Chapter 1: Introduction

1.1 Introduction

Agriculture is the mainstay of Pakistan's developing economy. Contribution of agriculture in GDP is in excess of 23 percent and it accounts for about 32 percent of the total export earnings. Over 55 percent of the country's labor is actively involved in agricultural sector. Therefore, increasing growth rate in agricultural sector is taken as tantamount to country's economic development.

For accelerating growth in agriculture the government of Pakistan, since 1960's, has been following a multidimensional approach consisting of construction of vast irrigation network and mass extension services coupled with distribution of High Yielding Varieties seed and subsidisation of key agricultural inputs namely chemical fertilisers.

The first chemical fertiliser was introduced, in Pakistan, in 1952-53 with a 100 percent subsidy. Till 1986-87 there has been heavy subsidy on chemical fertilisers. In 1986-87 the government introduced a new policy for chemical fertilisers. The major element of the new policy includes gradual reduction of the subsidy from chemical fertilisers. The present study is an attempt to analyse the impacts of this gradual reduction of the subsidy on farmers' demand for chemical fertilisers.

1.2 Background to the study

Agriculture in Pakistan is characterised by small scale farming. In Pakistan 31.6 percent of the total farm units are under 2.5 hectares, 58.6 percent are between 2.5 to 12.5 hectares and only 9.8 percent farms are above 12.5 hectares. Land fragmentation is common. Sixty-five percent of the total farm area is operated by the owner, 19 percent by owner-cum-tenant and 16 percent is operated by tenants. Small size of holding, fragmentation and tenancy do not permit adoption of large scale mechanisation.

(Agricultural Statistics of Pakistan, 1995-96). Therefore, productivity is generally low in Pakistan's agriculture.

It is recognised that crop yields in Pakistan are generally one third of the potential yields. There is a wide gap of 50 to 80 percent in yields obtained by progressive farmers, who apply a complete package of crop production technologies, and the traditional farmers. (Agricultural Statistics of Pakistan, 1995-96)

Chemical fertilisers occupy a key position in Pakistan's unique agrarian set up. In 1953-54, sales of fertiliser was 72,000 tones. Since then the expansion in fertiliser use has been rapid. It took only seven years to double the 1953-54 sales, three more years to double them again and a further four years to triple these again. In 1968-69 the demand for fertiliser was twenty times that of 1953-54. Fertiliser subsidy and improved marketing practices seem to be the major contributing factors towards this increased use (Leonard, 1969). However, the fertiliser use in Pakistan is still about 83 kg/ha (NFDC, 1995-96).

Both the public and the private sectors participate in production and import of fertilisers in Pakistan. In 1986-87 the government of the Pakistan initiated a policy of deregulation and privatization. One of the main component of this policy includes a package of incentives for private sector to induce them to participate in import, production and distribution of fertilisers in the country. All the concessions which were being enjoyed by FID (Fertiliser Import Department) are now extended to the private sector. There has been an encouraging response from the private sector (NFDC, 1995-96).

1.3 The research problem

Pakistan is under tremendous pressure to increase both its food supplies and exportable cash crops. Increased production can be achieved either by horizontal or vertical expansion in agriculture. By horizontal expansion we mean that more area is brought under the plough. Limitation of availability of irrigation water makes this type of expansion virtually impossible. Alternatively, by vertical expansion Pakistan may increase its agricultural output by either ploughing the same land more intensively or by increasing productivity. Productivity increase may come either by increased capitalisation in the agrarian sector or by the use of high yielding varieties, better management and increased use of high quality inputs. Among quality inputs chemical fertilisers offer one of the cheapest and immediate mean of increasing productivity in agriculture.

In most LCD's government intervenes to influence both supply of and demand of fertilisers. On supply side the objective of the government is to make sure that adequate supplies of fertilisers are available at the farm gate at the right time. This involves increasing domestic production, liberalising imports and increasing investment in infrastructure. On the demand side farmers are encouraged to use recommended doses of fertilisers. This involves provision of credit and extension services to farmers.

Subsidisation of fertiliser influences both demand and supply. Subsidy may be defined as the cost of fertiliser minus the cost of fertiliser paid by the farmer. With subsidy on fertiliser the price of fertiliser is lower for the farmers and, thus, demand increases. Increased domestic demand stimulates domestic industry to produce more fertilisers. Thus, the domestic production of fertilisers is increased. Thus, subsidy has a double welfare effect on the economy. On the other hand, the government bears the difference between price charged by the fertiliser manufacturers/distributors and the price paid by the farmers. So a balance has to be maintained between government costs and welfare associated with fertiliser subsidisation.

The government of the Pakistan has been following the policy of fertiliser subsidisation quite rigorously. In 1971-72 fertiliser subsidy bill was Rs. 25 million. In early and mid 80's the fertiliser subsidy bill increased to around Rs. 2400 million (Economic Survey of Pakistan, 1996-97). The principal reasons for this rapid increase included:

- A rapid expansion in fertiliser use by the farmers;
- Repeated devaluation of Pak Rupee; and
- Increase in fertiliser prices in the international market.

In view of this, in 1986-87, the government decided to deregulate the fertiliser prices and gradually reduce subsidy on fertilisers. So subsidies on all nitrogenous fertilisers were reduced in May 1986, phosphate in August 1993 and potash in October 1995. At the same time gradual reduction of fertiliser subsidy continued and in 1995-96 the fertiliser subsidy bill of the government was reduced to Rs. 46 million only. (NFDC, 1995-96).

This reduction of subsidy resulted in rapid increase in fertiliser prices. In last eight years the fertiliser prices have more than doubled (Economic Survey of Pakistan, 1996-97). As economic theory suggests, the increased fertiliser prices will cut its use. Reduction of subsidy, thus, may run contrary to the national goals of gaining food self-sufficiency.

An empirical study is needed to fully assess the impact of this reduced fertiliser subsidy. In addition, an empirical study of fertiliser demand in Pakistan is important for at least two other reasons. First, the various factors responsible for the determination of demand can be identified. Secondly, a study of demand will enable some estimates of the price elasticity of demand. Knowledge of the price elasticity of demand is essential for the government to make informed policies.

In the late sixties and seventies there have been some studies on the fertiliser demand in Pakistan (Leonard, 1969; Ayub, 1975; Chaudhry and Javed, 1976; Mustafa, 1976; Salam, 1977 and Tariq, 1992). But in recent past, when the scenario was changed due to the reduction of subsidy, no such study is taken up. Thus the present study is justified.

1.4 The objectives of the study

In view of the above discussion, the present study aims to:

1. Identify the factors which affect the demand for fertilisers in Pakistan;

2. Determine implications of reduction of subsidy on fertiliser consumption; and

3. Make policy recommendations on the basis of the research findings.

1.5 The hypothesis to be tested

In accordance with the above stated objectives of the study, the following null hypothesis is tested in the present study.

H_0 : Fertiliser subsidy has no significant impact on demand for fertilisers.

The alternative hypothesis is:

H_A : Fertiliser subsidy has significant impact on demand for fertilisers

1.6 Scope and outline of the study

The study is limited to analyse the impact of fertiliser subsidy on its use from 1967-68 to 1995-96. This does not provide a full view of the impact of the policy on food production in Pakistan. It, however, provides enough basis for a decision on whether the subsidy is an effective strategy for the realisation of the food self sufficiency and whether the effectiveness of the resources put into it can be improved.

The study is arranged in six chapters, including this one. Chapter two contains a description of the market structure of the fertiliser industry in Pakistan along with production, distribution and supply sources. Chapter three contains a discussion of the theory of factor demand and a review of previous empirical studies. An econometric model of demand for fertiliser is developed in Chapter four. Detailed discussion of the regression results and elasticity estimates are presented in Chapter five. Chapter six concludes the study with policy implications of the findings. A review of the limitations of the study and suggestions for areas for future research are also discussed in chapter six.

Chapter 2: Fertiliser consumption and supply in Pakistan

2.1 Introduction

This chapter opens with a short general description of the agriculture and the land utilisation in Pakistan. Section 2.5 is devoted to a detailed account of the fertiliser consumption in Pakistan. This section covers consumption aspects like nutrient wise consumption, crop usage of fertiliser nutrients and seasonal variation in consumption. Section 2.4 provides information on different sources of supply i.e. local production and imports. Distribution channels of fertiliser along with various distributing agencies is discussed in Section 2.5. Fertiliser policy with respect to subsidy and prices is taken up in Section 2.6. The chapter ends with a summary.

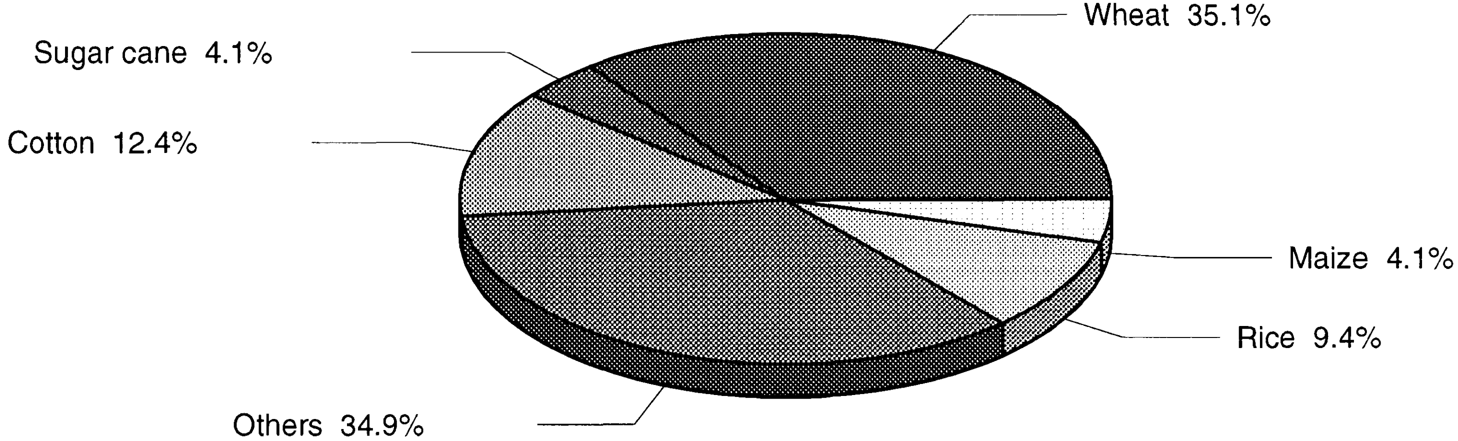
2.2 Agriculture in Pakistan

Pakistan is a sub-tropical semi-arid country characterised by two distinct seasons (summer and winter) and monsoon period which, in most parts of the country, brings heavy rains from July through September. Summers are hot all over the country for about five months (May - September). Winters are cool, especially in the north and west of the country and last for four to five months (October -February).

Rabi (October - March) and *Kharif* (April - September) are two major crop growing seasons of Pakistan. Wheat, rice, cotton, sugarcane and maize are five principal crops (in any typical year the share of these major crops in total cropped area is in excess of 65 percent). Wheat is grown in *Rabi* season. Rice and cotton are grown in *Kharif* season. Maize is grown in both *Rabi* and *Kharif* whereas sugarcane is a year long crop. Bajra, jawar, barley, gram, tobacco, rapeseed and mustard are among other important crops. Figure 2.1 shows the area under major crops in any typical year in Pakistan. In a 1995-

96 the share of food crops in total cropped area was 12,415 hectares followed by the cash

Figure 2.1: Area under major crops



Source: Pakistan fertiliser related statistics (1993) crops 4,014 hectares, pulses 1,599 hectares and edible oilseeds 600 hectares. (Agriculture Statistics of Pakistan, 1995-96).

2.3 Fertiliser consumption

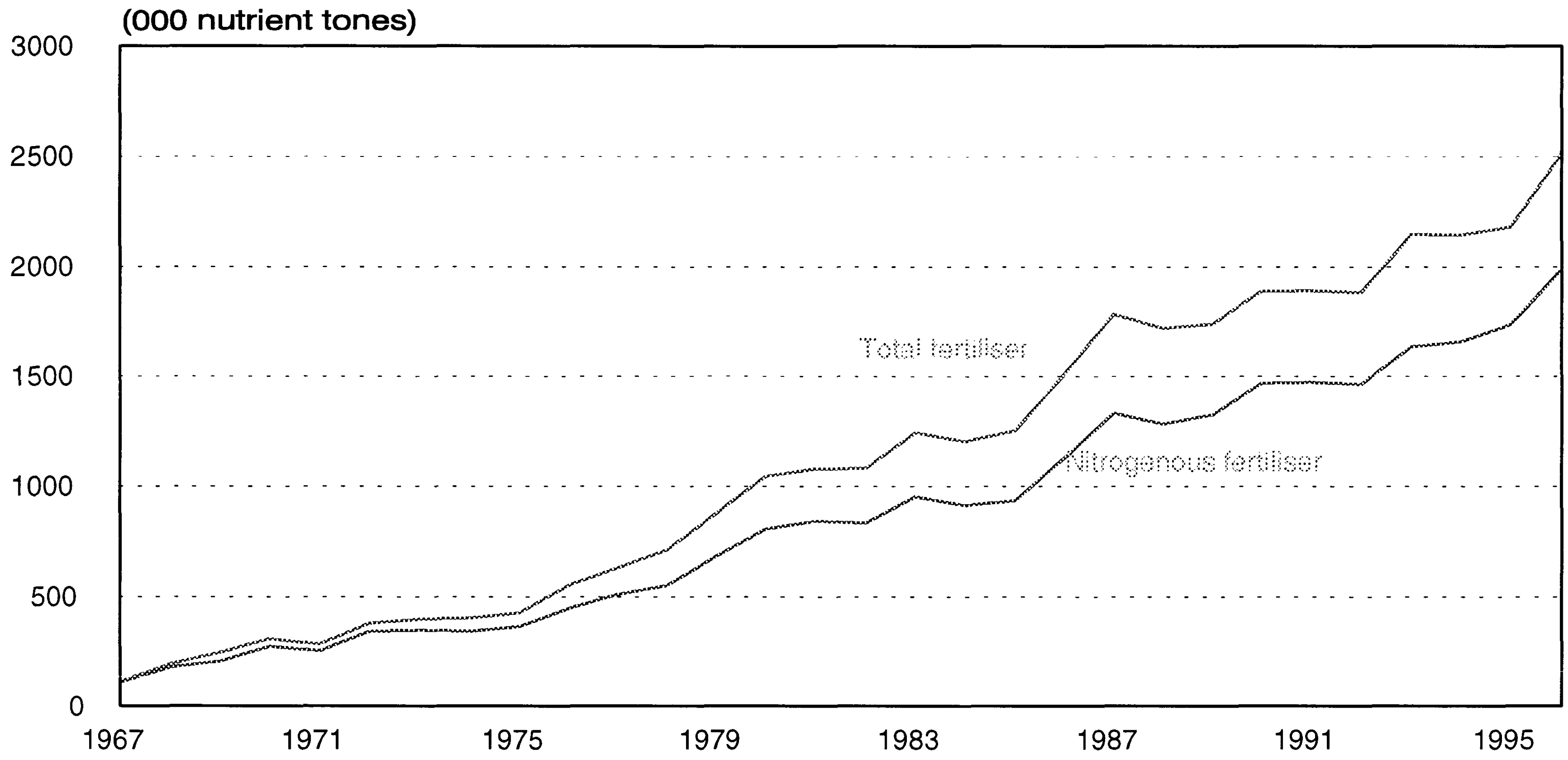
First chemical fertiliser was introduced in Pakistan in 1952-53. Since then the consumption has increased considerably. Figure 2.2 shows the total fertiliser use in Pakistan during the study period (1967-68 - 1995-1996). Figure 2.2 also shows the use of nitrogenous fertilisers. Fertiliser use prior to 1956-57 was nine thousand nutrient tones of nitrogen and did not include phosphate or potash, because these nutrients were not considered deficient in the soil. The use of phosphate fertiliser started in 1959-60 when simple trials on farmers' fields revealed widespread deficiency of phosphorus. This indicates the impact research findings had on fertiliser development in Pakistan. The fertiliser demand grew only slowly before the mid-sixties. However, the introduction of semi-dwarf wheat varieties during mid sixties helped fertiliser to take off from 87 thousand nutrient tones in 1964-65 to 283 thousand nutrient tones in 1970-71 (from 5 kg/ha to 17 kg/ha). The use of potash was also introduced in the late sixties. The pace of development of fertiliser use continued and in the next ten years the fertiliser use increased to more than one million tones of nutrients (55 kg/ha). The annual growth rate from 1952-53 to 1960-61 was 53.9 percent while it was 24.6 percent during 1960-61 to 1970-71 and 14.2 percent during the decade ending 1980-81. (NFDC, 1987).

