INORGANIC FERTILISER INPUTS

TO HIMALAYAN AGRICULTURE:

SOME ISSUES IN PRICING+

J.M. Dixon*

+ Paper to be presented at the Annual Conference of the Australian Agricultural Economics Society, La Trobe University, Melbourne, February 8-11, 1988.

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ABSTRACT

Increased population pressure in the mid-altitude hills of the Himalayas in general and Nepal in particular has pushed cropping onto marginal land, depressing average crop productivity. One promising avenue for improving crop yields is the greater use of inorganic fertilisers. However, the prevailing level of fertiliser subsidy is not sustainable in the face of expanding fertiliser sales.

Some implications of reducing the subsidy are considered in this paper. The evaluation of alternative fertiliser price policies is complex given the diversity of farming systems. Indicative results from a simple economic surplus analysis of eliminating the fertiliser subsidy are presented. Some issues in connection with pricing fertiliser are noted.

1 INTRODUCTION

Until the middle of this century, the largest part of the increase in world food production was due to expansion of cultivated area. Additional lands were mostly of reasonable quality - sometimes even of higher quality than the existing stock of cropland - and thus productivity of land was maintained or even grew.

A great proportion of the considerable increase since 1950 in global food production arose from intensification on the existing stock of cropland.[1] Along with improved varieties, irrigation and mechanization, inorganic fertiliser (hereafter referred to simply as fertiliser) led to substantial

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increases in yields. Barker, Herdt with Rose (1985) report a study showing that fertilisers, mechanization and irrigation each contributed about one-quarter of the total growth in rice production of eight large Asian countries during the period 1965-1980.

The traditional source of supplementary plant nutrients in much of the developing world is farmyard manure-compost, which has increasingly been supplemented and substituted by commercial fertiliser. Global fertiliser use increased nearly nine-fold (to 121 Mt over the period 1950-1984, and nearly five-fold on a per capita basis during the same period. Brown (1987) claims that eliminating fertiliser use altogether would probably reduce total food production by at least a third.

Among the marginal areas that have been bypassed by the Green Revolution, Hill and Mountain areas pose exceptionally complex develpment problems. They generally were settled earlier than lowlands, suffer high population densities (relative to the resource base), and severe or impending erosion. The remoteness of mountain areas delayed the provision of infrastructure, notably transport, and served to contain populations, thus aggravating the pressure on land. Given the minimal activity of foodgrain markets and the traditional life styles, most farming systems feature a high degree of self-sufficiency and complexity. In recent decades strong links have evolved between most mountain systems and nearby lowland agricultural/urban systems. Many mountain communities survive only by the export of labour. The Hills of the Kingdom of Nepal exhibit many of the foregoing characteristics, and are taken as an example for the analysis of the role of fertiliser in such Hill and Mountain systems.

In particular, existing fertiliser subsidies impose a heavy burden on the Government, and are not sustainable in the face of expanding fertiliser use. This paper contains the results of a preliminary analysis of some of the effects of dispensing with the fertiliser subsidy. This economic surplus analysis is based on estimated actual crop response to fertiliser application.

2 FERTILISER POLICY FRAMEWORK

2.1 Agricultural Systems of Nepal

The country comprises three distinct ecological zones: the high-altitude Mountains above approximately 3000 m, the steep and dissected Hill zone and the flat low-lying Terai. The fertile and highly productive Kathmandu Valley lies in the central Hills. Somewhat more than half the population resides in the Hills and Mountains, where the population pressure is 8.2 persons/ha (cultivated), compared with [illegible].9 persons/ha in the Terai. Total cultivated area is expanding by approximately 1.5 per cent per annum (but this must be set against the average population growth rate of 2.6 per cent per annum, rising to 2.8 per cent per annum in the early 1980s). The rate of expansion in cultivated area is likely to reduce in the near future given the shortage of free arable land.

Mixed farming predominates, with strong interdependence between crop production, livestock husbandry and the associated forests (especially in the Hills and Mountains). The forests and other grazing areas provide livestock fodder and litter (for compost) and, most importantly, firewood. Most forest and grazing lands are under communal management. Consequently, cattle and buffalo numbers far exceed the carrying capacity of the grazing areas. As in India, cattle are considered sacred and are essential for draught power. Buffalo are the principal source of milk products. Rice is the single most important cereal in Nepal, accounting for some 1.3 M ha. Maize is the dominant crop in the Hills, and wheat is spreading rapidly in both zones.

