contribution on the subject.

The overall conclusion of the resource paper is that there has been a substantial impact of the modern rice varieties on fertilizer consumption in the Asian rice economy. We do not disagree with this. However, it seems that in certain situations, so far, this impact has not been so much through increase in the rates of fertilizer application due to upward shifts in the response functions; it has been through accelerating diffusion of fertilizer use on rice. The reason for this appears to be little difference between the response functions of the modern varieties and those of the traditional ones in many situations. Thus, in a way, our position differs from one of the major conclusions of the resource paper which attributes growth in fertilizer use mainly to shifts in response functions. The basis of our position is spelled out below by focusing on certain issues related to fertilizer response and demand implications.

Response Function Analysis

The response function analysis in the resource paper raises two main questions. First, how superior are the fertilizer response functions of modern varieties as compared to those of the traditional varieties? Second, what sort of fertilizer demand functions are implied by the fertilizer response functions of the two types of rice varieties? Other que tions arising from the esource paper are such as the following: Is the differeuce bet een fertilizer response functions of the two types of varieties, estimated from experiment station data, likely to be greater or smaller under the farm conditions? Is it likely to be more or less stable over time under the farm conditions? How do fertilizer response functions for rainfed conditions compare with those for irrigated conditions? An attempt is made below to answer some of these questions.

Response Functions of Modern Vis-A-Vis- Traditional Rice Varieties

Even a cursory examination of the average response functions (averaged over several years) of the two types of varieties support the conclusions of the resource paper on this aspect summarized in Section I above. However, Appendix Table A1 and A2 of the resource paper reveal that, even under the conditions obtained on experiment stations, the respo se functions are not st ble over time. D. . David and Dr. Barker have drawn our ttention to this aspec.. We have further probed into the aspect for its possible implication on demand for fertilizers.

Table 1 presents means and coefficients of variation of the coefficients of estimated fertilizer response functions given in the resource paper. Following conclusions emerge from the table.

In the Philippines, the traditional variety (PETA) does not respond to fertilizer use during the wet season. In several cases, the b coefficient of the quadratic response function of this variety is negative. Even when it is positive, its value is quite small. Against this, the mean values of b coefficient of modern varieties (IR8 and IR20) are quite high, and those of the c coefficient are quite small. Therefore, though the response functions of these varieties are quite unstable (C. V. of b and c often higher than 50), it is clear that the replacement of PETA by IR8 or IR20 would substantially increase fertilizer use even during the wet season. In the dry season, despite positive response of PETA, the impact on fertilizer use would be still greater. This is because of the substantially superior and more stable response of the modern varieties during the dry season.

During the wet season, the situation in India differs from that in the Philippines in some important ways. Unlike PETA, the local variety has a significant response to fertilizer use. More importantly, the response of IR8 to fertilizer is only marginally higher to that of the local variety and what is more, even this is coupled with greater instability of the response function.[2] The implications of this for the spread of the modern varieties, and more for the impact of the

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[2]This conclusion follows from the comparison of the average response functions of 19 locations of IR8 and local varieties. It is not unlikely that at some locations the response function of IR8 may be significantly superior and more stable than that of the local variety as in the case of the experiment station located in Orissa. On the other hand, there may be cases where the local variety has superior and more stable response to fertilizer than IR8 as indicated by the comparison between CO32 and IR8 at the experiment station in Tamil Nadu.

replacement of the traditional varieties by modern varieties on demand for fertilizer during the wet season are obvious.[3] This would be particularly true if we further assume that the difference between the response functions of the two types of varieties would be less under farm conditions than under experiment station conditions. While this conclusion is based on the comparison between the response function of only IR8 and local variety, it is supported by additional evidence on a number of modern varieties (Appendix Table 1).

In the dry season, however, the situation in India is similar to the one in the Philippines. The response function of IR8 is not only much superior to that of the local variety but also much more stable. This is confirmed by a more rapid spread of the modern varieties during the dry season as compared to the wet season, and also by micro data on rates of fertilizer application during the dry season.

Since bulk of the rice area in India is in the wet season, the above analysis suggests that till recently the modern rice varieties might not have a significant impact on fertilizer consumption in the Indian rice economy. Such a conclusion, however, is not supported by the trends in fertilizer consumption of the major rice growing states in India (Appendix Table 2). Possible explanation for this discrepancy between what is indicated by the response functions of the two types of varieties and the trends in fertilizer consumption could be as follows.