The tremendous increase in fertiliser use during this period may be attributed to a number of factors including policy measures adopted by the government such as:

- fertiliser extension and promotion;
- introduction of high-yielding varieties of wheat and rice;
- fertiliser subsidy;
- expansion of irrigation facilities;
- remunerative procurement/support price of crops;

Figure 2.2: Nitrogen and total fertiliser use in Pakistan

(1967-1996)



- availability of fertiliser supply and its easy accessibility;
- credit availability; and
- increase in cropped area.

The fertiliser use has been increasing steadily during the late eighties and early nineties. During early nineties Cotton Leave Curl Virus destroyed the cotton crop of Pakistan. This resulted in a little bit slower increase in fertiliser use. In 1994-95 a hope was developed that new cotton varieties can face Cotton Leave Curl Virus more rigorously. With this hope, more land was put under cotton and as a result fertiliser consumption took a big jump in last year of study (1995-96). It may be seen in Figure 2.2 that the gap between the total fertiliser curve and nitrogenous fertiliser curve started widening from 1983. It means that the farmers are now conscious about phosphate and potassium as well.

The fertiliser off-take data when converted into nutrients applied per cropped area provide a more meaningful base for international comparisons. The data for selected years are given in Table 2.1. Table 2.1 also gives fertiliser use level for some selected countries. From a comparison of the figures in Table 2.1 it is evident that the fertiliser use level in Pakistan is almost close to world average. However, it is much lower than the recommended level.

2.3.1 Nutrient wise use

Nitrogen is the major and most popular nutrient being used in Pakistan. During last ten years (1985-1995) nitrogen accounted for 76 percent of the total nutrient consumption. Figure 2.2 shows trend in the use of nitrogen fertiliser in Pakistan. The first nitrogenous fertiliser was introduced in 1952-53. At that time its use was only one thousand tones. Its use has been increasing steadily till mid sixties. However, during mid sixties, with the introduction of short stature Mexican wheat varieties, the use of nitrogenous fertiliser increased rather rapidly. Since then its use has been increasing. One of the principal reason for rapid expansion in its use was heavy subsidy on it. However, during 1981-84 the rate of growth in the use of nitrogenous fertiliser was close to zero. The reasons for this stagnation are not fully known. It is interesting to note that, in the case

Table 2.1: Fertiliser consumption in relation to cultivated area in selected countries (Kg/hectare)

Year	Netherlands	Germany	Japan	France	Egypt	Italy	USA	India	USSR	Pakistan
1980-81	789	471	372	301	232	170	112	31	81	53
1981-82	767	418	387	298	248	163	102	39	83	53
1982-83	738	435	412	299	335	161	87	35	87	61
1983-84	789	431	437	312	361	169	105	39	99	59
1984-85	841	445	452	326	387	178	126	N.A	N.A	63
1985-86	770	428	427	309	319	169	92	57	114	86
1986-87	688	421	433	299	351	190	93	54	182	83
1987-88	702	433	491	328	388	254	95	53	120	83
1988-89	685	468	468	335	448	231	94	67	119	84
1989-90	663	467	467	341	452	201	100	70	109	91
1990-91	610	394	451	316	401	200	96	72	111	92
1991-92	599	N.A	431	309	405	220	71	77	85	91
1992-93	599	239	395	253	339	156	101	72	42	101

Source:

1. Fertilizer Manual, United Nation, New York
2. FAO Fertilizer Year Book
3. FAO Annual Fertilizer Review 1971 to 1978.

of nitrogen, the actual use is almost 76 percent of the agronomic optimum. This is a very healthy situation. (NFDC, 1995-96).

Figure 2.3 shows trend in the use of P_2O_5 (Phosphate fertiliser). Phosphate fertiliser was introduced in Pakistan in 1959-60 when 0.10 thousand tones of phosphate was imported and distributed to the farmers. There has not been much increase in the use of phosphate fertiliser till 1966-67. Green revolution came in Pakistan somewhere in mid sixties. With the green revolution the use of phosphate fertiliser took a major jump in 1967-68. Another major jump in the use of phosphate fertiliser came in 1975-76. In the last ten years the share of phosphate in total fertiliser nutrient consumption has been around 22 per cent. However, in the case of phosphate fertiliser, the actual use is substantially below the agronomic potential i.e. 40 percent in case of phosphate. The low level of phosphate use is a major limiting factor on the productivity of various crops (NFDC, 1995-96).

Trend in the use of K_2O (Potash fertiliser) is presented in Figure 2.4. K_2O is the least common fertiliser nutrient in Pakistan. Its use was introduced in 1966-67 (almost along with green revolution). In 1966-67 its use was only 0.12 thousand tones. Its use could not gain any significant momentum principally because soils in Pakistan are not deficient in potash. Furthermore, the farmers could not be convinced of its use as its use does not bring any apparent improvement in vegetative growth of plants and crops. In 1981-82 the use of potash fertiliser took a major shift when its use was more than doubled. However, the reasons for this doubling in one year are not known. In the last ten years the share of potash fertiliser in total fertiliser nutrient consumption stood at about two percent. The use of potash fertiliser has been much lower than the agronomic optimum i.e. only nine percent. (NFDC, 1995-96).

2.3.2 Seasonal variations in fertiliser use

Figure 2.5 shows seasonal variations in the use of fertilisers. Typically more fertilisers are used in *Rabi* (about 56 percent) and less are used in *Kharif* (about 44 percent). This seasonal pattern of fertiliser use may be further split into individual nutrients, especially nitrogen and phosphate. The peak demand for nitrogen is during June to August in

Figure 2.3: Phosphatic fertiliser use in Pakistan

(1967 - 1996)

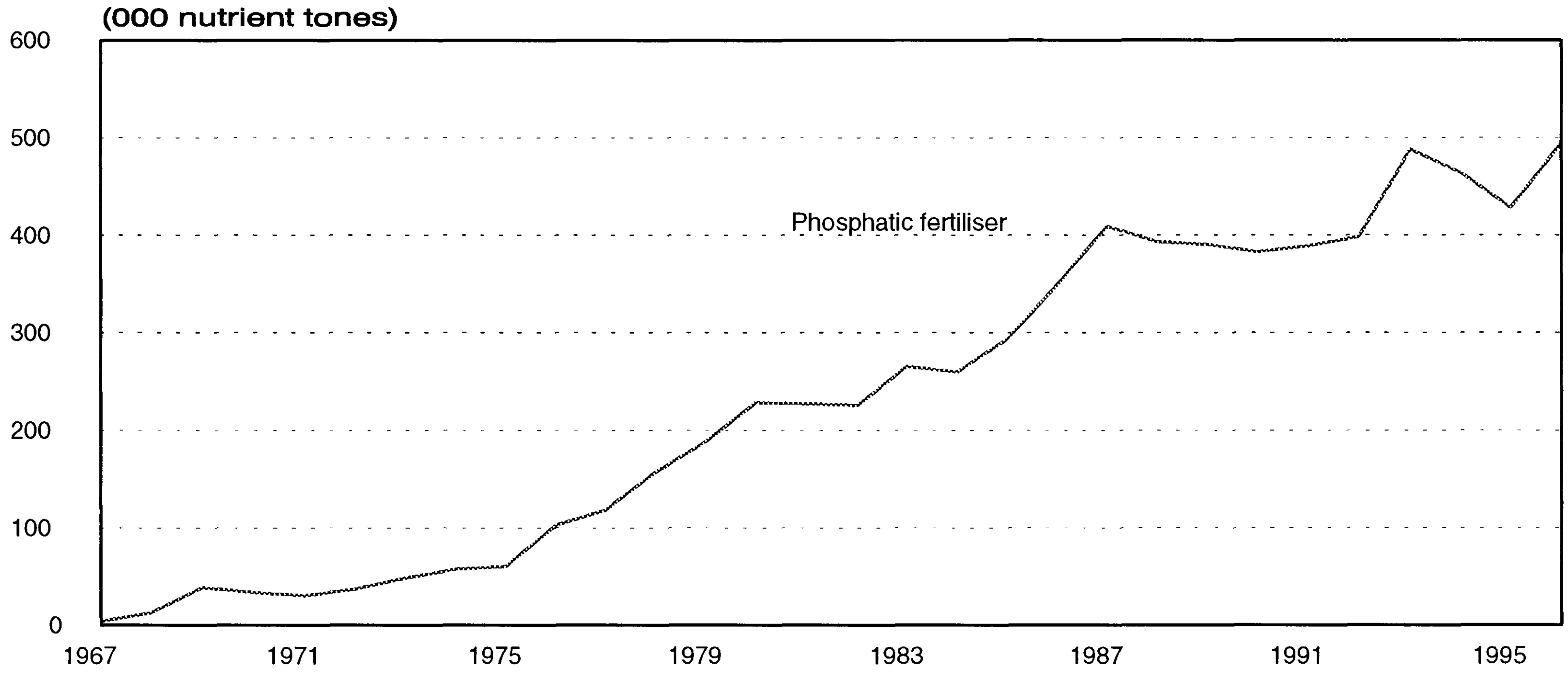


Figure 2.4: Potash fertiliser use in Pakistan

(1967 - 1996)

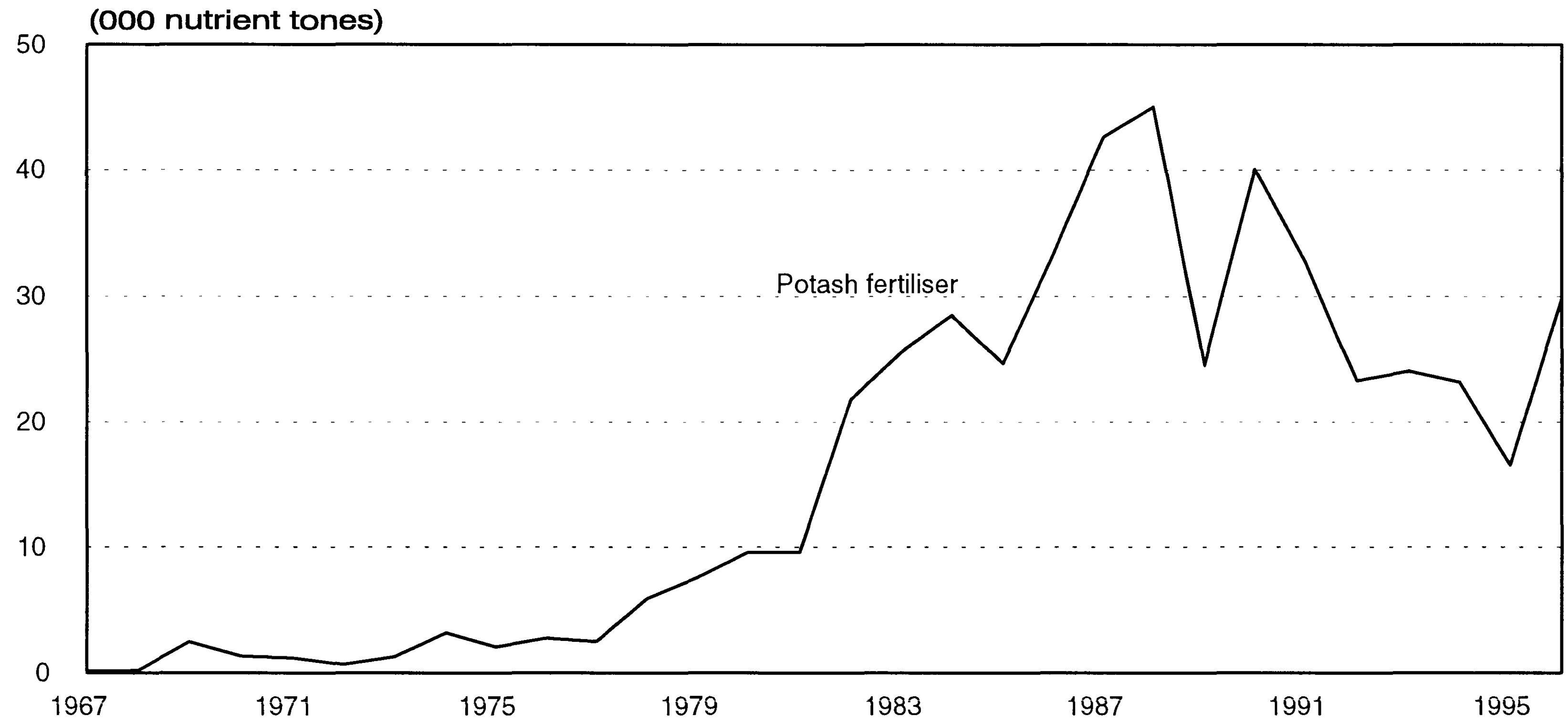
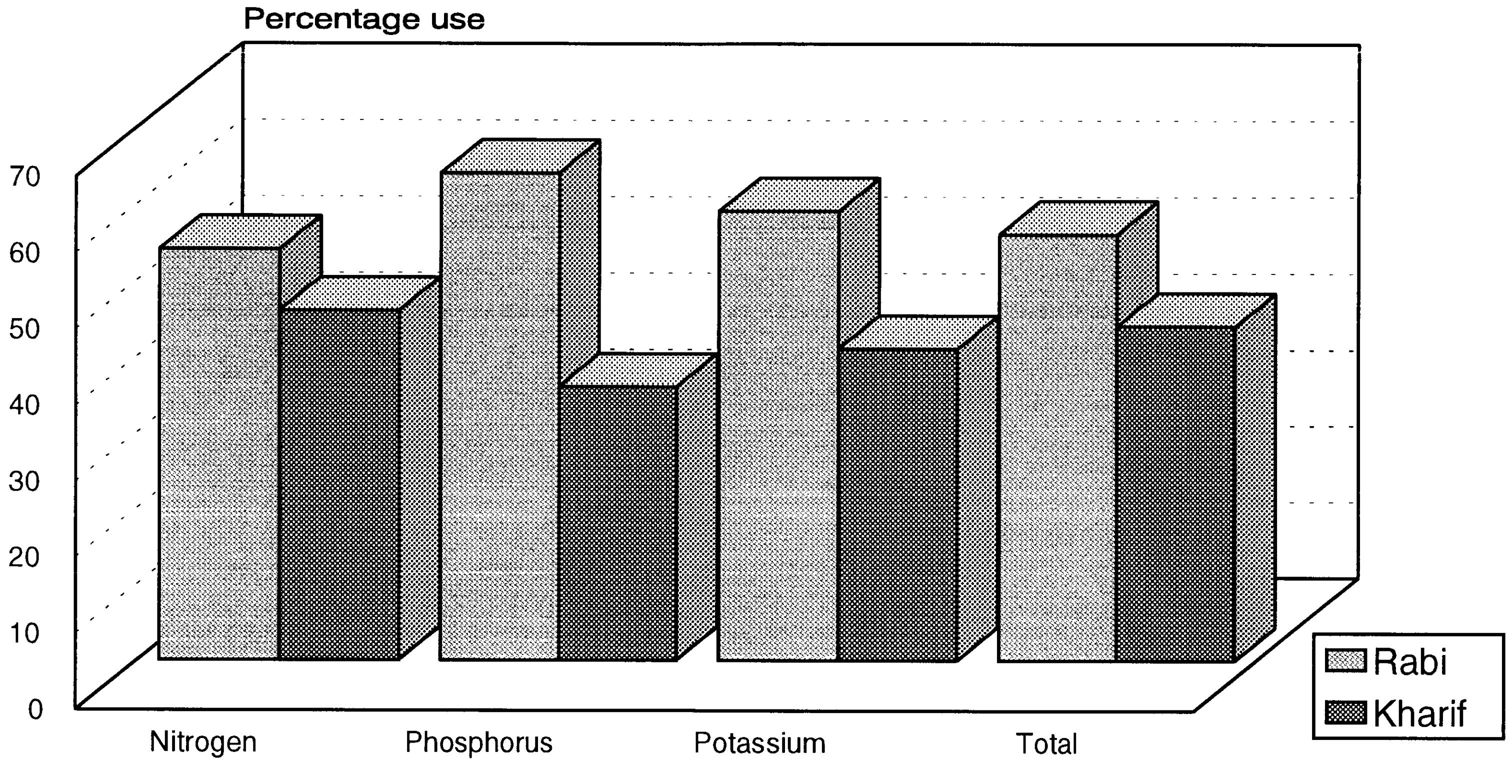


Figure 2.5: Nutrient wise seasonal variations in fertiliser use in Pakistan



Kharif (resulting in 46 percent of the annual consumption) and during November to January in *Rabi* season (about 54 percent of the total annual consumption). The demand for phosphate is 36 percent during *Kharif* and 64 percent during *Rabi* season with October to December being the peak months. About 41 percent of the total potassium application occurs during *Kharif* season and *Rabi* season accounts for 59 percent of the total potassium application. (NFDC, 1994-95).