2.2 Fertiliser Consumption

The average application rate of fertiliser to cultivated land in Nepal was approximately 15 kg/ha of nutrients in 1984/85 (Wallace 1986), where nutrients refer to nitrogen, phosphorus (P_2O_5) and potassium. Since the introduction of fertiliser to Nepal during the 1960s, consumption increased at about 15 per cent per annum (Hill 1982), encouraged by a substantial subsidy in recent years. Similar growth rates have been experienced by India and other Asian countries which subsidise fertiliser and have relatively low application rates.[2]

In Hill areas (excluding the Kathmandu Valley) average fertiliser application is 9 kg/ha of nutrients (on a harvested area basis) which amounts to 19 per cent of national consumption. The Terai makes use of the biggest share, 62 per cent, at the rate of 16 kg/ha. The Kathmandu Valley consumes a small but disproportionate amount -- equivalent to 15 per cent of total nutrients, implying an application rate of 95 kg/ha. The location of outlets and the evidence from farm surveys suggest that consumption in Hill areas is highly concentrated in districts enjoying good access or intensive agricultural development efforts.

Urea and complesol (a 20:20:0 compound fertiliser) each account for slightly less than half of total consumption. Thus, approximately three times more nitrogen than phosphorus is used. Most fertiliser is applied to rice and wheat. In the Hills, 22 per cent of rice and 28 per cent of wheat is fertilised; and in the Terai 50 per cent of rice and 61 per cent of wheat receives fertiliser (DFAMS 1986). Fertiliser application appears to be associated with good water control, but not necessarily with the use of improved varieties.

2.3 Fertiliser Subsidy

Food shortages emerged more than two decades ago as a result of growing population pressure and stagnating productivity, and worsened in the ensuing decades. The problem is particularly acute in the Hills where annual cereal production variability (coefficient of variation 7.9 per cent) exceeds by half that for the national level, and great spatial variation can also be observed. A solution was sought in modernization of agriculture, especially of the Terai. The modernization strategy included expanding the supply of, *inter alia*, improved varieties, modern tools, fertiliser, credit and irrigation.

Fertiliser offered the prospect of quick production increases at low capital cost. All fertiliser is imported, for which the Agricultural Inputs Corporation (AIC) holds sole rights. The AIC also distributes most fertiliser. Official prices are uniform across the country for each fertiliser type (currently approximately US$185/t for both urea and complesol at AIC distribution outlets).

A fertiliser subsidy was introduced in 1972, initially to offset the high transportation costs to the isolated Hill and Western Terai districts which suffered from high farm-gate prices for fertiliser. It has been argued that subsidies increase early adoption in circumstances of poor knowledge by farmers of fertiliser response, often found in the early stages of adoption in remote areas. Some maintain that the fertiliser subsidy policy has not had the desired effect of encouraging farmers to use more improved inputs (Lohani and Sharma 1984). In fact, the expansion of fertiliser usage parallels many Asian and African countries which also had fertiliser subsidies, whilst exceeding the average growth rate of fertiliser consumption in countries without fertiliser subsidies.

There was considerable evidence from elsewhere in the region to support the practice of subsidising fertiliser. Timmer (1974) found a strong relationship between (relative) fertiliser price and fertiliser adoption in Asian countries. Barker and Hayami (1976) showed that a fertiliser subsidy would be more cost-effective than an output subsidy as a means of expanding food production in the Philippines.[3] The subsidy might also be viewed as a means of redressing the declining (barter) terms of trade for agriculture vis-a-vis the non-agricultural sector (Svejnar and Thorbecke 1986).

Over time the small fertiliser transportation subsidy in Nepal evolved into a substantial price and transportation subsidy on fertiliser -- approximately 40-64 per cent of the full fertiliser cost, of which only about 10 per cent constituted a transportation subsidy (Kupferschmid 1983). As a consequence, AIC fertiliser distribution operations run at a large loss which can be ill-afforded now, and losses would be even greater in future years as fertiliser sales expand.