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[3]It may be of interest to note that by 1973-74 the modern varieties had spread to only one-fourth of the total rice area in India against nearly two-thirds of the rice area in the Philippines. For details, see IRRI, World Rice Statistics, mimeographed. April 1976, Table 12, p.36.

Fertilizer use had not spread to about three-fourth of the rice area by 1965-66 when the modern varieties were introduced in India.[4] This was so due to varied reasons such as time-lags in diffusion of fertilizer use and rudimentary state of fertilizer distribution arrangements in most parts of the country, besides relatively low prices of paddy and low responsiveness of the traditional varieties to fertilizer.[5] Thus, it would be incorrect to look for the impact of the modern varieties on fertilizer consumption in India only through raising the rates of application as indicated by the response function analysis. It seems to us that, for the Indian rice economy as a whole, this impact has been more significant in terms of accelerating the diffusion of

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[4]This estimate is supported by findings of several micro studies. More importantly, it is supported by a large survey carried out by the National Council of Applied Economic Research, New Delhi. According to this survey, only 37 percent of the total rice area was fertilized by 1968-69. It increased to about 50 percent by 1970-71. For details, see National Council of Applied Economic Research and Fertilizer Association of India, Fertilizer Use on Selected Crops in India, New Delhi, September 1974.

[5]For a detailed analysis of factors behind growth of fertilizer use in India, see Desai, Gunvant M., Growth of Fertilizer Use in Indian Agriculture, Past Trends and Future Demand. Mimeographed. Cornell University, 1969; Desai, Gunvant M., Chary, P. N., and Bandopadhyay, S. C., Dynamics of Growth in Fertilizer Use at Micro Level. Mimeographed. Ahmedabad: CMA, Indian Institute of Management, 1973; and Desai, Gunvant M., and Singh, Gurdev, Growth of Fertilizer Use in Districts of India, Performance and Policy Implications. Mimeographed. Ahmedabad: CMA, Indian Institute of Management, 1973.

fertilizer use on rice than in terms of raising the average rates on fertilized rice area. And this has been so, not so much due to the substantial superiority of the response functions of the modern varieties over those of the traditional varieties, but because the decision to introduce the modern varieties simultaneously led to policies and programmes which accelerated the diffusion of fertilizer use on rice. This was further facilitated by a very favorable paddy price situation until the impact of the oil crisis on prices of agricultural inputs.

Perhaps it is necessary to stress at this stage that the above arguments are not intended to belittle the importance of the response functions in determining demand for fertilizers. In fact, as shown in the next sub-section, the response function crucially affects the fertilizer demand function; and thus the future of fertilizer use in the Asian rice economy critically depends on the availability of ecologically adapted modern rice varieties.

Fertilizer Demand Functions Implied by the Response Functions of the Traditional and Modern Rice Varieties

The use of a micro response function to study demand for fertilizer is not new. Here, we extend the conventional use by deriving fertilizer demand functions of modern and traditional varieties from their respective fertilizer response functions to examine the impact of the modern varieties on fertilizer demand functions. Our analysis is based on the estimated response functions of the resource paper.

The nitrogen demand function derived from a quadratic nitrogen response function is given by the following equation, and is shown in Figure 1.

$$N = \frac{b}{2c} - \frac{1}{2cP_p} P_n$$

where:

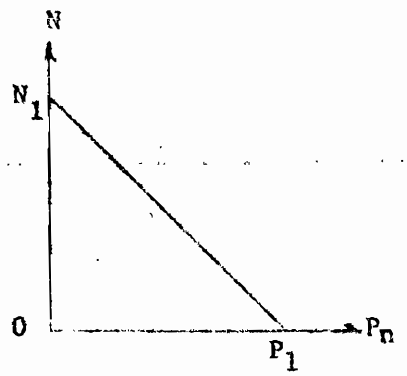
N = Economic optimum demand for N in kgs per hectare