2.3.3 Crop usage of fertiliser

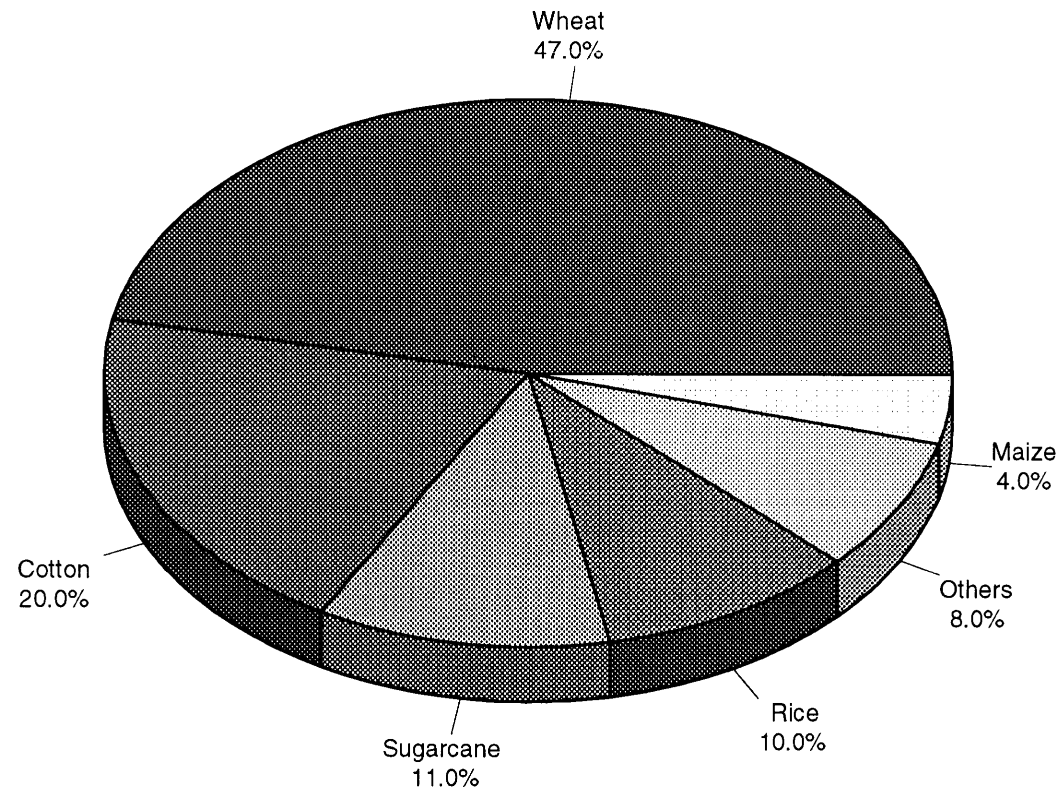
Five crops i.e. wheat, maize, rice, cotton and sugarcane account for about 90 percent of the total fertiliser use. It is estimated that in irrigated areas about 85 percent farmers use nitrogen and only about 50 percent use phosphate. In rain-fed areas, however, the rate of adoption of nitrogen is almost half than that of the irrigated areas and the rate of phosphate adoption is even less than half. (NFDC, 1992-93).

The crop wise usage of fertiliser is depicted in Figure 2.6. Wheat accounts for 47 percent of the total fertiliser consumption followed by cotton (20 percent), sugarcane (11 percent), rice (10 percent) and maize (4 percent). All other crops account for 8 percent of the total fertiliser consumption in any typical year. Application of nitrogen gives a boost to the vegetative growth of crops and gives a healthy lush green look to the plants. Phosphorus is mainly associated with the grain yield and disease resistance. Nitrogen and phosphorus are applied on all the major crops. Potassium fertiliser increases the sugar contents of plants and is, therefore, mainly used for sugarcane, sugar-beet and potato crops.

2.4 Fertiliser supply in Pakistan

The fertiliser requirements are met from domestic production and imports. The quantities from each source have varied over the years.

Figure 2.6: Crop wise fertiliser use in Pakistan



2.4.1 Local production

Fertiliser production in Pakistan dates back to the late 50's. Since then major expansion in production capacity (mainly as nitrogen) has taken place. Various fertiliser plants and their production capacity is given in Table 2.2 and the locations are shown in Figure 2.7. Only nitrogen and phosphate are produced locally and all potash is currently imported.

Domestic fertiliser industry in urea production has shown an impressive growth and present production capacity is 3,246 thousand tones per annum. This increase in urea production is a result of capacity additions, solely by the private sector. The overall fertiliser production during 1995-96 was 4,165 thousand product tones or 1,789 thousand nutrient tones, which represented an increase of 8.9 percent in product or 9.4 percent in nutrient tones over 1994-95 production figures. The production in nutrients was 1,693 thousand tones of nitrogen (94.6 percent share) and 96 thousand tones of phosphate (5.4 percent share) (NFDC, 1995-96).

It may be said that five products namely urea, CAN, AS, NP (23:23) and SSP (18 percent of P_2O_5) are manufactured within the country. The SSP plants have been closed down recently (October 1996) and SSP is no more being produced. The share of urea in total production decreased slightly to 78.2 percent (78.4 percent during 1994-95) in percentage terms but in fact was higher by 246 thousand tones in product tones. The share captured by CAN was 9.2 percent, nitrophosphate (8.1 percent), SSP (2.5 percent) and AS (2.0 percent). (NFDC, 1995-96).

2.4.2 Imported supplies

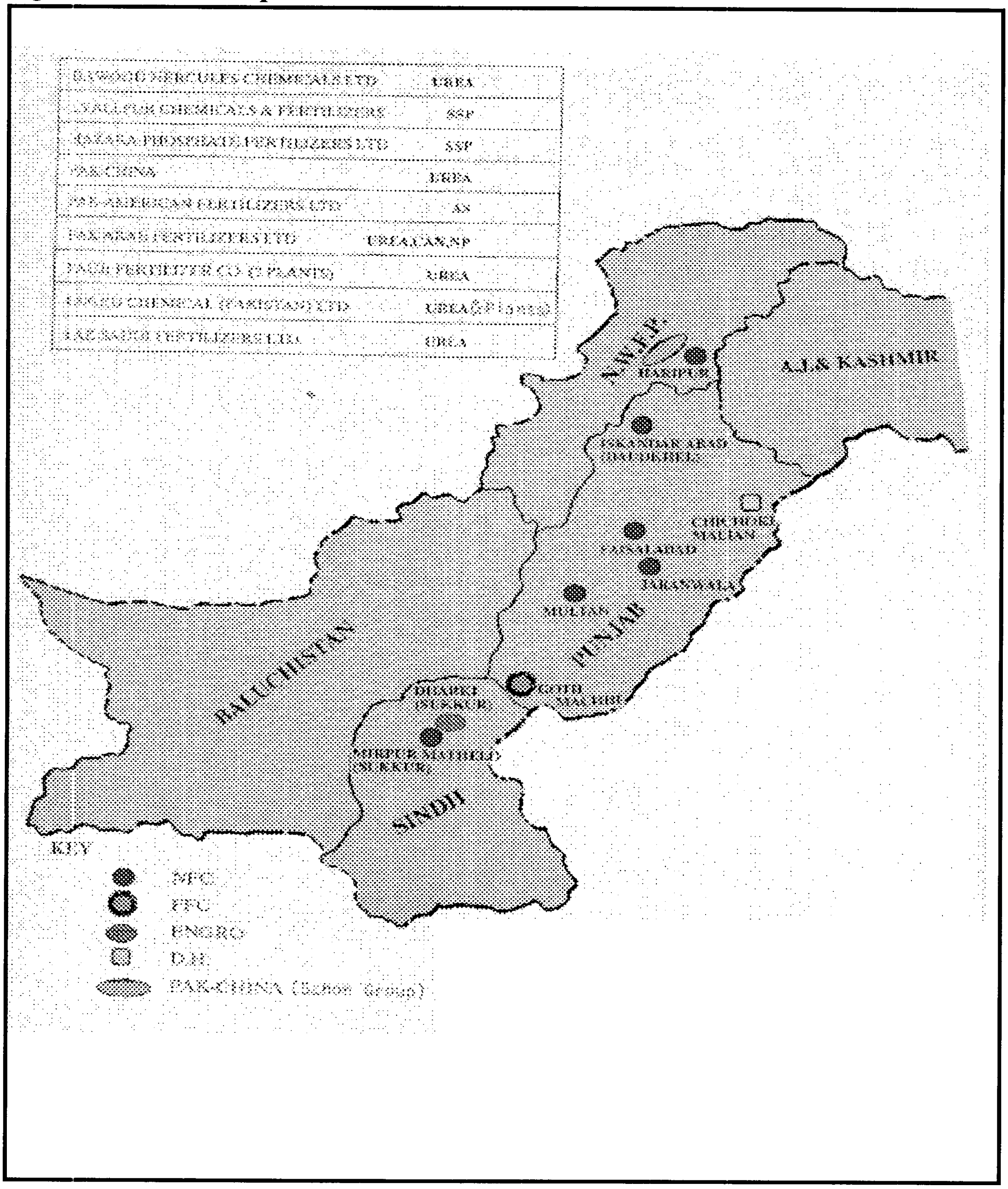
Both the private sector and the public sector participate in import of fertiliser in Pakistan. Data for import of important fertilisers for last ten years are presented in Table 2.3. From the table it is evident that in early eighties the local production increased rapidly and, as a result, imports of fertilisers were reduced. However, during 1989-93 there had been an increase in the imports of fertilisers. However, since 1993-94 the imports are decreasing gradually.

Table 2.2: Fertiliser plants and their installed capacity

Plant	N	P_2O_5	Total
NFC: LC&FL	0	5	5
NFC: Pak-American	0	19	19
NFC: Pak-Arab	117	0	117
NFC: Pak-Arab	42	0	42
NFC: LC&FL	0	15	15
Engro Chemical Pak. Ltd. Plant 1	152	0	152
Engro Chemical Pak. Ltd. Plant 2	150	0	150
Daweed Hercules	205	0	205
NFC: Pak-Arab	70	70	140
NFC: Pak-Saudi	256	0	256
Pakistan Steel Mills	4	0	4
Faui Fertiliser Company FFC. Plant 1	320	0	320
Fauji Fertiliser Company FFC. Plant 2	292	0	292
Schone: Pak-China	44	0	44
NFC: Hazara Fertiliser Co.	0	14	14

Source: Pakistan fertiliser related statistics, NFDC (1993).

Figure 2.7: Fertiliser plants and their location in Pakistan



Source: Pakistan fertiliser related statistics (1993)

Table 2.3: Local production and import of fertilizers (1980-81 to 1995-96)

Year	Local Production	Import
1980-81	640	574.4
1981-82	753	202.0
1982-83	1072	400.1
1983-84	1107	286.8
1984-85	1119	341.9
1985-86	1129	331.0
1986-87	1212	522.4
1987-88	1193	521.6
1988-89	1212	461.6
1989-90	1262	637.9
1990-91	1226	685.0
1991-92	1150	632.0
1992-93	1332	759.1
1993-94	1659	903.0
1994-95	1637	261.0
1995-96	1792	581.0

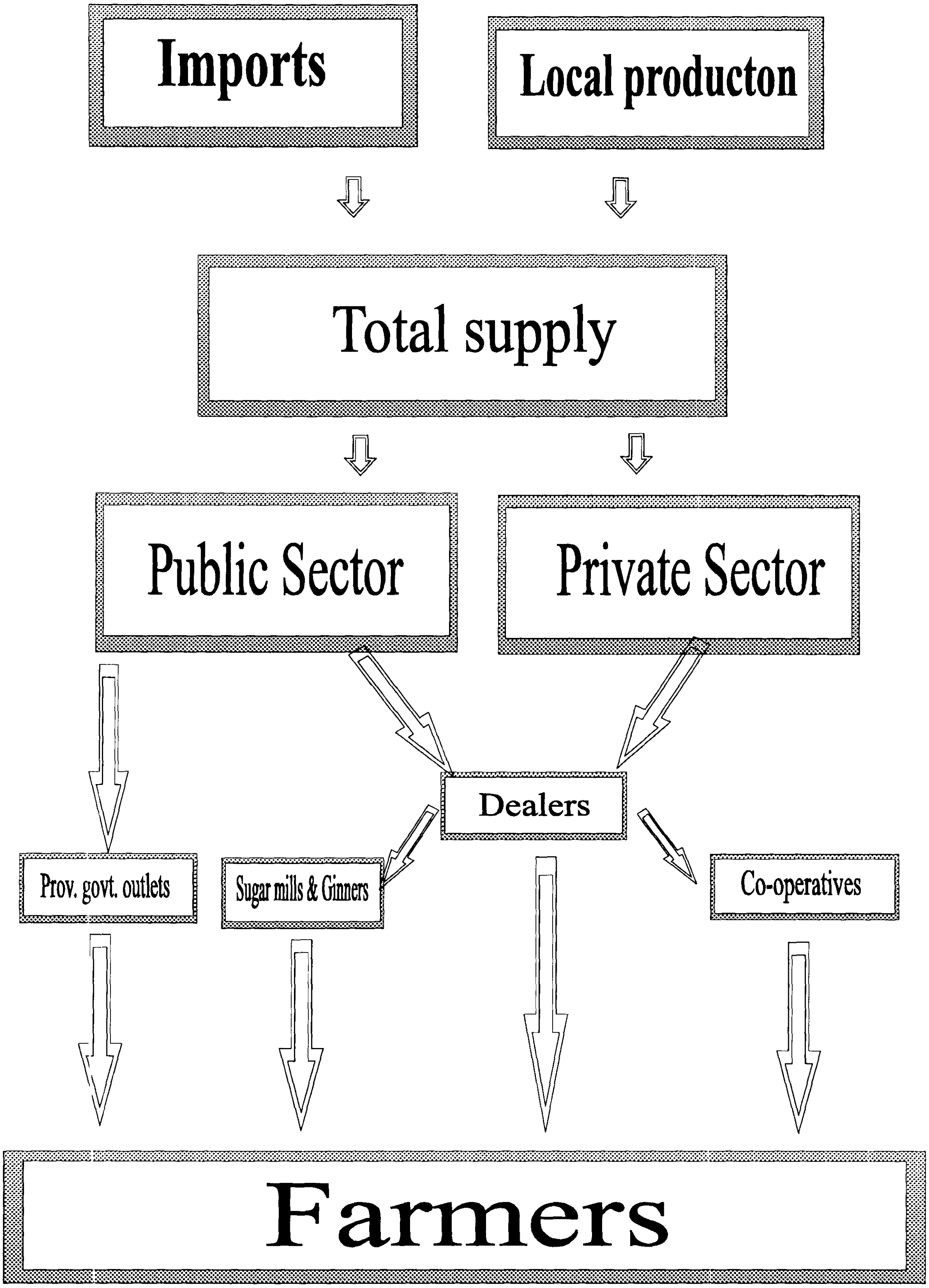
Source:
1. National Fertilizer Corporation
2. Fertilizer Import Department, Ministry of Food and Agriculture

Till 1986-87 there was heavy involvement of Government in fertiliser imports, marketing and regulating prices of fertiliser. A process of deregulation was initiated in 1986-87. Along with this process of deregulation price controls and subsidy were reduced on straight nitrogenous fertiliser in May, 1986. The import of phosphate and potassium was deregulated in August 1993 and October 1995, respectively. Now there are no restrictions on import of fertilisers. Most of the facilities, concessions and privileges allowed to Fertiliser Import Department have been extended to the private sector. The private sector has already entered in the importation business. Now private sector market and distribute the products through their marketing network, but, still bulk of the imports are made by the public sector. In 1995-96 the public sector imported 74.4 percent of the total fertilisers whereas private sector imported 25.6 percent of the total fertiliser imports. Major reasons for the reluctance on the part of the private sector include rapidly deteriorating exchange rate and increase in the price of imported fertiliser.