In order to meet the economic costs of fertiliser acquisition and distribution by AIC, Kupferschmid (1983) estimated that 1983 fertiliser prices would have had to be increased by 64 per cent. To cover all costs including those of donor countries and agencies, 1983 fertiliser prices would have had to be increased by approximately 125 per cent. Although the implicit tariff on urea declined in the early 1980s as world prices fell and internal prices were raised, the effective average subsidy in 1986/87 was 29 per cent (of AIC prices) for urea and 71 per cent for complesol (Wallace 1986).

2.4 Policy Choices

Total fertiliser consumption in India has been limited in part by shortcomings of the supply system (Desai 1982). The observation probably holds true for Nepal too. However, whether or not distribution costs can be contained and timeliness improved by reforms to the distribution system, important questions related to fertiliser demand remain to be answered.

The responsiveness of total food production and market surplus to fertiliser application, the distribution of response over regions and the treasury cost of various levels and forms of subsidy are the central issues. The fertiliser policy options which Nepal faces include the following:

(a) continue the present fertiliser subsidies;
(b) phase out fertiliser subsidies completely;
(c) phase out Terai subsidies but retain (transport and price) subsidies for the Hills and Mountains.

Option (c) appears relevant because of the large food deficits in the Hills and Mountains, and the costly food distribution programmes. However, option (c) is not explicitly analysed for lack of accurate data. After considering the micro-level evidence related to crop response to fertiliser and the effect of relative fertiliser price changes, the policy alternative (b) is considered in section 5.

3 CROP RESPONSE TO FERTILISER APPLICATION

Fertiliser response analysis has generally been cast in a single-period, i.e., one-crop framework, although the existence of benefits for succeeding crops has been considered (see Dillon 1977). Some authors have investigated the economic significance of residual impact (see Kennedy, Whan, Jackson and Dillon 1973; Helyar and Godden 1977). Generally speaking, the significance of carryover will be lower where (a) application rates are low (judged in relation to the native soil fertility); (b) application costs are low when compared with the farm-gate cost of the fertiliser; and, (c) soluble nutrients, particularly nitrogenous, predominate over slower-release nutrients including phosphorus. For these reasons, and the lack of data to calculate residual functions, a single-period framework is adopted.

The most common sources of data for estimating crop response to nutrients are experiment station results, on-farm fertiliser trials or demonstrations, and farm surveys.[4] Taking these sources in order, decreasing goodness of fit in response functions is usually found, as the variability in exogenous factors increases. For the same reason, aggregate response, e.g., regional or national functions, usually have poorer fits than site specific response function. The sources of data used here are farm survey and fertiliser demonstrations.

Many fertiliser response analyses are cast in a single-crop, as opposed to whole farm or farm-household, context. There is no difference in results if unconstrained risk-neutral profit maximization can be assumed for the whole decision unit. The context is crucial if (a) non-profit goals, e.g., survival, assume importance; (b) farmers are risk averse (the evidence of a number of studies shows that farmers are moderately risk-averse); (c) the quantity of fertiliser is limited, e.g., restricted supply, lack of capital (cash); or, (d) the farm and household are interdependent such that the household choices influence farm production relations.

In order to estimate cereal crop response to fertiliser in Nepal, results from about 300 fertiliser verification trials conducted by the HMG/FAO Fertiliser and Related Inputs Project in 21 districts in the Hills and Inner Terai during the years 1984-87 were analysed. An eight-plot incomplete factorial trial design was used, with nitrogen applications of 0, 60 and 120 kg/ha, and phosphorus and potassium applications of 0, 40 and 80 kg/ha. Ordinary least squares regression was utilized to test various functional forms, including double-log (after adjusting zero values), square root and quadratic. In order to counter the variation between trial sites, yield increments (from fertiliser application) were regressed on nutrient application.

Preliminary results of the quadratic models appear in annex table 2. Response to potassium was not significant in either crop or zone, and the nitrogen-phosphorus interaction terms were also not significant (at the 10% level). Evaluating production elasticities at typical nutrient application levels gave the values shown in annex table 3, ranging from 0.03 to 0.20.

These responses pertain to relatively favourable conditions, albeit farmer managed. The results are similar to the (highly variable) responses from on-farm cropping sequence trials reported by Mathema, Van der Veen and Anjan (1981).[5] Somewhat lower production-nutrient (all sources) elasticities were obtained from Cobb-Douglas production functions estimated by the author from farm survey data from the Hills, e.g., local paddy 0.03, improved paddy 0.03, wheat 0.06 (comparable to the elasticities reported by Gautam, 1987).