b & c = Coefficients of the nitrogen response function

P_p = Price of rough rice per kg

P_n = Price of nitrogen per kg

Figure 1 : Nitrogen Demand Curve Derived from Nitrogen Response Function



Equation of D curve N_1P_1 : $N = \frac{b}{2c} - \frac{1}{2cP_p} P_n$

Intercept on N axis : $ON_1 = \frac{b}{2c}$

Intercept on P_n axis : $OP_1 = bP_p$

Slope of $N_1P_1 = \frac{1}{2cP_p}$

The demand curve shown in Figure 1 is a straight line because the underlying response function is quadratic. It shows demand for N at various prices of nitrogen for one set of values of b, c, and P_p.[6] Inasmuch as the curve presents economic optimum rates at different prices of N - rates towards which the actual rates could be expected to move over time if other things remain the same - it may be said to represent a long term demand curve for nitrogen for the given values of b, c, and P_p. A change in these three parameters could shift the demand curve as well as change its slope. An upward shift of the response function, without any change in P_p, would shift the demand curve to the right and make it flatter (Figure 2A). Similarly, an increase in P_p, without any change in the response function, would shift the demand curve to the right and make it flatter. However, in this case, the intercept on N axis will remain unchanged (Figure 2B).

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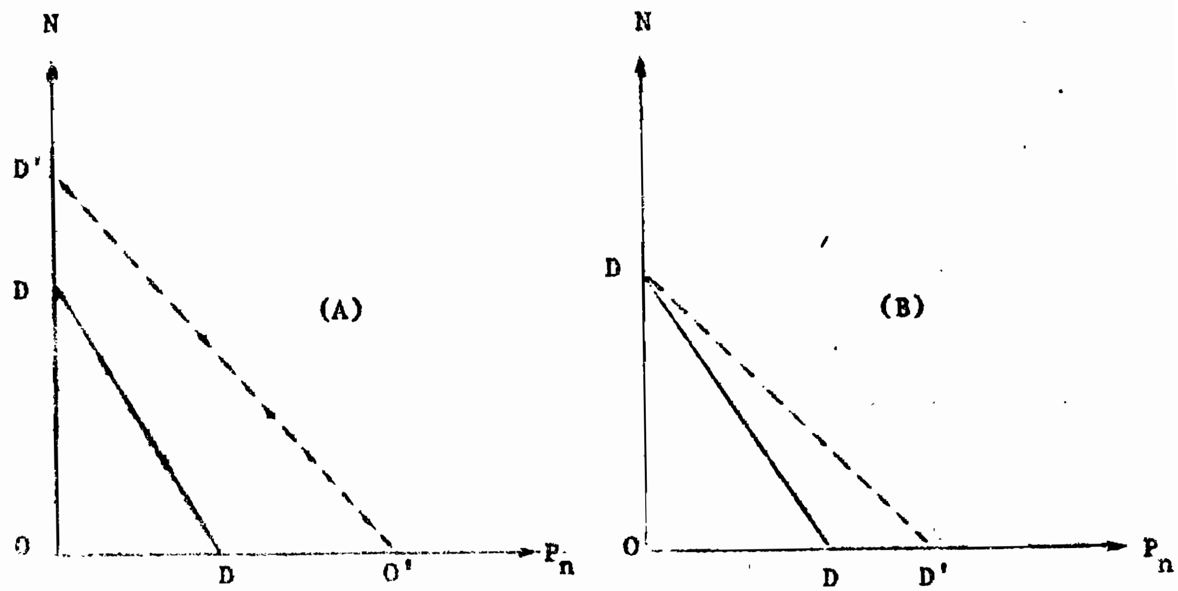
[6] Conventionally, demand for fertilizer has been studied by using the ratio of fertilizer to product price. In some situations this could be misleading because the same price ratio gives different magnitudes of total net returns from fertilizer use at different combinations of the two prices even though the optimum rate remains the same (Appendix A). Since the absolute size of the net returns play an important role in a cultivator's decisions about fertilizer use, we have taken the two prices separately. This procedure also makes it explicit that a shift in the demand curve for fertilizer is governed by both changes in the parameters of the response function as well as the price of the product. The importance of recognizing this, in a world where prices of input and output change at different rates, needs no emphasis.

Figure 2: Changes in Nitrogen Demand Curve Consequent to Changes in Response Function and Price of Rice



The impact of the modern rice varieties on nitrogen demand function, implied by the estimated response functions given in the resource paper, is examined below using the above conceptual framework.[7] For analytical convenience, to begin with it is assumed that there is no difference between the prices of the traditional and modern varieties of rice.

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[7] It is recognized that the conceptual framework would have to be further extended in certain directions if it is to be used to analyze a cultivator's behaviour as a consumer of fertilizer. This would be necessary because the effective function would be demand governed by expected response function and expected P_p, and not by ex post values of these parameters. However, for the limited objective of this paper, the conclusion would not change materially.

Table 2 shows the values of the intercepts on the two axes and slope of nitrogen demand curve derived from <u>average</u> response functions of different traditional and modern varieties. It reveals the following.