2.5 Fertiliser distribution

The flow of fertilisers from source of supply to the farm is out lined in Figure 2.8. The manufacturing and marketing organisations supply fertilisers, derived from the local plants or imports, directly to the fertiliser dealers (90 percent) who operate retail outlets or sell direct to customers like sugar mills, cotton ginners, rice mills, large farms and cooperative etc. (about-10 percent). The various manufacturing/marketing organizations in operation are presented in Table 2.4. There are fifteen marketing agencies in operation in the country. Out of them eleven are in the private sector and only four in the public sector. Public sector distributing agencies are managed by the provincial governments and they operate within their respective province. The share of the public sector agencies in total market is very low. It can be, therefore, said safely that the distribution of fertilisers in Pakistan is mainly in the hands of private sector. In private sector there are four agencies which deal in both manufacturing and marketing. In public sector there are only two such agencies.

Figure 2.8: Fertiliser distribution channels in Pakistan



Source: Fertiliser related statistics of Pakistan (1993)

Table 2.4: Fertilizer manufacturing/marketing agencies

Private Sector	Public Sector
Manufacturing/Marketing	**Manufacturing/Marketing**
Fauji Fertilizer Company Limited	National Fertilizer Corporation
Engro Chemicals Pak. Ltd	National Fertilizer Marketing Limited
Dawood Hercules/Dawood Corporation	
Pak.China (Schon)	
Marketing Only	**Marketing Only**
Jaffer Brothers (JBL also imports)	Punjab Agricultural Development and Supplies Organisation (PAD&SC)
Kissan Board	
MATAG	Sindh agricultural Supplies Organisation (SASO)
Agrolink	
Anjuman-e-Kashtkaran	Agricultural Development Authority (ADA) NWFP
B.R.R.	
Haroon and Hussain	Department of Agriculture, Balochistan
Land Feeds	
Al Farid	
Bulk Shipping	
National Farm Guides	

Source: Pakistan fertiliser related statistics, NDFC 1992.

Market share of different distributing agencies is presented in Figure 2.9. From the Figure 2.9 it is evident that FFC has the biggest share in marketing (32%) followed by NFML (31%) and Engro Chemical Pak. Limited (17%).

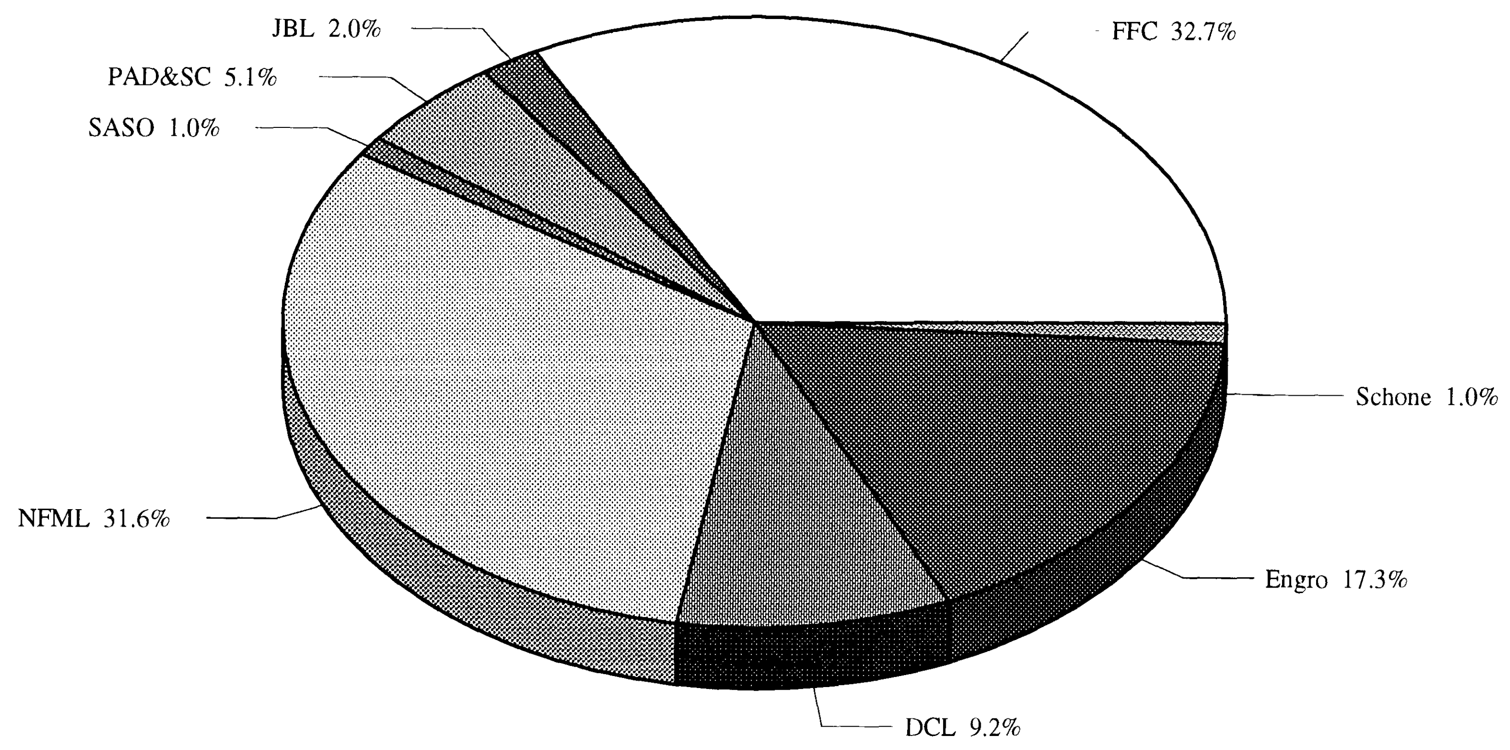
The fertiliser dealer is the backbone of the fertiliser distribution system in Pakistan. Fertilisers are sold through the dealers of private agencies. Fertilisers are also being sold through the sale points of the provincial public sector agencies. The sale points of the provincial agencies are manned by the employees of the respective governments. These outlets are spread throughout the respective province particularly in the remote areas.

There are 6,169 dealers appointed by the private sector while public sector has 3,077 dealers. All the provincial agencies have 600 sale points spread throughout the country. However, all the outlets are not active. (NFDC, 1995-96).

The fertiliser dealer - the last link in the chain of fertiliser distribution - have the following typical characteristics in line with the socio-economic structure of the country:

- Almost one hundred percent of the dealers run their business as a private enterprise.
- About 50 percent of dealers exclusively deal in fertiliser and are attached to a single company while the rest are multiple both in dealership as well as in the business mix.
- The average storage capacity of a dealer is about 1000 cubic feet or 115 tones.
- More than 50 percent dealers have hired storage, while the rest have own storage. About three percent have company provided stores.
- Majority of dealers operate on cash terms both with the companies as well as with farmers.
- Lack of funds/credit is a major constraint to expanding their fertiliser business.
- A fertiliser dealer is not as yet important regarding technology transfer to the farmers, a source that needs to be tapped seriously in the context of the current privatisation of fertiliser marketing in Pakistan.
- Dealer network of different marketing companies in Pakistan is as follows:

Figure 2.9: Market share of various fertiliser distributing agencies In Pakistan



Agency	No. of Dealers
National Fertiliser Marketing Limited	3089
Fauji Fertiliser Company	2179
Dawood Corporation Limited	1899
Engro Chemicals Pak. Limited	491
MATAG Fertiliser (Pvt) Limited	223
Total	7881

Source: Pakistan Fertiliser Related Statistics, 1993

2.6 Fertiliser subsidy and prices

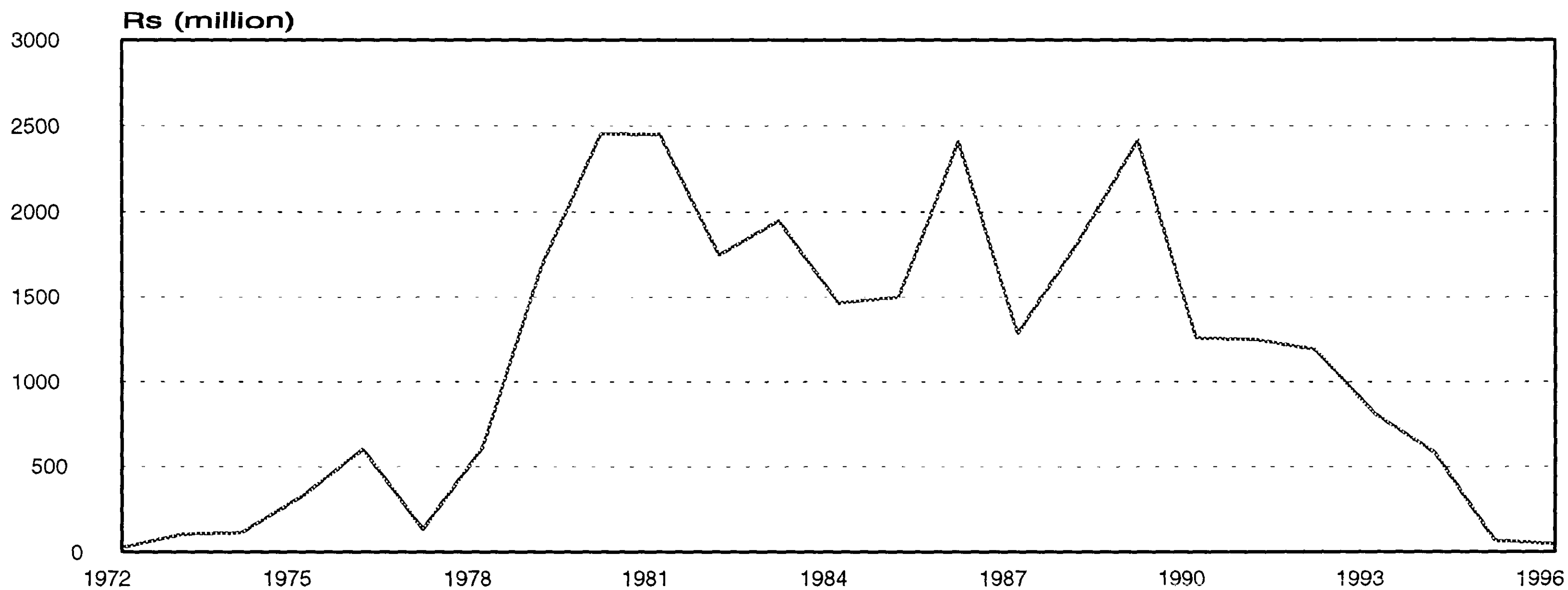
In 1952-53 there was 100 percent subsidy on fertilisers. Since then the subsidy bill has been rising. Over time trend in the total fertiliser subsidy paid by the government is depicted in Figure 2.10. In 1971-72 the subsidy bill was only Rs. 25 million which was increased to Rs. 2400 million in just one decade i.e. in 1981-82. From 1986-87 the subsidy bill started declining and in 1995-96 it was reduced to Rs 46 million.

Government fixes different subsidy rates for locally produced and imported fertilisers. In general there has been higher subsidy rate for imported fertilisers. Typically there has been over 90 percent subsidy on imported fertilisers. In 1995-96 subsidies from local fertilisers were removed completely. However, there is still some subsidy on imported fertilisers namely DAP and potassium. Subsidy is paid to the fertiliser manufacturer or importer.

Fertiliser prices are determined by the operation of the forces of demand and supply. Till 1986-87, after the forces of demand and supply fixed the price, the state used to fix one price at which the fertiliser manufacturers/importers were asked to sell the fertilisers to the farmers. The state paid the difference between the price set by the state and the price

Figure 2.10: Fertiliser subsidy in Pakistan

(1972 - 1996)



determined by the market forces. In 1986-87 the deregulation was started and today the prices are determined solely by the operation of market forces. Over time trend in prices of various fertiliser nutrients is presented in Figure 2.11. From Figure 2.11 it is evident that since 1986-87, when reduction of fertiliser subsidy was started, the prices have more than doubled.

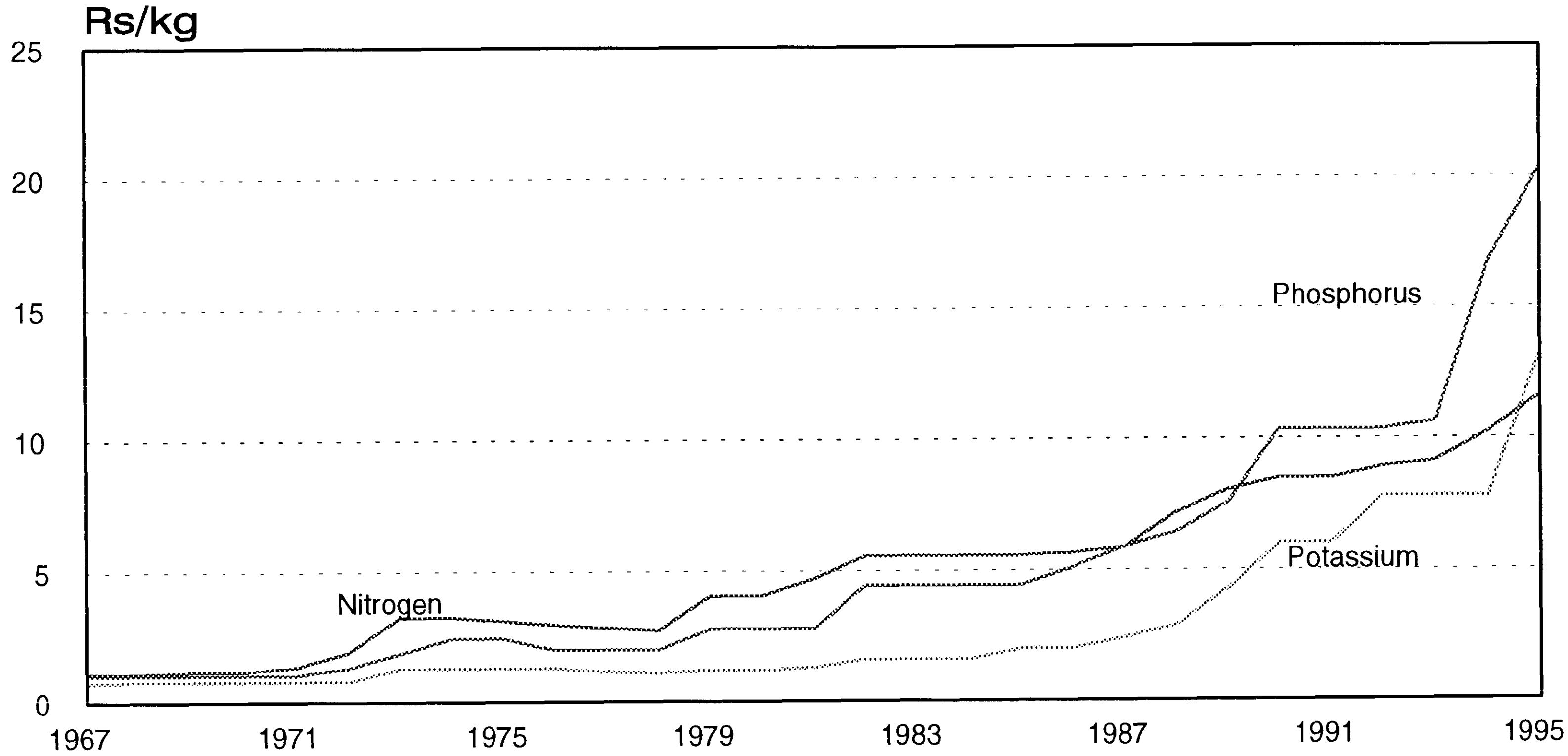
2.7 Summary

In this chapter an outline of the consumption, production, supply and distribution of fertiliser in Pakistan is presented. In Pakistan, the first chemical fertiliser was introduced in 1952-53. At that time there was 100 percent subsidy on fertiliser. Fertiliser use has been increasing rapidly since its introduction. Today the use of fertilisers stand at 2523 thousand nutrients tones. However, still the fertiliser use on per cropped area basis is much lower than the recommended level. About 46 percent of the total fertiliser is used in *Kharif* season (April-September) and 56 percent is used in *Rabi* season (October-March). Wheat, rice, cotton, sugarcane and maize account for more than 90% of the total fertiliser consumption. Nitrogen accounts for about 76 percent of the total fertiliser nutrient use followed by P_2O_5 (22%) and K_2O (2%).