Despite the subsidy, the prevailing nutrient-grain price ratios are greater than those in many other countries in the region.[6] Annex table 1 shows that nitrogen-rice prices have not fallen as low as 1.0, and in the 1980s fluctuated between 1.3 and 1.8. Nonetheless, the responses reported herein suggest that even at these price ratios fertiliser is quite profitable, after adjusting for fertiliser acquisition costs, capital costs and low harvest prices for grain, as outlined by Anderson (1967).

From the above response analysis, optimal (risk-neutral) application rates exceed the actual application rates calculated from zonal fertiliser consumption da' or from farm survey results. When farmers are assumed to be moderately risk averse, optimal application rates diminish, by up to about 30 per cent at typical levels of yield variance. In this case, the risk-adjusted optimal rates are still far above the average rates in the Hills.

A change in relative fertiliser price caused by a removal of the subsidy often leads to changes in the combination of inputs used in production.[7] Assuming that substitution of other factors for fertiliser is feasible, the outcome can be simply demonstrated by an isoquant analysis (Parish and McLaren 1982). Whether substitutes for fertiliser exist or not, a contraction of output would follow the increase in the price of fertiliser. The evidence from farm surveys in Nepal does not indicate that fertiliser is substituted for manure-compost, and the data on substitution of fertiliser for other inputs is inconclusive. In this paper it is assumed that the intensity of other input use does not change with the increase in fertiliser price.

4 ECONOMIC SURPLUS ANALYSIS

As mentioned above, the current effective subsidies are 29 and 71 per cent on urea and complesol respectively. Thus, an increase of AIC fertiliser prices to Rs 6/kg would eliminate (very roughly) the present subsidy. In a free market setting the reduction in fertiliser subsidy generally would shift the fertiliser supply curve to the left. However, in Nepal, the quantity supplied is determined by AIC, not necessarily in accordance with anticipated equilibrium positions of the domestic fertiliser market.

The shape of the demand schedule can be inferred from a knowledge of the underlying production functions for fertiliser use, estimated from data or elicited directly from users. Wallace (1986) elicited farmers' subjective price elasticities of demand for fertiliser in Nepal, which ranged from -0.3 to -1.7 (the more elastic observations may have been associated with non-grain cash crop production). The more inelastic observations in this range are comparable to findings from elsewhere in the region.[5]

For the purposes of this paper, rice and wheat (being the two crops to which most fertiliser is applied) are grouped with maize and millet as cereals. Initially a closed economy is assumed. Annex figure 1 shows the likely effect of the price increase on the domestic fertiliser and foodgrain markets. Assume that the aggregate supply curve for cereals shifts from S_0S_0 to S_1S_1 as a consequence of the fertiliser price increase and the subsequent contraction in fertiliser use and foodgrain production. Commonly, two methods are used to estimate changes in producer surplus: (a) revenue increase less extra fertiliser costs and (b) area above the supply curve. The former appears unrealistic, in that other (non-fertiliser) additional variable costs underly the supply curve and must be accounted for. Using the latter method, the increase in producers' surplus is area <u>bdfc</u> less <u>chif</u>. The reduction in consumers' surplus is area <u>bdfc</u>. There is also a change in treasury cost equivalent to the size of the fertiliser subsidy.

The parameter assumptions for a national-level analysis of removing the fertiliser subsidy are listed in annex table 5. The supply response was derived from the acreage elasticity of supply of 0.067 estimated by Karki and Neupane (1984). The production elasticity of fertiliser was calculated by weighting the appropriate marginal physical products with fertiliiser consumption, and re-evaluating the aggregate production elasticity at national level. Foodgrain volumes refer to total production. The elasticity of demand for fertiliser was chosen from Wallace (1986), and the elasticity of demand for foodgrains is comparable to north Indian data.

Calculations of the new equilibrium quantity and price in the fertiliser and foodgrain markets were made under the assumption of constant elasticity supply and demand schedules, and linear schedules (shown in figure 1). There was little difference in the resulting equilibrium positions, but there could be substantial differences in the change in producers' surplus. Given the approximate nature of the parameters used in this study, linear schedules were assumed.