In the Philippines, the modern rice varieties have shifted the demand curves for nitrogen substantially upwards and to the right in both wet and dry seasons. In fact, in three out of the four cases for the wet season, the nitrogen demand curves of PETA have negative intercept on the price axis, thus indicating zero demand for nitrogen at any price. It is also clear that in most cases, the modern varieties have not only higher but also flatter demand curves for nitrogen than the traditional varieties. This implies lower price elasticities of demand for the modern as compared to the traditional varieties.

Against this, in the case of India, the situation is quite different. The upward shift of the demand curves for nitrogen due to the modern varieties is much smaller than in the case of the Philippines during both wet and dry seasons. Similarly, the demand curve of the modern variety is flatter than the one of the traditional variety only during the dry season. Nor is the reduction in the slope of the demand curve as high as in the Philippines.[8]

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[8] In the case of wheat, the situation in India is quite different. The upward shifts in nitrogen demand curves are quite pronounced. See Appendix Table 3 for details.

The above analysis is based on the assumption of the same price for both traditional and modern varieties of rice. If this assumption is relaxed to allow for a lower price of the modern variety, the difference in the slopes of the demand curves of the modern and traditional varieties would be reduced. While this may still imply higher and flatter nitrogen demand curves for the modern as compared to the traditional varieties in the Philippines, in the case of India, the difference in the slopes of the demand curves of the two types of varieties may not remain significant.

It was pointed out above that while the intercept on the nitrogen price axis of a demand curve derived from a response function would be affected by a change in the price of the product, the intercept on the nitrogen axis would remain unaffected. From this, it follows that an upward change in the price of rice would shift the demand curve of the same variety outwards and make it flatter. The importance of recognizing this is obvious, particularly in a situation represented by India, because of two reasons. First, there has been a substantial rise in the price of rice after mid-1960s when the modern rice varieties were introduced. Second, as the above analysis indicates, the nitrogen demand curves implied by the modern varieties do not have significantly different slopes than those implied by the traditional varieties. Therefore, it appears to us that perhaps the rightward shifts in the nitrogen demand curves between mid-1960s and early 1970s were more due to increase in rice prices than change in the nitrogen response functions.

Demand Functions Estimated from Fertilizer Consumption Data

The analysis based on a fertilizer demand function derived from a fertilizer response function focuses on the relationship between demand for fertilizer and physical response of crop to fertilizer.[9] This demand function cannot be taken as representing effective (or actual) demand because it is derived from a physical as distinguished from a behaviourial relationship. Viewed thus, the attempt in the resource paper to estimate demand models which take account of both actual fertilizer consumption and responsiveness of fertilizer is a contribution in a direction which has not received adequate attention. We, however, feel that some of the results of this attempt might have been affected by the specification of the basic demand model in the resource paper.

The basic demand model in the resource paper specifies fertilizer consumption as a function of (i) relative price of rice to fertilizer, (ii) proportion of area planted to the modern rice varieties, (iii) value of production (a proxy for farmers' ability to finance fertilizer), and (iv) variables which represent variations in fertilizer response functions.

It seems that the above specification leaves out a very important variable which influences demand for fertilizers, namely, diffusion of fertilizer use over time. This would be particularly true when the

[9] If the degree of representativeness of the response function could be ascertained, some useful conclusions about potential demand could be drawn from such a demand function.

model is estimated from the aggregate time series (1950 to 1972) observations from 12 rice growing countries. In most of these countries, fertilizer use had just begun in the early 1950s. Furthermore, as the Indian experience reveals, the diffusion of fertilizer use was not complete even by late 1960s. Therefore, it would not be unreasonable to assume that in such situations fertilizer use would increase up to a level even without significant changes in the values of the explanatory variables from the ones they had in the early 1950s. That there was significant growth in fertilizer use before 1965, when the modern rice varieties were introduced in most of these countries, clearly indicate this.[10] Thus, both logic and empirical evidence seem to suggest a specification error in the basic demand model. If this is the case, it could result into overestimation of the coefficients of the explanatory variables included in the model. This is because of the likelihood of high positive correlation between these variables and those representing diffusion of fertilizer use over time but which are not present in the model.