The first chemical fertiliser was manufactured in Pakistan in 1955-56. Since then there has been rapid expansion in the production capacity. Only nitrogen and P_2O_5 are produced locally, all the K_2O is imported. Till 1986-87 FID (Fertiliser Import Department) used to import fertiliser for meeting the domestic needs. In 1986-87, the fertiliser market was deregulated. Now private agencies are also participating in importing of fertiliser. Both the public and the private sectors participate in the distribution of fertiliser. The producer or importer sells the fertiliser to the distributing agencies who then sell it to the dealer and finally the dealer sells to the farmers. The Dealer also sells to industrial buyers like sugar mills.

Figure 2.11: Fertiliser prices in Pakistan

(1967 - 1996)



Chapter 3: Theoretical background and review of previous studies

3.1 Introduction

This chapter provides theoretical background on the derivation of input demand functions and impact of fertiliser subsidy on fertiliser consumption. The likely impacts of fertiliser subsidy on domestic production are also discussed. The chapter also includes a brief review of previous studies.

3.2 Theory of derived demand

Demand for inputs differ from demand for final output as the demand for final products reflects directly the utility attached to them, while demand for inputs does so indirectly (Friedman, 1970).

The demand for an input is a derived demand. That is, a demand that is derived from the demand for the final goods and services, which are produced by the input. For instance, the demand for the services of shearers of sheep is derived from the demand for wool. Therefore, the demand for an input can not be separated from the demand for the products produced by it (Tisdell, 1982).

The demand for an input by an individual firm can be derived from the firm's production function and the assumption of profit maximisation. In this case, under a competitive market situation, a firm will purchase an input up to the point at which the cost of the last unit of input is the same as the additional revenue generated by it. At this point, profit cannot be further increased. In other words, a profit maximising firm should use an input up to a level where the value of marginal product (VMP) of the input is equal to its price.

The producers profit maximising problem is formulated as follows:

First, let the production function for the firm be:

$$Y = f(X_1, X_2), \tag{3.1}$$

where X_1 and X_2 are the inputs used in the production of output Y. Secondly, assume that a rational producer's objective is to maximise profit. The objective function can then be written as follows:

Maximise

$$\pi = P\, f(X_1, X_2) - r_1X_1 - r_2X_2, \tag{3.2}$$

Subject to

$$Y = f(X_1, X_2),$$

where r_1 and r_2 are respective input prices and P is the price of output.

By solving (3.2), we get a system of input demand functions which are a function of input prices and output price. That is,

$$X_i^* = f(r_1, r_2, P), \tag{3.3}$$

$$i = 1 \text{ and } 2.$$

Further, we can determine the price responses by the manipulation of first order conditions of profit maximisation.

The first order conditions for maximisation of (3.2) are:

$$\frac{\partial \pi}{\partial X_1} = P\, f_1 - r_1 = 0, \text{ and} \tag{3.4}$$

$$\frac{\partial \pi}{\partial X_2} = P\, f_2 - r_2 = 0\ . \tag{3.5}$$

Rearranging (3.4) and (3.5), we get

$$Pf_1 = r_1, \text{ and} \tag{3.6}$$

$$Pf_2 = r_2. \tag{3.7}$$

In equations (3.6) and (3.7), the partial derivatives of the production function with respect to the inputs, f_1 and f_2, are the marginal products (MP) of the respective inputs. The first-order conditions for profit-maximisation (3.6 and 3.7) require that each input be utilised up to a point at which the value of its MP equals its price. The entrepreneur can increase his profit as long as the addition to his revenue from the employment of an additional unit of X_1 exceeds its cost.

As prices change the producer will alter his input levels to satisfy his first-order conditions (3.6 and 3.7). By totally differentiating equations (3.6) and (3.7) and rearranging the terms, we get

$$Pf_{11}dX_1 + Pf_{12}dX_2 = - f_1dP + dr_1, \text{ and} \tag{3.8}$$

$$Pf_{21}dX_1 + Pf_{22}dX_2 = -f_2\, dP + dr_2. \tag{3.9}$$

Solving (3.8) and (3.9) by Cramer's rule, we get

$$dX_1 = \frac{1}{P\Re} [f_{22}dr_1 - f_{12}dr_2 + (f_{12}f_2 - f_{22}f_1)dP], \text{ and} \tag{3.10}$$

$$dX_2 = \frac{1}{P\Re} [-f_{21}dr_1 + f_{11}dr_2 + (f_{21}f_1 - f_{11}f_2)dP], \tag{3.11}$$

where

$$\Re = (f_{11}f_{22} - f_{12}^2) > 0 .$$

Dividing both sides of the equation (3.10) by dr_1 and letting $dr_2 = dP = 0$, we get

$$\frac{\partial X_1}{} = \frac{f_{22}}{} < 0. \tag{3.12}$$

$$\partial r_1 \qquad P\Re$$

Equation (3.12) can be expected to be negative under the assumption of diminishing marginal product. Equation (3.12) states that as the price of input X_1 increases its demand decreases, i.e. the demand curve is downward sloping.

Dividing both sides of (3.10) by dr_2 and letting $dr_1 = dP = 0$, we get

$$\frac{\partial X_1}{\partial r_2} = \frac{-f_{12}}{P\Re}. \tag{3.13}$$

Equation (3.13) tells about the change in the use of X_1 with a change in the price of X_2. This derivative will have a sign opposite of the second cross partial f_{12}. In most cases considered by economists, an increase in the quantity of one input will increase the marginal product of the other; that is, $f_{12} > 0$. Therefore, an increase in the price of one input normally will reduce the usage of other input. However, if this assumption is not made, the sign on equation (3.13) can only be determined empirically.

Dividing both sides of (3.10) by dP and letting $dr_1 = dr_2 = 0$, we get

$$\frac{\partial X_1}{\partial P} = \frac{(f_{12}f_2 - f_{22}f_1)}{P\,\Re} \tag{3.14}$$

Equation (3.14) will be positive if $f_{12} > 0$. Equation (3.14) states that as the price of farm output increases, the demand for input X_1 also increases (Henderson and Quandt, 1980).

3.3 Impact of fertilizer subsidy on fertilizer demand and agricultural output

Agricultural economists make extensive use of demand and supply functions to represent the behaviour of consumers and producers. These functions show relationship between quantities demanded (and supplies) and important explanatory variables, including the price of the commodity. The impacts of the policy changes can then be observed by using these demand and supply functions.

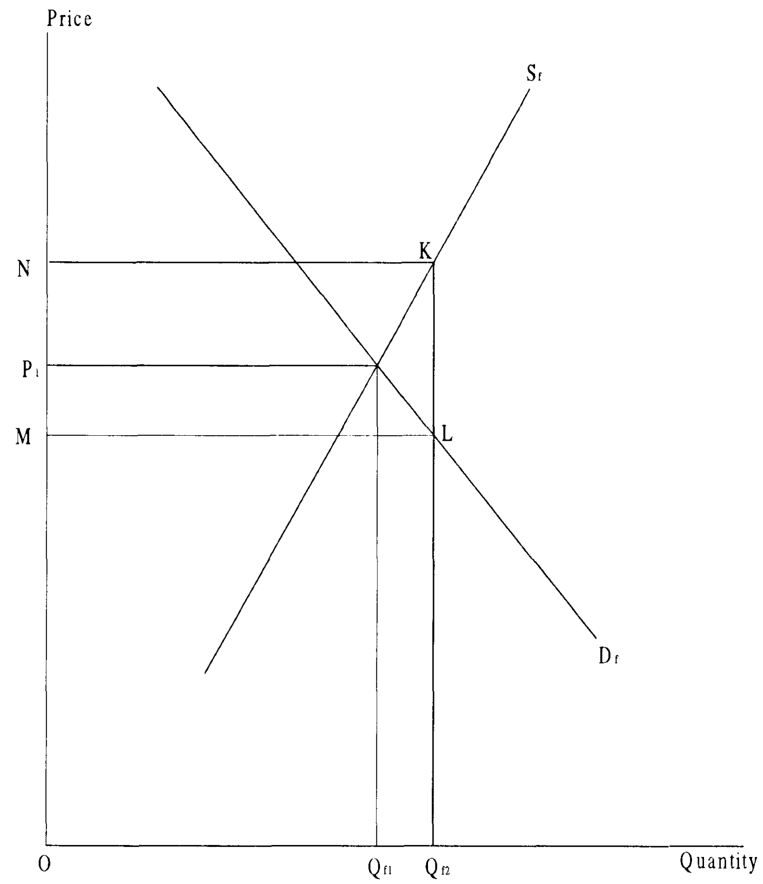
Figure 3.1 shows a conventional downward sloping demand curve (D_f) and upward sloping supply curve (S_f) for fertiliser in Pakistan. In the absence of any policy intervention the domestic fertiliser demand is OQ_{f1}. The equilibrium price is OP_1 and the equlibrium quantity is OQ_{f1}. Let us now suppose that the state introduces a subsidy on fertiliser. With the subsidy the farmer pays a price OM rather than OP_1. At this lower price OQ_{f2} of fertiliser is demanded. In order to meet this demand the producers are paid ON price and a subsidy of MN per unit of fertiliser is offered.

The government cost of subsidy can be calculated by multiplying the subsidy per unit (MN) and the marketed quanity (OQ_{f2}). Hence, the subsidy cost is represented by the area KLMN in Figure 3.1.

In Figure 3.2 the impact of fertiliser subsidy on the total agricultural output is shown. Fertiliser susbidy lowers the price of fertiliser and the supply curve of agricutlural output is shifted from S_0 to S_1. This shift occurs becuase the costs of production are lower due to the subsidy, and each farmer finds it profitable to supply a higher output. A more technical way of describing the same event is to observe that the supply curve can be regarded as the horizontal summation of individual firms' marginal cost curves. Then the subsidy has the effect of lowering the marginal cost of producing.

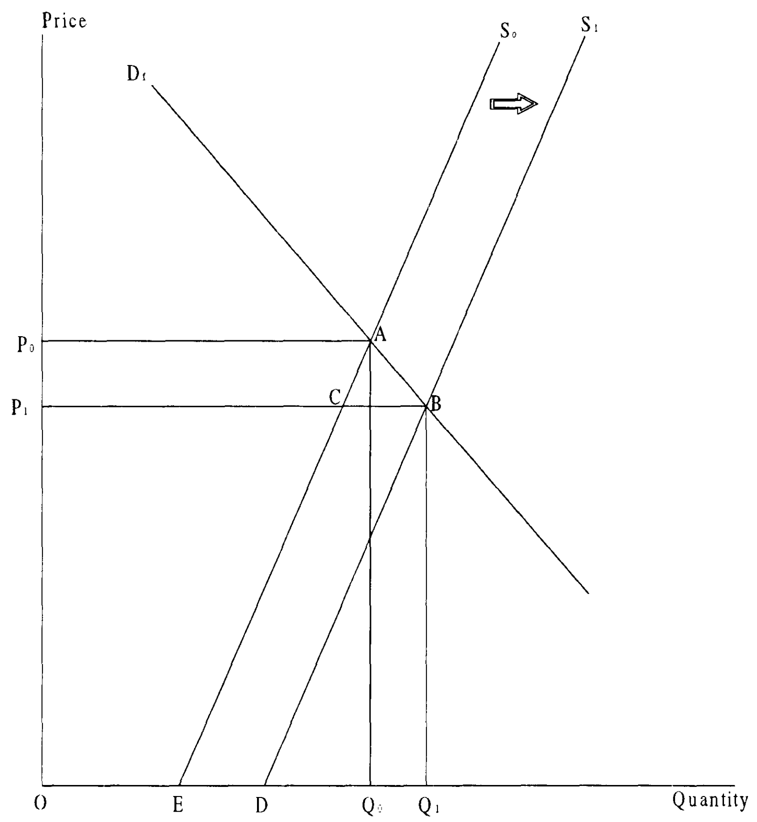
With this shift in supply curve, price is lowered to OP_1 and quantity demanded is increased to OQ_1. The susbidy increases both consumers surplus and producers' surplus. In Figure 3.2 the consumers' surplus is measured by the area ACP_1P_0 whereas, the producers' surplus is measured by the area ABDE. Net impact of the fertiliser subsidy can be measured by substrating gains in consumers' surplus and producers' surplus (in Figure 3.2) from the total cost of susbidy (in Figure 3.1).

Figure 3.1: Effect of fertiliser subsidy on the fertiliser market



Source: Piggot *et al.*, (1993)

Figure 3.2: Effect of fertiliser subsidy on agricultural output



Source: Piggot *et al.*, (1993)

3.4 The partial adjustment process

It is known that there is a long-run demand for fertiliser nutrients. This long-run demand function was supposed to be a linear function of the own-price of fertiliser nutrients, the price of farm output, availability of the credit for the purchase of fertiliser, time trend and acreage under major crops. In mathematical form this model may be stated as follows:

$$Y^{*} = \beta_0 + \beta_1 X_{ti} + \mu_{t,} \qquad (3.15)$$

where

Y^{*} = long-run fertiliser demand;

X_{ti} = represents price of fertiliser nutrients, price of farm output, credit availability for the purchase of fertiliser, time trend and acreage under major crops; and

μ_t = Error term.

Since the long-run or desired level of demand is not directly observable, Nerlove (1958) postulated the following hypothesis:

$$Y_t - Y_{t-1} = \delta\,(Y_t^{*} - Y_{t-1}), \qquad (3.16)$$

where

$0 \leq \delta \leq 1$ and is known as the coefficient of adjustment;

$Y_t - Y_{t-1}$ = actual change; and

$Y_t^{*} - Y_{t-1}$ = desired change.

Equation (3.16) postulates that the actual change in demand for fertiliser in any given time period is some fraction of 'δ' of the desired change for that period. If $\delta = 1$, it means that the actual change in demand is equal to the desired change, that is, actual demand adjusts to the desired demand instantaneously. However, if $\delta = 0$, it means that there was no adjustment to the deviation. In case of agricultural inputs, due to rigidity, inertia and other constraints, the value of 'δ' is always less than unity. Equation (3.16) may also be re-written in the following form:

$$Y_t = \delta Y_t^* + (1 - \delta)Y_{t-1} \text{ ,} \qquad (3.17)$$

Equation (3.17) shows that the observed demand for fertiliser at any time "t" is a weighted average of the desired demand at that time and the demand in the previous time period. By substituting (3.15) into (3.17), we get

$$Y_t = \delta\ (\beta_0 + \beta_1 X_{ti} + \mu_t) + (1\text{-}\delta)Y_{t-1}, \qquad \text{or}$$

$$Y_t = \delta\beta_0 + \delta\beta_1 X_{ti} + (1\text{-}\delta)Y_{t-1} + \delta\mu_t. \qquad (3.18)$$

Equation (3.18) is the partial adjustment model and is, in fact, a short-run demand function for fertiliser nutrients. The long-run demand function can be recovered after estimating the short-run demand function and the coefficient of adjustment (Gujarati, 1988).

3.5 Review of previous empirical studies

In this section a brief review of previous studies is presented. Here, the functional forms and the variables included in the demand functions for fertiliser are considered.

Griliches (1958) formulated a model using fertiliser price ratios and total plant nutrient use, lagged by one year, as explanatory variables in both a long-run demand function and an adjustment function for total plant nutrients used in USA between 1911-1956. In 1959 he also analysed the regional demand for fertiliser. He used log functional form. He found that real price of the fertiliser nutrients had a negative and significant effect on the demand for fertiliser nutrients. He got a small value of coefficient of adjustment. He acknowledged that multicollinearity between real price and lagged consumption of nutrient may cause a downward bias of the estimate of adjustment coefficient.

Heady and Yeh (1959) also examined a similar area and period of study. They specified their model in linear form. They included one year lagged income, cropped acreage and time along with fertiliser price index, average crop price index (lagged by one year), cash receipt from farming, cash receipt from crops and government payments, and one year lagged fertiliser consumption. Their results were different to those of Griliches (1958). Their justification for including "time" as a "catch all" and crop acreage is as follows:

> *"One of the signs in regression analysis based on time series data is to include a time variable as a catch all. But, while we might be slightly guilty in this respect, we actually included it for reasons which we believe are important. We included it to represent the greater technological knowledge (i.e. an increase in the marginal product ratio) which has come to the farmers over time."*

The time variable was significant at one and five percent levels in the two equations reported by them. The variable of fertiliser price index was negative and significant in both equations. Cash receipt from farming had a positive and statistically significant (at 1% level) influence on the use of fertiliser. The study period, 1926-56, was of considerable length but, as acknowledged by authors, in many parts of the study area the fertiliser use was not recommended before 1940. Thus, inclusion of time variable in all thirty years of study cast some doubts. However, an inclusion of a dummy time variable for first fifteen years of the study might have improved the quality of estimates. The sign on acreage variable was negative. It means that as acreage under crops decreases the fertiliser consumption increases. The authors had argued that national experiments on fertiliser use showed that in USA land and fertiliser substitute at diminishing rate i.e. gains from fertiliser use are decreased as more land is fertilised. This may be true for peculiar situations of USA, but, in most LDC's it is not true because in LDC's fertiliser use level is much lower than the level of diminishing returns.