For the 50 per cent fertiliser price increase required to eliminate the subsidy, the quantity of fertiliser nutrients demanded would contract from the (1984/85) volume of 42.8 kt to about 35.1 kt. A cereal-fertiliser production elasticity of 0.13, and the contraction in fertiliser use would lead to a drop in cereal production of 76 kt to 3.12 Mt and a resulting shift in the cereal supply schedule S_0S_0 to S_1S_1 (assumed parallel in this case). As a consequence, the short-run equilibrium shifts from f to c, characterised by a higher price Rs 4.54/kg at the reduced supply of 3.12 Mt.

On this basis, the following changes in surplus and subsidy would result:

consumer surplus	Rs -850 million
producer surplus	Rs +530 million
fertiliser subsidy	Rs +170 million

The interesting result is the substantial increase in producers' surplus as a consequence of the reduction in fertiliser subsidy. The benefit to producers arises from the price increase (under the assumption of fixed marketing changes) which is also the source of the loss to consumers. In the event of a substantial price rise foodgrains would flow into Nepal from India (and Indian producers would share in the benefits). The shift in prices implied in this analysis (6.25%) is unlikely to alter the trade patterns along the India-Nepal border very much. The final distribution of benefits, which is not apparent from this short-run partial equilibrium analysis, depends upon the means of utilization of the potential saving of Rs 170 million from the elimination of the fertiliser subsidy. If the saving were to be passed on to consumers through, for example, reduced customs duties on Indian goods, consumers' losses would diminish. However, it is more likely that a proportion of the saving (not all domestic) would be reinvested in the agricultural sector thereby adding further to producers' benefits.

5 ISSUES

5.1 Open economy

The relatively uncontrolled border with India means that the economy is far from closed. Considerable amounts of grain are said to be moved illegally to India. Wallace (1986) believes cross-border fertiliser sales explain the large discrepancy in fertiliser use data between AIC sales figures (1980/81 winter and 1981/82 summer) and CBS agricultural census data. For nearly two years from July 1981 to April 1983 urea and complesol were 10-20 per cent cheaper in Nepal, providing a strong incentive for cross-border trading of fertiliser from Nepal. However, one cannot discount the likelihood of opposite flows, albeit low volume, i.e., Terai farmers purchasing fertiliser and other inputs in India at times of shortage in Nepal, or simply to ensure having inputs on time.

A full analysis would take account of the price formation for foodgrains (and inputs) across the markets of the Hills, Kathmandu Valley, the Terai and North India, and the resulting trade flows. For instance, in terms of low domestic prices of fertiliser in Nepal, a price increase in Nepal may lead to somewhat greater availability of fertiliser to Terai farmers owing to the staunching of the unofficial fertiliser flows across the border to India. The excess demand for foodgrains in the Hills is largely met from the excess supply in the Terai.

The open border also has the effect of placing severe limits on the freedom of policy makers to adjust prices (for whatever reason). In practice, it would seem sensible to maintain Terai fertiliser prices at least higher than the Indian price less transfer costs to India, and perhaps there are advantages to Nepal in even higher Terai fertiliser prices.

5.2 Suboptimal Application Rates

Parton and Piggott (1984) have discussed some of the consequences of price not equaling marginal value product for the calculation of producers' benefits. In these circumstances, there are also difficulties in estimating derived demand for inputs such as fertiliser from the underlying production function.

In the absence of sound empirical direct estimates of demand for fertiliser (which would be very difficult to obtain in Nepal), the best approach seems to be to derive the demand schedule from a farm-household model. This approach would confer the additional benefit of providing estimates of short-run supply response (the magnitude of which are notoriously uncertain).

5.3 Equity

Ironically, a major part of the total subsidy is now captured by Kathmandu Valley producers who consume approximately 15 per cent of total nutrients but in excess of a third of the volume for which the transportation subsidy is applicable. Even in the Western Terai and the Hills, however, the major benefits of the fertiliser subsidy would have accrued to the larger farmers who were in a position to purchase fertiliser and to bear the risk of applying fertiliser. For small farmers in the Hills who are also food deficit, there could also be initial benefits from the adoption of subsidised fertiliser since the increase of production by the local surplus producers could quickly drive down local market prices -- but note that the local wage rate (whether cash or in kind) would be expected to follow suit in the medium term.

Equity can also be considered in terms of the Hills vs Terai. There is some degree of market segmentation, arising in large part from natural barriers to easy transportation between the Hills and Terai. Accordingly, price policies for the Hills and Terai can be formulated separately, with price differentials of up to Rs 1/kg for inputs or produce -- this differential is borne out by historical price data. It is assumed that foodgrain supply and demand are inelastic in the Hills and somewhat more elastic in the Terai; and the fertiliser production elasticities are greater in the Hills than in the Terai.