When estimated from the aggregate time series data, perhaps, there is one more limitation of the basic demand model. Presumably, the observed values the dependent variable (fertilizer consumption) relates to the entire economy of the countries. On the other hand, the explanatory

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[10]It is not clear what is the empirical connotation of the term "modern variety" in estimating the model. We have assumed that it means the same thing as the data given in Table 12 of IRRI, World Rice Statistics, April 1976. For details of growth in fertilizer use, see Table 42 of the same publication.

variables relate only to the rice economy of the countries. This may not pose a problem in countries where most of the fertilizer consumption is confined to rice. But the 12 countries include countries like India and Pakistan where rice accounts for a relatively small proportion of total fertilizer consumption, and where growth in fertilizer consumption has been governed by economies of crops other than rice.

The above arguments are not meant to challenge the overall conclusion of the demand function analysis that the modern rice varieties have made a definite impact on fertilizer consumption in the Asian rice economy. In fact, as Table 3 shows, there has been a significant acceleration in fertilizer consumption during 1965 to 1973 when the modern varieties were increasingly adopted in a large majority of the Asian rice growing countries. However, it is not clear up to what extent this acceleration has been due to the superiority of the fertilizer response functions of modern over traditional varieties as opposed to such other factors as the diffusion of fertilizer use on rice and the impact of the modern varieties on this process, favorable developments in the economies of other crops, and the price trends favorable to cultivators between mid-1960s and early 1970s in different countries covered by the study.

Finally, if the above doubts on the specification of the basic demand model are relevant, then it appears that the shifts in fertilizer response functions associated with the spread of the modern varieties will play a critical role in further rapid growth in fertilizer use in the Asian rice economy because of two reasons. First, there is a finite upper limit to diffusion of fertilizer use, and the past growth might have exhausted much of the effective potential in this direction. Second, the relative price situation has dramatically changed due to the impact of the oil crisis on prices of agricultural inputs.

APPENDIX TABLES

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APPENDIX A

Table 1 : Mean and C.V. of the response coefficients given in the Appendix Tables A1 and A2 of the resource paper.[1]

Period	Mean and C.V.	Wet season			Dry season		
		a	b	c	a	b	c
				Philippines: IRRI, Laguna			
1968–75	Mean	3436	16.54	−0.066	4243	38.20	−0.116
	C.V.	27	81	129	26	30	73
1969–75	Mean	3797	19.68	−0.149	4549	33.47	−0.115
	C.V.	21	50	37	20	25	40
1968–75	Mean	2235	−4.22	0.005	4780	1.17	−0.111
	C.V.	32	179	874	15	1848	71
				Philippines: MRRTC, Central Luzon			
1968–75	Mean	3425	16.18	−0.156	4236	29.78	−0.105
	C.V.	27	51	108	9	36	77
1968–75	Mean	3442	29.74	−0.164	3616	25.97	−0.086
	C.V.	23	16	29	21	31	59
1968–75	Mean	2950	−7.82	+0.011	3974	13.05	−0.128
	C.V.	30	145	473	15	89	53
				Philippines: BRCES, Bicol			
1968–75	Mean	3416	26.04	−0.149	4081	37.28	−0.148
	C.V.	26	38	38	27	16	13
1968–75[2]	Mean	3141	28.13	−0.163	3942	36.57	−0.147
	C.V.	26	39	37	17	11	28
1968–75	Mean	3089	−1.97	+0.023	4129	9.44	−0.105
	C.V.	25	631	274	26	105	43
				Philippines: VRES, Visayas			
1968–75[2]	Mean	3259	19.36	−0.084	3554	21.84	−0.071
	C.V.	18	84	106	27	76	75
1968–75[2]	Mean	3567	45.34	−0.235	3697	28.40	−0.095
	C.V.	19	35	60	20	55	80
1968–75[3]	Mean	3691	4.03	−0.041	3300	−3.60	−0.039
	C.V.	22	357	171	29	635	219

1 contd...

Period	Mean and C.V.	Wet season a	Wet season b	Wet season c	Dry season a	Dry season b	Dry season c
				India: CRRI, Orissa			
1967–69	Mean	3314	24.73	–0.082	3058	42.69	–0.078
	C.V.	18	40	7	23	27	80
1967–69	Mean	2509	11.47	–0.058	1551	21.74	–0.090
	C.V.	8	61	7	28	65	116
				India: TNPBS, Coimbator			
1967–69	Mean	3070	24.86	–0.048	3086	21.11	–0.035
	C.V.	29	20	20	19	30	16
1967–69	Mean				2751	17.87	–0.059
	C.V.				25	30	26
1967–69	Mean	3235	31.60	–0.125			
	C.V.	27	13	9			
				India: MARS, Andhra Pradesh			
1971–75	Mean	4407	8.84	–0.071			
	C.V.	2	38	138			
1971–75	Mean	3853	–0.336	–0.084			
	C.V.	2	528	180			
				India: 19 Locations			
1967–69[4]	Mean	2985	17.46	–0.045	3242	28.30	–0.071
	C.V.	2	23	27	23	5	13
1967–69[4]	Mean	2592	15.08	–0.064	2315	19.30	–0.061
	C.V.	1	18	15	23	31	57