Hayami (1964) studied fertiliser demand in Japan between 1883-1937. He employed a simple linear model and tried to separate the effect of fertiliser price and the effect of technological change on fertiliser demand. He used time as proxy for technological change. In an attempt to overcome the adjustment problem and to eliminate the short-run and long-run response differences, he estimated logarithmic functions with five years average as observations. Both time and price variables were significant. The estimated own-price elasticity of -0.74 appears to be equivalent to a long-run response because of the use of five years average. The adjustment coefficient value of 0.5 implies that after a price change, seventy five percent of the total adjustment to a new equilibrium occurs in five years.

Parikh (1966) used double log functional form for analysing nitrogenous fertiliser demand in India. He estimated fertiliser demand functions for six states and for the country as a whole for the period 1951-65. He specified two models. In his first model he specified demand as a function of current irrigated area, price of nitrogen relative to price of rice and a time trend. In the second model he specified demand as a function of lagged irrigated area, deflated price of nitrogen and a time trend. For both models the irrigation effect was positive and significant in three states and insignificant in other three and at the level of India as a whole. The estimated own-price elasticity was not significant in any state or at the all India level, but, was negative for three states. This indicated that neither the relative nor the deflated price of nitrogen had any role to play in explaining nitrogen consumption. He also re-estimated his model by dropping time variable and found that both current and lagged irrigation were significant in all states as well as at the national level. The own-price elasticity was negative and significant in five states although it was negative but insignificant at the national level. Parikh concluded that his study showed that irrigation and time are important factors explaining nitrogen demand in the study area and India as a whole. His estimate of short-run own-price elasticity was -0.31 and long-run own-price elasticity was -0.34.

Metcalf and Cowling (1967) also included time as a proxy for technological changes. They employed static and dynamic models for studying fertiliser use development in UK between 1948-65. In contrast to Parikh (1966) they used real price of fertiliser. In static model both time and real price of fertiliser were found to be statistically significant. In dynamic model they included lagged income of farming community. It was found that time and net farm income were positively and significantly related to fertiliser use. It was also found that time and net farm income were highly correlated. The inclusion of a time variable has thus rendered both the static and dynamic models inadequate for examining the independent effects of other variables included in the model. They tried linear and log forms of the model.

Leonard (1969) followed an approach similar to Metcalf and Cowling (1967). He also used time as proxy for technological changes. Other variables of the model included real price of fertiliser, acreage under cultivation during last twelve months, irrigation index, income index and consumption of fertiliser in the last year. Time series data for 1952-68 were collected for these variables. Linear, log linear, adjustment model and a first difference functions were applied to the data. The results of the study showed that price of fertiliser was a non-significant determinant of the fertiliser demand. Time and acreage under crops, however, are major determinants of the fertiliser demand. The coefficient of lagged consumption of fertiliser was positive and statistically significant (at 0.1% level). To confirm the findings of his study he collected cross-sectional data from 32 districts of Pakistan. The cross-sectional data confirmed that own-price elasticity of fertiliser demand was non-significantly low. He, therefore, concluded that use of subsidy to lower the fertiliser price for consumers was, infect, an economic rent and a heavy burden on public exchequer with little effect on fertiliser demand, therefore, its reduction or elimination was proposed. He proposed that provision of credit to farmers for purchasing fertiliser was likely to have positive effect on fertiliser demand. He concluded that the own-price elasticity of fertiliser demand, while significant in the short-run, is insignificant in the long-run and so reduction of the fertiliser subsidy was desirable. Since the insignificant estimates have both bias an multicollinearity problems, they are unreliable.

Hsu (1972) analysed the fertiliser demand in Taiwan between 1950-1966. He used both static and dynamic adjustment models. He used separate functions for nitrogen, phosphorus and potash. Out of the three functions nitrogen function was statistically satisfactory. He used lagged yield as proxy for income in the sense that higher yield from the application of fertiliser generates higher income and induces the farmer to buy and use more fertiliser in the current year. This lagged yield and the time trend variable suffered from significant multicollinearity in the static model. He used price ratios between nutrients and clean rice because, in Taiwan, the official price of fertiliser is given in terms of fertiliser-paddy rice exchange ratios. Using these variables he obtained own-price elasticity value of -0.55 which was significant at the 20 percent confidence level only and an elasticity value of 1.5 with respect to lagged yield which was statistically significant. Compared to the static model, the dynamic model was more successful, with a short-run own-price elasticity of -2.0 and an adjustment coefficient of 0.68. The long-run own-price elasticity value calculated from the adjustment model was -3.0. Both these elasticity values were highly significant. Comparing the results of his static and dynamic models it appeared that dynamic model was superior to the static model in respect of sign and coefficient values of the variables and of the level of significance.

Ranjan (1971) carried out a study on the demand for fertiliser in Sri Lanka from 1955-1970. Like Metcalf and Cowling (1958) he included income as one of the explanatory variables. He expressed the consumption of fertiliser as a function of paddy revenue. The paddy revenue variable was highly significant. The proportion of variation explained by the fitted equation was low, but acceptable at 0.59. He attempted to look into the effect of the government subsidy on fertiliser use in Sri Lanka. The estimated coefficient value indicated that the effect of the subsidy was positive for all the nutrients namely, nitrogen, phosphorus and potash, but was significant for nitrogen only at 10 percent level of significance.

Rao (1973) fitted static and dynamic demand functions. He used two dynamic demand equations for nitrogen which had a partial static/dynamic model formulation. His second equation yielded a short-run own-price elasticity value of -0.53 for nitrogen with respect to real price, while the long-run value for the elasticity was -6.36 and the adjustment coefficient was 0.08. As Rao indicated, this result needed careful interpretation because of the presence of the specification bias previously outlined by Griliches (1958). However, his first equation provided long-run own-price elasticity value of -0.34. This fantastic difference in the long-run own-price elasticity value which is smaller than the short-run own-price elasticity value from the second equation, was caused by dropping the irrigation acreage variable from the first equation where it had been highly significant. This resulted in the lagged dependent variable capturing most of the effect of acreage variable while also raising its coefficient value from 0.08 to 0.92. Since irrigation acreage almost certainly exerts a significance and independent influence on nitrogen application, its omission should be expected to bias badly the estimate of the adjustment coefficient (Griliches, 1958, p. 602).

Rodriguez (1973) studied demand for fertiliser in Philippines. He used a static model and estimated parameters by using OLS. He collected time series data between 1958 and 1972. His study showed that fertiliser price was a significant determinant of consumption of nitrogenous fertiliser. The estimated own-price elasticity of demand had a value at the mean of about -0.6. His attempt to include the fertiliser demand function in an entire system of simultaneous equations yielded smaller and less significant own-price elasticity measures.

Sung et al. (1973) studied fertiliser demand in South Korea. They used time series data between 1960 and 1972. They used dynamic adjustment model for studying fertiliser demand in South Korea. They obtained a low short-run own-price elasticity value of -0.17 and the results in general were not statistically satisfactory. The lower own-price elasticity value obtained may be attributed to the short time period. However, the long-run own-price elasticity value was -0.88 and comparable to previous studies reviewed.

Larson and Cibautos (1974) used both static and dynamic adjustment models for studying Brazilian demand for fertiliser. In this respect their study is similar to Grilichiles (1958) and Leonard (1969). They found that results from the two models were quite different. The static model yielded own-price elasticity value of -1.12 which is a value in between the short-run and long-run elasticities of -0.33 and -1.94 estimated from the dynamic adjustment model, respectively. The low adjustment coefficient of 0.17 may be attributed to the fact that the lagged dependent variable picked up the effect of excluded variables such as irrigation and acreage. In the light of the arguments of Griliches (1958 p. 602) the short-run elasticities appear to be low and the long-run elasticity value of -2.0 turns out to be right.

Ayub (1975) used same set of variables as used by Leonard (1969). However, he gave due consideration to simultaneity. His study spread over a span of fifteen years between 1958-1973. Leonard (1969) applied OLS whereas Ayub (1975) applied Walli's three pass regression in both linear and log-linear forms. He concluded that the use of sophisticated estimation method did little to improve the estimations. He suggested that in the earlier stage of the introduction of fertiliser, the farmers were less responsive to its price but as time passed they become more responsive to fertiliser price. He confirmed this by dividing the total study period into two halves i.e. 1958-1965 and 1966-1973. He concluded that price is an important determinant of fertiliser use and removal of subsidy at this stage may curtail its use. He obtained short-run own-price elasticity value of 0.3 whereas the long-run own-price elasticity was 0.46.

In their study on demand for fertiliser in Pakistan, Chaudhry and Javed (1976) specified the demand function in nominal terms, which mean they used nominal price of fertiliser (a price not corrected for inflation). The specification of the demand function in nominal terms is often useful for price projections but is an incorrect specification for estimating the price elasticity because, it is simple change in the unit price measurement to affect the demand. As there is no unique relation between percentage change in real and nominal prices, the direction of bias of the specification error can not be determined. They defined the out put price variable as revenue per cropped acre. They do so in order to allow for changes in output price and yield per acre. This specification is incorrect, however, as fertiliser demand is not a function of yield unless the inclusion of yield is specifically stated. The authors utilised annual demand and fertiliser price data defined for the agricultural year instead of general fiscal year and they did not make it clear as how the data was converted to agricultural year. They estimated demand as a linear function of the nominal fertiliser price, nominal revenue per crop acre and time trend. Only one estimate was reported. They found that demand for fertiliser is responsive to fertiliser price. Revenue per cropped area also have a positive and statistically significant (at 1% level) effect on demand for fertiliser. Time trend was also positive and statistically significant (at 1% level). Their policy discussion is misleading because, while they concluded that demand is price responsive, they recommended the removal of price subsidy. The calculated own-price elasticity was -1.12.

Mustafa (1976), using aggregate time series data for the period 1966-74, estimated the demand for nitrogenous fertilisers and combination of all types of fertilisers abbreviated as fertiliser (F) in the Punjab province and Pakistan. By using simple linear model, he observed that the decline in relative price of nitrogenous fertiliser "N" was an important variable in explaining its increased use. Acreage under major crops also positively influenced the fertiliser use, whereas the variable of income was positive for nitrogenous fertiliser in case of the Punjab province but for other cases it was negative. Moreover, the variable of agricultural credit gave a negative sign in all cases which is contrary to economic theory. As such the analysis needed an improvement in the identification and construction of some variables affecting fertiliser demand.

Salam (1977) used all the variables in their natural logarithms. He studied fertiliser demand in the Punjab province of Pakistan. He used time series data between 1959-72. He hypothesised that demand for nitrogenous fertilisers was a function of relative price of fertiliser nutrient, one year lagged weighted price of major crops, number of tube wells and time. He concluded that relative decline in the price of fertiliser was one of the important variable in encouraging fertiliser use. Other important variables were the acreage under major crops and time, whereas the proxy variable for farm income, lagging by one year, gave a negative sign in his analysis. He acknowledged that the use of one year lagged prices of major crops as a proxy for farm income was a mis-specification. His estimate of own-price elasticity was -0.522. He confined his analysis to the Punjab province and did not extend the scope of his study at national level. He confined his analysis to the Punjab province in the expectation that demand analysis for a homogeneous region was likely to yield better results than national analysis. Better results are possible but these should not be much different as the Punjab province accounts for 70 percent of the national demand for nitrogenous fertiliser.

Akram (1979) like Mustafa (1976) collected time series data for the period 1966-77 and estimated the demand for nitrogenous, phosphatic and combination fertiliser. He concluded that increased price decreased fertiliser use. Time factor also influenced fertiliser use positively. However, time was not an important factor in case of phosphatic fertiliser. Parity ratio among agriculture and non-agriculture had negative influence on fertiliser use. Acreage under major crops and agricultural credit had given a positive sign.

Hussain (1982) studied fertiliser demand in Bangladesh between 1955 and 1981. He developed per hectare fertiliser demand functions for nitrogen, phosphorus and potash separately. He specified fertiliser demand as a function of price of fertiliser nutrient, price ratio between fertiliser nutrient and clean rice, irrigated rice area (hectares) lagged rice yield (kilograms per hectare) and time as proxy for technological changes. Static and dynamic demand functions were fitted through time series data for the period of 1955-56 to 1980-81. The results of dynamic model were superior to the static model and thus were selected for further analysis and discussion. He found that both input and output prices influence the demand for fertiliser significantly. He also found that in Bangladesh, the demand for fertiliser is significantly related to the availability of complementary inputs and services namely irrigation, extension and credit facilities. Own-price elasticity for nitrogen, phosphorus and potash in the short-run were found to be -0.53, -0.41 and -0.27 whereas in the long-run the corresponding values were -0.74, -0.76 and -0.47. He recommended for the continuation of subsidy on fertiliser.

Tariq (1992) employed OLS for estimating demand functions for N, P, K and combined fertiliser for the Pakistan. He included one year lagged price of fertiliser, one year lagged income from the major crops, one year lagged acreage under important crops, one year lagged consumption of fertiliser and time in his model. He used time series data from 1971-91. He found that price of fertiliser negatively and significantly influences the fertiliser use. Acreage had positive and non-significant effect on fertiliser use. Fertiliser consumption in previous years also had positive but non-significant effect on fertiliser use. Time was the most significant and positive variable. His study shows that adoption of fertiliser in Pakistan is not complete yet. His estimates of short-run own-price elasticity of N, P, K and NPK were -0.487, -0.4141, -0.2009 and -0.4189 respectively. In the long-run the own-price elasticity values for N, P, K and NPK were -0.4974, -0.6627, -0.2662 and -0.5741, respectively.

NFDC (1994) runs a regular series of forecasting fertiliser demand and import requirements on yearly basis. NFDC uses a variety of forecasting techniques to project both short and long term fertiliser demand. These techniques include time series analysis, econometric model as well as other computer assisted specialised packages. During 1992-93 a FAO developed model called "Computer System for Agriculture and Population (CAPPA)" was used to estimate fertiliser requirements for the 8th Five Year Pan. The econometric model used by NFDC is a linear equation. The model included relative price index, time and one year lagged deviation from the trend in agricultural income terms of trade.

Dholakia and Majumdar (1995) estimated price elasticity of fertiliser demand in India at the macro level. They used both static and dynamic functions. They expressed fertiliser demand as a function of the price of fertiliser, the price of other inputs, technological shifts, real income, population, the price of non-agricultural commodities and the weather conditions. While estimating the static model they found that irrigation, High Yielding Varieties, personal disposable income and population were highly correlated variables and rendered the other variables insignificant. The estimated own-price elasticity of fertiliser demand was -0.28 which was statistically significant. They found that both relative prices of inputs and output significantly influence the fertiliser demand in India. The estimates of own-price elasticity of fertiliser demand was -0.34. Thus, the static model suggested that fertiliser demand is inelastic with respect to its price.

In their dynamic model they used partial adjustment and found that short-run own-price elasticity of fertiliser demand was around -0.2 while the long-run own-price elasticity was around -0.35. The small difference between the two elasticities, in absolute terms, was due to a very high value of the coefficient of adjustment (0.53). This meant that more than half of the disequilibrium is eliminated within a year. It was also found that fertiliser demand in India was inelastic with respect to relative output price.

Gezahegn and Tekalign (1995) collected primary data for their study on determinants of fertiliser demand in Vertisol cropping systems in Ethiopia. They specified their model in linear and log linear forms. They assumed a Cobb-Douglas fertiliser response function. They included house size, age of the farmer, education level of farmer, number of oxen held by the farmer, income, availability of credit, time of delivery of fertiliser, fertiliser price ratio, distance from the market, crop yields, use of natural manure, fertiliser application, rainfall, occurrence of disease and price of fertiliser as the explanatory variables. In the linear model they found that house hold size, availability of credit, application of manure, fertiliser-crop price ratio, distance from the market and yield were important determinants of fertiliser demand. They found that log-linear model gave better estimates. The elasticity of fertiliser with respect to area under major crops was

0.235. Own price elasticity was found to be -0.67. The variables of education level, age, farm size and number of oxen had non-significant impact on fertiliser demand. However, they noted that these variables were not unimportant.