5.4 Production-consumption Interdependence

The above analysis assumes that intensity of input use (except for fertiliser) does not change as a result of the fertiliser price increase, which may hold in the short-run but is unlikely to do so in the long run. Also, the fertiliser price increase and change in output and price levels imply a change in real income, which will influence household consumption behaviour notably the leisure taken (assuming that hired labour is available to replace family labour.

Given the predominantly rural popultion, most producers are also consumers. Thus, in this unsegmented analysis, most of the consumers' losses of Rs 850 million are suffered by producers, who are gaining Rs 530 million. For quasi-subsistence farm-households the losses and gains are purely notional. The main impact would affect (a) fertiliser users and (b) significant market surplus producers and (c) urban consumers, who are all minorities in Nepal.

6 CONCLUSIONS

The fertiliser price policy setting in Nepal has been desribed in this paper and some implications of reducing the fertiliser subsidy have been considered. The preliminary analysis in this paper confirms substantial physical and economic responses to fertiliser application in the Hills of Nepal. Whilst the elimination of the fertiliser subsidy would apparently lead to a net social loss (borne by consumers), there are substantial treasury savings to be made.

Several issues related to fertiliser pricing were discussed. In particular, Nepal represents a classic "small country" case except for the strong influence of the large economy of neighbouring India. The long open border with India places severe practical limits on price policy choices.

The results of economic surplus analysis are sensitive to the assumptions about parameters, several of which are not known with any accuracy. In this paper a simple method has been used to estimate the relevant production elasticities of fertiliser, as a basis for determining the cereal grain supply shift.

Whilst producers qua market producers stand to gain from the elimination of the fertiliser subsidy, directly through the foodgrain price increase, food-deficit small farmers, landless-labourers and the urban populace would lose. Further analysis is needed to ascertain the real effects on each of these groups.

Notes

[1] In fact, many countries have become concerned about the loss of cropland to urbanisation and industrialisation. Typically, annual losses of cropland area during the 1960s and 1970s in Europe and North America are about 0.2-2.5 per cent per annum (Brown 1987). There is also widespread concern in some countries about depreciation of the stock of cropland, particularly through soil erosion.

[2] For example, Indonesian fertiliser use on food crops grew at 14 per cent per annum up to 1977 and 17 per cent per annum from 1977 to 1985 (Rosegrant et al., 1987) and Bangladesh fertiliser consumption also grew at about 17 per cent per annum up to the late 1970s.

[3] The analysis applied to a situation of sub-optimality in farmers' application of inputs, and thus the conclusion is not necessarily in conflict with the desirability of output subsidies in free market equilibrium settings. The policy in Nepal and many other countries in Asia of substantial fertiliser subsidy accords with this analysis for Laguna, Phillippines.

[4] District or regional data can also be used. Some estimates of the productivity in Nepal of fertiliser and other inputs to crop production at the regional and national level have been attempted (APROSC 1985). Although improved seeds and credit showed significant positive marginal productivities at the national level (and credit was significant and positive for the Hills and for the Terai separately), fertiliser inputs were not significant either nationally or for the Hills or Terai. A possible explanation is the very low use of fertiliser, or the highly concentrated use in the central development region, particularly Kathmandu valley.

[5] Approximate grain/nutrient ratios of 11 - 25 for rice, 12 - 48 for wheat and 11 - 59 for maize for either nitrogen or nitrogen and phosphorus.

[6] Rosegrant et al. (1987) report urea-paddy price ratios for Indonesia of 1.0 in the early 1970s decreasing to 0.5 in the early 1980s (nitrogen-rice price ratios are about 30 per cent higher); Tolley et al. (1982) imply a fertiliser-paddy price ratio for Bangladesh of about 0.8 in 1979 (based on procurement prices).

[7] There is ample evidence that small farmers adjust input combinations. In a similar situation in Ethiopia, small farmers favoured with additional access to cheap (subsidised) fertiliser reduced labour inputs for weeding (Dixon 1978).

[8] Note that the isoquants are then parallel to the axes, and intersecting at the expansion path, which passes through the origin only if there are constant returns and no other fixed (or variable) inputs - in which case average and marginal costs are identical.