1 Response function: $Y = a+bN+cN^2$, where Y = Yield of rough rice (kg/ha), and N = Elemental nitrogen (kg/ha)

2 For the Dry season, the period is 1970–75

3 For the Dry season, the period is 1971–75

4 For the Dry season, the period is 1967–68

Table 2 : Parameters of the nitrogen demand curves derived from average response functions of the traditional and modern rice varieties

Variety	Period	Season	Intercepts		Slope[2]
			N axis $(\frac{b}{2c})$	P_n axis (bP_p)[1]	$(\frac{1}{2cP_p})$
			Philippines: IRRI, Laguna		
IR8	1968–75	Wet	125.3	16.54	–7.58
IR8	1968–75	Dry	164.7	38.20	–4.31
IR20	1969–75	Wet	66.0	19.68	–3.30
IR20	1969–75	Dry	145.5	33.47	–4.35
PETA	1968–75	Wet	398.1	–4.22	+94.3
PETA	1968–75	Dry	5.27	1.17	– 4.5
			Philippines: MRRTC, Central Luzon		
IR8	1968–75	Wet	51.9	16.18	– 3.2
IR8	1968–75	Dry	141.8	29.78	– 4.8
IR20	1968–75	Wet	90.7	29.74	– 3.1
IR20	1970–75	Dry	151.0	25.97	– 5.8
PETA	1968–75	Wet	355.5	–7.82	+45.5
PETA	1968–75	Dry	51.0	13.05	–3.91
			Philippines: BCES, Bicol		
IR8	1968–75	Wet	87.4	26.04	–3.36
IR8	1968–75	Dry	126.0	37.28	–3.38
IR20	1968–75	Wet	86.3	28.13	–3.07
IR20	1970–75	Dry	124.4	36.57	–3.4
PETA	1968–75	Wet	4.3	–1.97	+2.17
PETA	1968–75	Dry	45.0	9.44	–4.76

Table 2 contd ...

Variety	Period	Season	Intercepts: N axis ($\frac{b}{2c}$)	Intercepts: P_n axis (bP_p)[1]	Slope[2] ($\frac{1}{2cP_p}$)
			Philippines: VRES, Visayas		
IR8	1968–75	Wet	115.2	19.36	–5.95
IR8	1970–75	Dry	151.3	21.84	–7.04
IR20	1968–75	Wet	96.5	45.34	–2.13
IR20	1970–75	Dry	150.0	28.40	–5.3
PETA	1968–75	Wet	49.2	4.03	–12.2
PETA	1971–75	Dry	–46.2	–3.60	–12.8
			India: CRRI, Orissa		
IR8	1967–69	Wet	150.8	24.73	–6.1
IR8	1967–69	Dry	273.7	42.69	–6.4
Local	1967–69	Wet	98.9	11.47	–8.6
Local	1967–68	Dry	120.8	21.74	–5.6
			India: TNPBS, Coimbatore		
IR8	1967–69	Wet	259.0	24.86	–10.4
IR8	1967–69	Dry	301.6	21.11	–14.3
ADT27	1967–69	Dry	151.4	17.87	–8.5
CO23	1967–69	Wet	126.4	31.6	–4.0
			India: MARS, Andhra Pradesh		
Pankaj	1971–75	Wet	62.3	8.84	–7.0
Mashuri	1971–75	Wet	– 2.0	–0.336	–6.0
			India: 19 Locations		
IR8	1967–69	Wet	194.0	17.46	–11.11
IR8	1967–68	Dry	199.3	28.3	–7.0
Local	1967–69	Wet	117.8	15.08	–7.8
Local	1967–68	Dry	158.2	19.30	–8.2

Table 2 contd ...