3.5 Summary

The derived demand for inputs can be derived from a profit maximisation process. The result is that the demand function of any input is a function of its own-price, prices of related inputs and the price of output. With an increase in the own-price of an input its demand goes down and hence a negatively sloping demand function is expected. The change in the demand of an input with a change in the price of related inputs depends on the type of relationship between the inputs. Generally, with an increase in the price of outputs the demand for inputs, which are used in the production of that output, goes up.

From a review of previous studies it was found that dynamic models which incorporated partial adjustment processes were superior to static model. Moreover, the demand function for fertiliser is, in general, specified as a function of price of fertiliser, price of farm output, time and acreage under crops. In most studies a time trend is used as a proxy for technological advances. Irrigation index, area under high yielding varieties, price ratio between fertiliser and output prices and lagged consumption of fertilisers were other variables used by most studies. Linear, log linear and some double log functional forms were employed by different studies.

Chapter 4: The methodology

4.1 Introduction

This chapter contains information on the methodology used in the present study. The chapter includes a discussion of the variables of the model, functional form of the model and formulae used for the calculation of elasticities. In the last section of the chapter sources and limitations of the available data are discussed. The chapter ends with a brief summary.

4.2 Demand for fertilisers

In Pakistan three main fertiliser nutrients are being used as an important input in crop production. These are nitrogen, phosphorus and potassium. Besides these macro nutrients, some micro-nutrients such as sulphur, zink and iron etc. are also used in Pakistan. However, the present study will focus on macro nutrients of nitrogen, phosphorus and potassium. In the present study a separate demand function is developed for each of these nutrients. In addition, an aggregate fertiliser (NPK) demand function is developed. The detailed specifications for each of the fertiliser nutrients are discussed later in this chapter.

From the previous studies reviewed in Chapter 3, it was concluded that the dynamic model gives better results than static models (Hsu, 1972). The dynamic model is, therefore, adopted here. From previous studies, especially studies on Pakistan, Bangladesh and India, it was deemed appropriate to use dynamic models which incorporate partial adjustment process (Hussain, 1982).

From the theoretical model, presented in Chapter 3, it was learnt that demand function of an input should include the own-price of input, prices of related inputs and the price of output among the explanatory variables. In the present study, own-price of input and the price of output are included. The reasons for not including prices of related inputs are two-fold. First, different fertiliser nutrients are not substitutes, i.e. nitrogen, phosphorus and potassium are used independently. Therefore, a change in the price of nitrogen, for example, affects the demand for nitrogen only and a change in the price of phosphate affects only the demand for phosphate. Secondly, preliminary analysis which included prices of all fertiliser nutrients also suggested that prices of other fertiliser nutrients could be omitted from the analysis.

4.3 Variables of the model

Based on the previous studies and the unique situation of Pakistan, it is postulated that demand for any fertiliser nutrient is a function of one year lagged consumption of nutrient, own-price of the nutrient, the price of output, a time trend, credit available for purchase of fertiliser and acreage under major crops. So the model used has a general form as:

$$Y_i = f\,(Y_{it-1}, P_i, P_o, L_f, T, A, D), \qquad (4.1)$$

$$i = \text{N, P, K and NPK},$$

where

Y_i	=	demand for fertiliser nutrient i;
Y_{it-1}	=	one-year lagged consumption of the fertiliser nutrient i;
P_i	=	price of nutrient i;
P_o	=	price of output;
L_f	=	credit availability for purchase of fertiliser;
T	=	time trend;
A	=	acreage under crops; and
D	=	dummy variable.

A detailed rationale for the inclusion of these variables is presented below.

4.3.1 Demand for fertiliser nutrient (Y_n, Y_p, Y_k and Y)

Demand for fertiliser nutrient namely N, P, K and NPK is the dependent variable in the model. It is simply the quantity demanded of particular nutrient in any particular year. The unit of measurement is thousand tonnes.

4.3.2 Partial adjustment process ($Y_{nt-1}, Y_{Pt-1}, Y_{kt-1}, Y_{t-1}$)

Inclusion of one year lagged consumption of fertiliser is one way of taking into account the length of time in the adjustment process. Moreover, it leads to a substantial reduction in the serial correlation of the residuals. Griliches (1958) argued that farmers, once formed a behaviour, take time to respond to new changes in the market situation. Leonard (1969), Ayub (1975), Hussain (1982) and Tariq (1992) used one year lagged consumption of fertiliser nutrient among the explanatory variables. This variable measures the consumption level of specific nutrient in previous year. It is expected that previous years' consumption of fertiliser is positively associated with its consumption in current year. Therefore, a positive sign is expected for the coefficient associated with this variable. Moreover, its value should lie between zero and one.

4.3.3 Price of nutrient (P_n, P_p, P_k, P)

The price of a commodity is an important factor in the determination of its demand. Demand theory suggest that when the price of a commodity increases, *ceteris paribus*, its demand goes down. It is hypothesised that the own-price of a fertiliser nutrient bears an inverse relationship with its consumption, i.e. when the own-price of a fertiliser nutrient goes up, *ceteris paribus*, its consumption goes down. The price is measured in Rs/kg deflated by the 1974-75 prices.

Data on own-price of specific fertiliser nutrient were not available. Rather data on the price of specific variety of fertiliser such as Urea, DAP, SSP and CAN along with their nutrient percentage were available. From these data on nutrient price were calculated by using simple manipulation. For example the price of urea per 50 kg bag in 1995-96 was Rs. 267.0 and the percentage of nitrogen in urea is 46 percent. Thus, a 50 kg bag of urea contains 50*.46 = 23 kg of nitrogen and the price of 23 kg of nitrogen was Rs. 267 in 1995-96. From this per kg price of nitrogen is estimated by dividing 267 by 23 (267/23 =11.6086). The prices for other fertiliser nutrients namely, phosphorus and potassium, were arrived at by the same procedure.

4.3.4 Price of output (P_o)

Economic theory suggests that demand for an input is directly related to the price of the output produced by the use of that input (Debertin, 1986). In case of the present study the price of output is calculated as an index price of wheat, rice, maize, sugarcane and cotton based on the following procedure:

Prices and production of five major crops, i.e. wheat, rice, maize, sugarcane and cotton were collected from Agricultural Statistics of Pakistan (1995-96). From this, a price index was developed by using the following formula:

$$P_o = \sum_{i=1}^{5} W_i P_i , \qquad (4.2)$$

i = wheat, rice, cotton, sugarcane, maize,

where

$$W_i = \frac{P_i Q_i}{\sum_{i=1}^{5} P_i Q_i} , \qquad (4.3)$$

P_o = price of output (Rs/40 kg);

P_i = price of crop i (Rs/40kg); and

Q_i = total production of crop i (000 tonnes).

It is then deflated by 1974-75 Consumers Price Index (CPI). Chaudhry and Javed (1976) used per acre revenue from major crops as a proxy for the price of farm output. However, Salam (1977) used one-year lagged weighted price of farm output. Price of farm output bears a direct relationship with the demand for fertiliser. Therefore, a positive sign is expected for the variable of the price of output.

4.3.5 Credit for fertiliser (L_f)

It is postulated that if more credit is advanced for purchase of fertiliser, the more fertiliser will be bought and applied. Suleman (1982) stated that, during 1971-1981, in Pakistan, more than 40 percent of the total fertiliser purchases were made out of the credit advanced for fertiliser. He also argued that inclusion of the variable of credit, improves the estimates. Credit availability for purchase of fertiliser is measured in million Rupee deflated at 1974-75 CPI. Credit for the purchase of fertiliser is like additional resource at farmer's disposal. Therefore, a positive sign is expected for this variable.

4.3.6 Time trend (T)

The time trend explains the changes in fertiliser use over the years 1967-68 to 1995-96. It may serve as a proxy for such qualitative factors like improvement in farmer's experience regarding fertiliser use, development of tubewell technology and introduction and adoption of high yielding varieties.

Heady and Yeh (1959), Metcalf and Cowling (1967), Parikh (1966), Leonard (1969) and Ayub (1975) have argued that time trend is an adequate proxy for such factors as the introduction of new technology and the diffusion of technical knowledge among farmers. Suleman (1981) proposed that, when estimating a fertiliser demand function for Pakistan, a time trend should be included among the explanatory variables. It is postulated that technological advance bears a positive relationship with fertiliser use, therefore, a positive sign is expected for time trend.

4.3.7 Acreage under major crops (A)

In the case of Pakistan, chemical fertilisers are applied mainly to the major crops namely wheat, rice, maize, cotton and sugarcane. These five crops account for more than 90 percent of the total fertiliser off-take. Moreover increasing crop intensity leads to depletion of the soil fertility, so fertilisers are needed to restore its fertility (Tariq, 1992). Therefore, it is hypothesised that the change in the acreage of major crops will bring changes in the consumption of chemical fertilisers. A positive sign is expected for the coefficient associated with the acreage under major crops The area under these crops is measured in thousand hectares.

4.4 Functional form of the model

To decide on the functional form of the model the Box-Cox transformation procedure was used initially. However, the results of Box-Cox transformation were inconclusive. As such, semi-log, double log and linear forms were applied separately for each fertiliser nutrient demand function. Analysis was also conducted by employing systems of equation approach. Results obtained from different functional forms were compared on the basis of value of R^2, expected signs and magnitude of coefficients of variables, elasticity estimates, residuals and over-all goodness of the fit (Dougherty, 1992). It was found that the results from the single equation, in linear form, were superior to other functional forms. The empirical model estimated is specified as follows:

$$Y_i = \alpha + \beta_1 Y_{it-1} + \beta_2 P_i + \beta_3 P_o + \beta_4 L_f + \beta_5 T + \beta_6 A + \beta_7 D + \varepsilon_i, \qquad (4.4)$$

$$i = N, P, K \text{ and } NPK,$$

where

Y_i = demand for fertiliser nutrient i;

α = constant term in the regression equation;

Y_{it-1} = one year lagged consumption of the fertiliser nutrient i;

P_i = price of nutrient i;

P_o = price of output;

L_f = credit availability for purchase of fertiliser;

T = time trend;

A = acreage under crops;

D = dummy variable;

ε_I = error term; and

β_s are the parameters of the equation to be estimated.

In addition to the above stated variables, one dummy variable is used in nitrogen fertiliser demand function to reflect increase in the use of nitrogenous fertiliser in the last year of the study. Since early 90's the cotton crop of Pakistan has been facing a problem with Leaf Curl Virus. This resulted in decreased area under cotton crop and hence a decreased fertiliser use level. In recent years new varieties and improved cultural practices were developed for controlling Leaf Curl Virus of cotton. In the last year of the study (1995-96) there was an impression among farmers that this virus has been controlled and they increased the acreage of cotton crop. This resulted in an increase in the use of nitrogen fertiliser. To capture the effect of this increase a dummy variable was introduced.

4.5 Calculation of short-run and long-run elasticity

The elasticity of demand shows the percentage change in the quantity of a commodity demanded with a one percent change in a particular independent variable. Short-run and long-run demand elasticities with respect to own-price of fertiliser nutrient, the price of farm output and acreage under crops were calculated. Demand elasticity with respect to the price indicates the percentage change in the quantity demanded with one percent change in the own-price of fertiliser. Short-run elasticity was calculated by using following formula:

$$\eta_i = \beta_i * (X_i/Y), \tag{4.5}$$

where

η_i = elasticity for specific variable;

β_i = estimated value of ith coefficient;

X_i = mean of the ith variable; and

Y = mean of the dependent variable.

Long-run elasticity was computed by using following formula:

η_i

$$\lambda_i = \frac{\quad}{1 - \beta_1} , \tag{4.6}$$

where

λ_i = long-run elasticity for ith variable;

η_i = short-run elasticity for ith variable; and

$1-\beta_1$ = coefficient of adjustment.

4.6 The data

Time series data from 1967-68 to 1995-96 (29 years) were collected from Economic Survey of Pakistan (1996-97), Agricultural Statistics of Pakistan (1995-96) and Fertiliser Related Statistics of Pakistan (1993).

4.7 Data limitations

It is generally understood that demand for fertiliser nutrients is closely related to the availability of irrigation water. Leonard (1969), Ayub (1975) and Hussain (1982) included a variable for measuring area under canal irrigation. In case of the present study data on area irrigated by different sources was available, but, there was not a significant increase in the area irrigated by different sources. During preliminary analysis this data was used and it was found that its inclusion did not improve the results. Therefore, the variable of area under irrigation was dropped from the analysis. It may be noted that vast irrigation network was developed in Pakistan in sixties under Indus Water Treaty (Walter, 1990). Since then there has not been a significant increase in the irrigation water due to lack of investment. However, installation of private tubewell has taken a momentum in last two decades. But, the data on these private tubewell is not available as there exists no organised private irrigation water market in Pakistan.

In rain fed areas (*Barani areas)* intensity and frequency of rain fall is an important determinant of fertiliser use. Data on the intensity and frequency of rain fall in rain fed area were not available within the specified time period. So, this variable was also excluded from the analysis.

Hussain (1982) found that area under high yielding varieties is an import determinant of fertiliser demand. In the case of Pakistan, the data on the area under HYV were not available. Therefore, the variable of area under HYV could not be included in the model. However, it may be noted that planting of old traditional varieties was legally banned by the government in early seventies. Therefore, it may concluded safely that all the area under crops is in fact under HYV. However, fertiliser requirements vary among different varieties of wheat, rice, sugarcane, cotton and maize.

Reduction of fertiliser subsidy began in 1986-87. The major objective of the present study was to assess the impacts of reduction of this subsidy on the demand for fertilisers. One approach to this was to use a dummy variable to separate the total study period i.e. the period when there was subsidy on fertiliser (1967-68 to 1985-86) and the period when subsidy from fertiliser was reduced (1986-87 to 1995-96). It was not possible to do so because not enough data were available in the later period i.e. only six years for nitrogenous fertiliser, three years for phosphatic fertiliser and only one year for potash fertiliser.

4.8 Summary

This chapter provided a detailed description of the model used in the present study. Based on economic theory and review of previous studies it was postulated that demand for fertiliser in Pakistan is a function of one year lagged consumption of fertiliser, own-price of fertiliser, the price of farm output, availability of credit for purchase of fertiliser, time trend and acreage under major crops. From preliminary analysis it was found that a linear form with partial adjustment may be appropriate for specifying the demand functions for fertilisers.

Data for the specified variables were collected from Economic Survey of Pakistan (1996-97), Agricultural Statics of Pakistan (1995-96) and Pakistan Fertiliser Related

Statistics (1993). Data on the prices of nutrients were arrived at after accounting the fertiliser variety and the percentage nutrient content of the fertiliser variety. Data on the price of output were estimated from data on production and prices of wheat, rice, cotton, sugarcane and maize. The data on own-price of fertiliser nutrient, the price of farm output and the credit availability for the purchase of fertiliser were deflated by 1974-75 prices.

Availability of irrigation water is closely associated with the use of fertiliser. The data on this variable were not available and, therefore, the variable of availability of irrigation water was excluded from the model. Area under High Yielding Varieties was also excluded from the analysis for the lack of data.

Chapter 5: Regression results and discussion

5.1 Introduction

This chapter contains description of the regression results. Overall regression results are briefly presented in section 5.2. Separate results for individual demand functions for nitrogen, phosphate, potash and composite fertiliser are described and discussed in sections 5.3, 5.4, 5.5 and 5.6, respectively. Own-price elasticity of fertiliser nutrients is discussed in section 5.6 followed by description of elasticity of fertiliser nutrients with respect to the price of output, availability of credit for fertiliser and acreage under major crops.

5.2 The regression analysis

In general, the coefficient of all variables have the expected signs. The value of R^2 are reasonably high ranging from 0.8650 to 0.9905. Serial correlation was detected in the case of potash fertiliser only. This serial correlation was corrected by the Cochrane-Orcott iterative procedure (Dougherty, 1992). In the case of nitrogenous fertiliser, which account for more than 75% of the total fertiliser nutrient consumption in Pakistan, the coefficient of own-price has a negative sign and is statistically significant (at 10% level). However, the estimated own-price elasticities are relatively small in both short-run and long run. The coefficient of own-price is negative but statistically insignificant (at 5% level) for phosphatic and potash fertiliser. The time trend and the acreage under major crops appear to be the main determinants of fertiliser demand in Pakistan.