[9] David (1978) reported a long-run fertiliser-rice price elasticity of -0.8 for Asian countries; and short-run elasticities of -0.4 to -0.7. Some other comparable estimates of elasticities can be found in Timmer (1974).

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ANNEX

Table 1: Fertiliser and Nutrient Prices

Year	Urea	Complesol	Nitrogen		Phosphorus	
			Price[a]	N/rice[b]	Price[c]	P/wheat[b]
	(Rs/kg)	(Rs/kg)	(Rs/kg)		(Rs/kg)	
1970/71	1.34	1.06	2.91	1.23	2.39	1.66
1975/76	2.44	2.27	5.30	1.55	6.65	2.65
1980/81	3.10	2.80	6.74	1.79	7.26	2.61
1985/86	3.50	3.25	7.61	1.41	8.64	2.22
1986/87	3.99	3.99	8.67	1.32	11.28	2.71

Notes: [a] effective N nutrient price calculated from urea price and P_2O_5 effective price calculated from the complesol price given the foregoing N price; [b] ratio of official nutrient price to average wholesale coarse rice (or wheat) price -- the corresponding urea/rice price ratios are approximately half these; and harvest price ratios will be about one-quarter greater. Prices drawn from DFAMS (1987).

Table 2: Models of Crop Response to Fertiliser

Hills

Paddy:

$$Y = \underset{(44.3)}{45.5} + \underset{(1.4)}{16.3\,N} - \underset{(.011)}{0.035\,N^2} + \underset{(2.1)}{15.4\,P} - \underset{(.026)}{0.097\,P^2} \quad \text{adj } R^2=0.39$$

Wheat:

$$Y = \underset{(63.4)}{0.0} + \underset{(1.8)}{18.8\,N} - \underset{(.016)}{0.049\,N^2} + \underset{(2.7)}{19.6\,P} - \underset{(.036)}{0.070\,P^2} \quad \text{adj } R^2=0.34$$

Inner Terai

Paddy:

$$Y = \underset{(121.7)}{-12.6} + \underset{(3.8)}{13.7\,N} - \underset{(.032)}{0.057\,N^2} + \underset{(5.7)}{11.3\,P} - \underset{(.072)}{0.034\,P^2} \quad \text{adj } R^2=0.39$$

Wheat:

$$Y = \underset{(132.1)}{-6.7} + \underset{(4.1)}{23.4\,N} - \underset{(.035)}{0.128\,N^2} + \underset{(6.1)}{21.7\,P} - \underset{(.078)}{0.189\,P^2} \quad \text{adj } R^2=0.41$$

Notes: Y is the increment in yield due to fertiliser, N is nitrogen application and P is phosphorus (P_2O_5) application (all in kg/ha). Potassium and N x P interaction terms were not significant.

Table 3: Production elasticities

	Nitrogen	Phosphorus
Hills		
Paddy	.14	.05
Wheat	.20	.08
Inner Terai		
Paddy	.08	.03
Wheat	.16	.07

Notes: Evaluated at the typical application rates of 35 kg N/ha and 12 kg P/ha for both paddy and wheat. Aggregate national cereals production elasticity estimated by weighting responses by share of fertiliser consumption, and reevaluating the elasticity.

Table 4: Fertiliser Price Ratios w.r.t. India

Year	Urea	Complesol
1970/71	1.10	0.83
1975/76	1.00	0.64
1980/81	0.94	0.99
1985/86	0.92	0.76
1986/87	1.06	0.95

Notes: Based on official AIC fertiliser prices and annual averages from the Fertiliser Association of India, cited by Wallace(1986).

Table 5: Base Data Assumptions (1984/85): National Level

	Cereals*	Fertiliser (nutrients)
base quantity (000 mt)	3,190	42.8
base price (Rs/kg)	4.27	7.90
price elasticity of demand	-0.40	-0.50
price elasticity of supply	0.10	--
production elasticity, fertiliser	0.13	--

Notes: * all major cereals included, weighted as rice 0.56, maize 0.24, wheat 0.16, millet 0.04, barley neg.; production from CBS Statistical Year Book of Nepal, drawn from DFAMS; prices weighted; elasticities for fertiliser derived from Wallace (1986), for supply from the acreage elasticity provided by Karki and Neupane (1984).

Figure 1 : Market adjustments