1. The value of the intercept on P_n axis would be the b values given in the column multiplied by P_p.

2. The value of slope would be the value given in the column $(\frac{1}{2c})$ divided by P_p.

Table 3 : Growth in fertiliser consumption in some Asian countries

	Per cent of arable land under rice	Per cent of total rice area under modern varieties		Average annual increment in NPK consumption between	
		1965-66	1973-74	1950-51 & 1965-66	1965-66 & 1973-74
				kgs/ha	
Bangladesh	NA	-	16.1	0.39	1.68
Burma	25	-	5.1	0.04	0.30
India	23	0.02	25.6	0.27	1.56
Indonesia	44	-	36.6	0.41	2.36
Japan	47	NA	NA	13.77	8.53
Malaysia	21	10.3[1]	37.4[1]	1.28[2]	7.03
Pakistan	8	-	43.2	0.23	2.14
Philippines	49	-	63.3	0.56	2.60
South Korea	50	-	11.8	9.18	21.3
Sri Lanka	30	-	64.5	0.72	0.81
Taiwan	81	NA	NA	11.05	9.71
Thailand	50	-	5.6	0.19	1.06

1 Relates to West Malaysia

2 Between 1951-52 and 1965-66

Source : Compiled from Tables 3, 12, 41, 42 and 47 of IRRI, World Rice Statistics, April 1976

Appendix A : Impact of Price Changes on Net Returns from Fertiliser Use

The objective of this Appendix is to illustrate that for the same ratio of fertiliser price to product price, the magnitude of total net returns from fertiliser would change for different combinations of fertiliser and product prices even though the optimum rate remains the same. For this exercise, we use the average response functions of the local variety (wet season) for India given in the resource paper. The estimated response function is given by the following equation.

$$Y = 2592 + 15.08\,N - 0.064\,N^2$$

where,

Y = Yield of paddy (kgs/ha)
N = Nitrogen (kgs/ha)

The ratio of nitrogen to paddy price we use is 1:4. The two sets of prices, giving this ratio, are as follows:

	Set-I	Set-II
Price of N (Rs. per kg)	2.00	4.00
Price of Paddy (Rs. per kg)	0.50	1.00

Incidentally, Set-I prices roughly correspond to the price situation in late 1960s, and Set-II prices to the situation after the hike in the price of fertiliser due to the Oil Crisis.

The economic optimum rate for both the sets of prices is 86.6 kgs per hectare. This is so because the price ratio is the same. The total net returns from nitrogen use at optimum rate, however, are substantially different as shown below:

	Set-I	Set-II
	Rs. per hectare	
Gross revenue at optimum rate	412.90	825.79
Total cost at optimum rate	173.12	346.24
Net revenue at optimum rate	239.78	479.55

Appendix Table 1 : Coefficients of the nitrogen response functions of local and high yielding varieties at some locations in Karnataka, India.[1]

Varieties	Year (Season)	Coefficients of Response Function		
		a	b	c
		Mandya		
HYVs (Irrigated)				
IR8, Jaya, IR5	1969–70 (Kharif)	3654	15.01	–0.060
Padma, Jaya	1969	3920	19.64	–0.050
IR8, Jaya	1970 (Kharif)	4885	16.23	–0.070
Jaya, Vijaya, IR20, IR22, IR8, IET 1039	1971 (Kharif)	3969	35.68	–0.110
Local (Irrigated)				
S – 705[2]	1969	2597	13.28	–0.060
		Mangalore		
HYVs (Irrigated)				
IR8, Jaya, MR2, IET1996	1972–73	2663	7.31	–0.021
Jaya, IR8, IET1996	1973–74 (Rabi)	2972	9.95	–0.030
HYVs (Rainfed)				
Jaya, IR8, IET1996	1973–74 (Kharif)	4249	10.88	–0.030
Jaya, IR8, MR2, IET1996	1973–74 (Kharif)	3946	12.10	–0.035
Jaya	1974–75	2773	6.63	–0.028
IET2295	1974–75	2511	14.05	–0.028
Local (Rainfed)				
GMR2[2]	1974–75	2874	19.42	–0.086
GMR17[2]	1974–75	1944	0.059	+0.096
MTU20	1974–75	3039	5.66	–0.046

Appendix Table 1 contd ...

Varieties	Year (Season)	Coefficients of Response Function		
		a	b	c
		Raichur		
HYVs (Irrigated)				
IR8	1969-70	5036	16.60	-0.060
IR8, Jaya	1970-71	4808	21.28	-0.082
Local (Irrigated)				
Local	1969-70	3607	15.64	-0.051
Local	1970-71	3816	13.45	-2.69
		Shimoga		
HYVs (Irrigated)				
IR8	1969-70	3522	20.67	-0.010
IR8	1970-71	3767	12.35	+0.020
Jaya	1970-71	3947	12.37	+0.070
Jaya, IR8	1970-71	3854	12.07	+0.020
HYVs (Rainfed)				
IR8	1969-70 (Kharif)	3003	11.35	-0.018
IR8	1970-71 (Kharif)	3205	6.38	+0.124
Local (Irrigated)				
Local	1969-70	2434	10.22	-0.010
Local (Rainfed)				
Local	1953-54 1955-56	936	11.32	-0.083
Local[2]	1953-54 1955-56	1384	3.48	+0.067
S701[2]	1970	3018	8.45	-0.019
S701	1969-70	2563	8.27	-0.027
		Chitradurga		
HYVs (Irrigated)				
Jaya	1974-75 (Kharif)	2403	4.88	-0.019
Jaya	1974-75 (Summer)	2984	4.03	-0.017

Appendix Table 1 contd ...

Varieties	Year (Season)	Coefficients of Response Function		
		a	b	c
		Mysore		
HYVs (Irrigated)				
Jaya	1974-75	3590	20.59	-0.056
Jaya	1974-75 (Rabi)	3638	16.75	-0.009
Local (Irrigated)				
S701[2]	1974-75	3006	36.22	-0.281
S701[2]	1974-75	2972	19.66	-0.077

Response function : $Y = a + bN + cN^2$ where Y = Yield of paddy (kgs/ha), and N = elemental nitrogen (kgs/ha). The functions listed under Mandya and Mangalore were estimated from experiment data while the rest were estimated from data on trials on farmers' fields.

Locally improved varieties

Source : Derived from information in Appendix E-1 of Gurushri Swamy and S.M. Sunder Raju, Agricultural Development in Karnataka, 1956-57 to 1974-75, Institute for Social and Economic Change, Bangalore, India. (Mimeographed First Draft of the Study).

original source: Various issues of the Mysore Journal of Agricultural Sciences, a quarterly publication of the University of Agricultural Sciences, Hebbal, Bangalore, India.

Appendix Table 2 : Annual increase in nitrogen use in major rice growing states of India before and after the introduction of high yielding varieties

State	Per cent of total cropped area under rice	Per cent rice area under HYVs by 1973-74	Annual increase in N use (kgs/ha) between	
			1956-57 & 1965-66	1965-66 & 1973-74
West Bengal	71	15	0.32	0.43
Orissa	68	8	0.14	0.56
Assam	54	14	0.06	0.04
Bihar	48	12	0.24	0.46
Tamil Nadu	36	78	0.91	1.89
Kerala	30	31	0.39	0.89
Andhra Pradesh	26	56	0.51	0.91
Madhya Pradesh	21	18	0.15[1]	0.35[2]
Uttar Pradesh	19	22	0.40	1.22
Karnataka	10	25	0.28	0.85
All India	23	6	[illegible]	0.79

1 Relates to 1956-57 to 1966-67

2 Relates to 1966-67 to 1973-74

Note : The 10 states listed in the table account for about 90 per cent of total rice area, and 85 per cent of the area under high yielding varieties of rice in the country.

Source: Compiled from various issues of Fertiliser Association of India, Fertiliser Statistics, New Delhi.

Appendix Table 3 : Parameters of the nitrogen demand curves derived from average response functions of the local and high yielding wheat varieties

Variety	Intercepts		Slope[2]
	N axis $(-\frac{b}{2c})$	P_n axis (bP_p)[1]	$\frac{1}{(2cP_p)}$
Sonara-64	136.3	49.07	- 2.78
Sonara-63	108.9	37.01	- 2.94
Larma Rojo	118.3	54.41	- 2.17
C306	94.0	20.67	- 4.55
NP876	82.1	32.83	- 2.50
NP887	72.1	25.95	- 2.78

1. The value of the intercept on P_n axis would be the b values given in the column multiplied by P_p.

2. The value of slope would be the value given in the column $(\frac{1}{2c})$ divided by P_p.

Source: The coefficients of nitrogen response functions used to derive this table are from Singh, I.J., and Sharma, K.C., Production Functions and Economic Optima in Fertiliser Use for Some Dwarf and Tall Varieties of Wheat, Research Bulletin No. 5, Feb. 1969, U.P. Agricultural University, Pantnagar, U.P.