In the case of nitrogen, phosphorus and composite fertiliser, the coefficient of one year lagged consumption of the nutrient is statistically insignificant (at 5% level). It may be noted that the variables of time trend and the consumption of fertiliser nutrients are correlated. This correlation may be the reason for the non-significance of the coefficient of one year lagged consumption of fertiliser nutrients.

5.3 Demand for nitrogenous fertiliser

Table 5.1 presents the regression output for nitrogenous fertiliser. The proportion of variation in dependent variable explained by the included independent variables is 0.9905. It was not possible to compute Durbin-h statistics because the expression, 1-N*var(β_1), was greater than one. However, an examination of the residuals indicate that there is no serial correlation. All the variables have the expected signs.

A perusal of the Table 5.1 reveals that the coefficient of one year lagged consumption of nitrogenous fertiliser has a positive sign and is statistically insignificant (at 5% level). It means that farmer's previous year's experience with the use of fertiliser may not influence its use in the current year. This is a surprising result. However, Tariq (1992) also found that one year lagged consumption of nitrogen had a positive effect on the demand for nitrogenous fertiliser.

The coefficient of own-price of nitrogenous fertiliser has a negative sign and is statistically significant (at 10% level). It means that demand for nitrogenous fertiliser decreases with an increase in its price. This is in line with the theory which states that as the price of an input goes up its use goes down. Somewhat similar results were obtained by Ayub (1975). Salam (1977) concluded that a relative decline in the price of fertiliser was one of the important variable in increasing fertiliser use. Chaudhry and Javed (1976) also found that demand was responsive to price changes. Arkam (1979), Hussain (1982) and Tariq (1992) observed that use of nitrogenous fertiliser was inversely related to its price. Dholakia and Majumdar (1995) observed that, in India, the prices of fertiliser nutrients were inversely related to their use. However, Leonard (1969) found that, in Pakistan, the fertiliser demand was not responsive to fertiliser prices.

Table 5.1 reveals that the coefficient associated with the the price of farm output has a positive sign. These results again are in line with the theory. However, the coefficient is statistically significant (at 1% level). Similar results were reported by Hussain (1982). Chaudhry and Javed (1976) observed that revenue per cropped area which was used as a proxy for prices of farm oupt had a positive effect on demand for nitrogenous fertiliser.

Table 5.1: Regression results for nitrogenous fertiliser (1967-68 to 1995-96)

Variable	Coefficient	T-ratio
Y_{nt-1}	0.3012	1.601
Pn	-4079.3	-1.827
Po	25.421	2.641
Lf	2.7611	1.318
Time	35.581	2.377
Acreage	50.701	2.172
Dummy	201.16	3.366
Constant	-877.93	-2.291

Coefficient of adjustment = 0.6988

R^2 adjusted = 0.9905

The coefficient of availability of credit for the purchase of fertiliser has a positive sign and is statistically insignificant (at 5% level). In Pakistan, agricultural credit is often tied up with its use, i.e. credit is provided for purchase of farm inputs or machinery. This may explain why credit for the purchase of fertiliser is directly related to its use by farmers. Akram (1979) found that the variable of credit for the purchase of fertiliser has a positive coefficient.

The coefficient of time trend has a positive sign and is statistically significant (at 1% level). Similar results were reported by Leonard (1969), Ayub (1975), Salam (1977), Chaudhry and Javed (1976), Arkam (1979), Hussain (1982) and Tariq (1992).

Acreage allocation for the major crops is one of the most important factor for use of any farm input. The coefficient of acreage under major crops has a positive sign and is statistically significant (at 5% level). It means that demand for nitrogenous fertiliser increases with an increase in the acreage under major crops. A similar set of results were reported by Leonard (1969), Ayub (1975), Salam (1977), Chaudhry and Javed (1976), Akram (1979) and Tariq (1992). However, Heady and Yeh (1959), in USA, found that the coefficient of acreage under crops was negative. They argued that national experiments on fertiliser use showed that in USA land and fertiliser substitute at diminishing rate, i.e., gains from fertiliser use are decreased as more land is fertilised. This may be true for peculiar situations of USA, but, in most LDC's it is not true because in LDC's fertiliser use level is much lower than the level of diminishing returns and cropping intensity in LDCs is higher than USA.

In summary own-price, time trend and acreage under major crops were found to be the most important determinants of demand for nitrogenous fertiliser. Previous year's experience with the use of nitrogenous fertiliser, the price of farm outputs and provision of credits for purchase of fertilisers have a positive effect on the demand for nitrogenous fertiliser.

5.4 Demand for phosphate fertiliser

Table 5.2 presents the regression results for phosphatic fertiliser. The value of R^2 is 0.9816. The value of Durbin-h statistics is -0.80240. The value of Durbin-h statistic lies within the critical values of -1.96 and 1.96. Therefore, it is concluded that there is no serial correlation. All the variables have expected signs.

A perusal of the Table 5.2 reveals that one year lagged consumption of phosphatic fertiliser (Y_{pt}) is positively related to the use of phosphatic fertiliser. However, it is statistically insignificant (at 5% level). Hussain (1982), in Bangladesh, also found that one year lagged consumption of phosphate fertiliser has a positive effect on the use of phosphate fertiliser in current year. Tariq (1992) also found that the coefficient for one year lagged consumption of phosphate has positive sign.

The coefficient of own-price of phosphatic fertiliser has negative sign and is statistically insignificant (at 5% level). Similar results were reported by Tariq (1992).

From Table 5.2 it is evident that, like nitrogenous fertiliser, the coefficient of the price of farm output has a positive sign and is statistically significant (at 5% level). It means that an increase in the prices of farm outputs will increase the demand for phosphatic fertiliser. This is in line with *a priori* expectations. The demand for fertiliser is a derived demand and, thus, these results seem to be in line with the theory. Similar results were reported by Hussain (1982) and Dholakia and Majumdar (1995).

Provision of credit for the purchase of fertiliser also have a direct and statistically significant (at 1% level) effect on demand for phosphatic fertiliser. It may be because phosphatic fertilisers are costly as compared to nitrogenous fertilisers. So, the farmers apply phosphatic fertiliser only when credit is provided for its purchase. Furthermore, in Pakistan, the credit is often tied up with the purchase of farm inputs including fertiliser. This also explains why credit for the purchase of fertiliser is directly related to its use by farmers. These results agree with those of Akram (1979).

Table 5.2: Regression results for phosphatic fertiliser (1967-68 to 1995-96)

Variable	Coefficient	T-ratio
Y_{pt-1}	0.26162	1.545
Pp	-2079.8	-1.489
Po	8.7832	1.978
Lf	2.9124	3.087
Time	11.732	2.574
Acreage	13.936	1.478
Constant	-276.02	-1.732

Coefficient of adjustment = 0.7383

R^2 adjusted = 0.9816

Durbin h-statistic = -0.80240

The coefficinet associated with the time trend also has a positive sign and is statistically significant (at 1% level). Similar results were reported by Leonard (1969), Ayub (1975), Salam (1977), Chaudhry and Javed (1976), Arkam (1979) and Tariq (1992).

In the case of P_2O_5, the coefficient of acreage under major crops has a positive sign and is statistically insignificant (at 5% level). It means that, unlike nitrogenous fertiliser, the demand for phosphate fertiliser is not influenced by the acreage under major crops. A similar set of results were reported by Leonard (1969), Ayub (1975), Salam (1977), Chaudhry and Javed (1976), Akram (1979) and Tariq (1992).

In short, like nitrogenous fertiliser the use of phosphate fertiliser is most significantly influenced by the time trend and the acreage under major crops. Farmers' previous year's experience with the use of phosphate fertiliser is directly but insignificantly associated with the demand for phosphate fertiliser in current year. The price of farm output and provision of credit for purchase of phosphatic fertiliser affects the demand of phosphate fertiliser directly and significantly. Own-price has a negative sign and is statistically insignificant at five percent level.

5.5 Demand for potash fertiliser

In Pakistan potash has been the least important and least common fertiliser nutrient used by farmers. Potash accounts for only two percent of the total fertiliser consumption in Pakistan. Probably potash is only used on experimental farms or model farms.

In the case of potash fertiliser, significant serial correlation was detected. This serial correlation was corrected by using Cochrane-Orcott iterative procedure (Dougherty, 1992). This was done by using AUTO Command in SHAZAM. Regression results for potash fertiliser, after correcting for serial correlation, are presented in Table 5.3. The

Table 5.3: Regression results for potash fertiliser (1967-68 to 1995-96)

Variable	Coefficient	T-ratio
Y_{kt-1}	0.51422	4.704
P_k	-51.407	-0.1563
Po	0.60045	0.7154
Lf	0.86207	4.197
Time	-0.53789	-1.010
Acreage	3.1479	1.519
Constant	-55.177	-1.570

Coefficient of adjustment = 0.4857

R^2 adjusted = 0.8650

Durbin h-statistic = -1.5875

value of R^2 is 0.8650. The value of Durbin-h statistics is -1.5875. All the variables, except time trend, have the expected signs.

From the Table 5.3 it is evident that the coefficient of one year lagged consumption of potash has a positive sign and is statistically significant (at 1% level). It means that farmers' pervious year's experience with the use of potash fertiliser has positive and significant influence on his demand for potash in the current year. It also indicates that use of potash fertiliser is getting common among farmers. Hussain (1982) and Tariq (1992) found that the coefficient of the one year lagged consumption of potash fertiliser has a positive sign.

The coefficient of own-price of potash has a negative sign and is statistically insignificant (at 5% level). A negative sign on the coefficient of own-price of potash implies an inverse relationship between own-price of potash and its demand by the farmers. Hussain (1982) and Tariq (1992) also found that the price of potash had a negative effect on the demand for potash fertiliser.

The coefficient of the price of farm output has a positive sign. However, it is statistically insignificant (at 5% level). Hussain (1982) found that the price ratio between the price of potash and clean rice had a negative relation with the use of potash fertiliser.

A perusal of Table 5.3 reveals that availability of credit for the purchase of fertiliser is directly and statistically significantly (at 1% level) associated with potash use. It means that bulk of the additional funds made available in the form of credit are used for purchasing potash fertiliser. Akram (1979) also mentioned that credit availability increases the demand for potash nutrient.

The coefficient of time trend has a negative sign. However, it is statistically insignificant (at 5% level). This is a surprising result. However, Tariq (1992) also got a negative sign on the time trend for potash fertiliser. But, Hussain (1982) found that time trend has a positive effect on the use of potash fertiliser.

The coefficient of acreage under crops, like phosphate fertilisers, is also positive and statistically insignificant (at 5% level). Tariq (1992) also mentioned that with the increase in acreage under crops the demand for potash fertiliser increases.

In brief, one year lagged consumption of potash and availability of credit are the main determinants of the use of potash fertiliser. The price of output and acreage under crops has positive effect on demand for potash. Whereas, the own-price of potash has a negative effect on its demand.

5.6 Demand for composite fertiliser

A demand function for composite fertiliser means the overall demand function for fertiliser in Pakistan. The results for composite fertiliser are similar to those of nitrogenous fertiliser. This is because nitrogenous fertiliser account for more than 75% of the total fertiliser off-take in Pakistan. The results for composite fertiliser are presented in Table 5.4. The value of R^2 is 0.9877 which means that the included variables explained more than 98 percent of the variation in the demand for composite fertiliser. The value for Durbin-h statistics could not be computed. However, an examination of the residuals suggested that there was no serial correlation. All the variables have the expected signs.

A perusal of the Table 5.4 reveals that the coefficient of one year lagged consumption of composite fertiliser has a positive sign and is statistically insignificant (at 5% level). As stated earlier, the variables of time trend and consumption of composite fertiliser are correlated. This correlation may be responsible for insignificance of the coefficient of one year lagged consumption. Tariq (1992) also observed that the variable of one year lagged consumption had a positive value.

The coefficient of own-price has a negative sign and is statistically significant (at 5% level). It means that increased fertiliser prices will decrease the demand for fertiliser. It is in line with theory. Griliches (1958), Hayami (1964), Metcalf and Cowling (1967) and Rodriguez (1973) also stated that the price of fertiliser nutrients were negatively associated with their use. In Pakistan, similar results were reported by Ayub (1975). Salam (1977) also concluded that a relative decline in the price of fertiliser was

Table 5.4: Regression results for composite fertiliser (1967-68 to 1995-96)

Variable	Coefficient	T-ratio
Y_{t-1}	0.23199	1.214
P	-7139.6	-1.981
Po	39.301	2.939
Lf	5.7825	1.819
Time	57.566	2.991
Acreage	52.760	1.541
Constant	-982.78	-1.723

Coefficient of adjustment = 0.7691

R^2 adjusted = 0.9877

one of the important variable in increasing fertiliser use. Chaudhry and Javed (1976) also found that demand was responsive to price changes. Akram (1979), Hussain (1982) and Tariq (1992) also observed that the application of fertiliser is inversely related to its price. Dholakia and Majumdar (1995), in India, also got similar results. Leonard (1969), however, found different results with fertiliser use. He found that the price of fertiliser was not a significant variable in explaining its use.

Prices of agricultural commodities also bear a direct and significant (at 1% level) relationship with fertiliser use. It means that an increase in the price of farm outputs will increase the over all demand for fertilisers in Pakistan. This is in line with the theory which states that as the price of output goes up, the use of inputs used for its production also goes up. Similar results were reported by Leonard (1969), Ayub (1975) and Tariq (1992). They used income of the farm families as a proxy for output prices and found that farmers' income is directly and significantly related to fertiliser use.

Table 5.4 reveals that the coefficient of credit for the purchase of fertiliser has a positive sign and is statistically significant (at 5% level). It means that increased availability of credit for the purchase of fertiliser will increase the demand for fertiliser. These results are in line with the theory as credit is like additional resource at the disposal of farmer. Akram (1979) also arrived at similar result.

The coefficient of the time trend have a positive sign and is statistically significant (at 1% level). Leonard (1969) also got similar results and concluded that the time trend is the most important variable in explaining fertiliser use in Pakistan. Similar results were also reported by Parikh (1966), Ayub (1975), Salam (1977), Chaudhry and Javed (1976), Arkam (1979) and Tariq (1992).

The coefficient of acreage under major crops is positive and statistically significant (at 5% level). So, as acreage under crops is increased, the more fertiliser is used. Leonard (1969), Ayub (1973), Salam (1977), Chaudhry and Javed (1976), Arkam (1979) and Tariq (1992) also reported similar results.

In summary, the fertiliser use is directly associated with its use in previous year, the price of output, credit for the purchase of fertiliser, time trend and acreage under major crops. Whereas, it is negatively related to the own-price of fertiliser.

5.7 Own-price elasticity

Own-price elasticities for nitrogen, phosphate, potash and composite fertilisers, both in the short-run and the long-run are presented in Table 5.5. In Table 5.6 a comparison of price elasticities calculated by different researchers are presented. It may be noted that some coefficients of one-year lagged consumption are statistically insignificant, and therefore, the estimated elasticities need to be interpreted with care. They are presented here for illustrative purposes.

Table 5.5: Own price Elasticity for fertiliser nutrients (1967-68 to 1995-96)

Fertiliser Nutrient	Short-run	Long-run
Nitrogen	-0.1216*	-0.1740
Phosphate	-0.2062*	-0.2792
Potash	-0.0415*	-0.0479
Composite fertiliser	-0.1607**	-0.2089

* = Significant at 10%

** = Significant at 5%

The short-run elasticity for nitrogen is -0.1216 which means that a one percent increase in the price of nitrogenous fertiliser will decrease its use by 0.1216 percent. This is fairly low and, thus, it can be concluded that the demand for nitrogenous fertiliser is price

Table 5.6: Own price elasticities estimated by various researchers

Author (s)	Country	Year	Own Price Elasticity	
			Short-run	Long run
Larson, D.W. and J.S. Cibautos	Brazil	1974	-0.33	-1.94
Parikh, A.K.	India	1966	-0.31	-0.34
Rao, M.S.	India	1973	-1.20	-2.50
Haymai,Y.	Japan	1964	-0.59	-0.74
Ranjan, D.	Sri Lanka	1971	-0.48	-0.74
Sung, B.Y., Dhal, D.C. and Y.K. Shim	South Korea	1973	-0.17	-0.88
Roreguez, G.	Philippines	1973	-0.59	N.A
Hsu, R.C.	Taiwan	1972	-2.03	-2.99
Leonard, P.L.	Pakistan	1969	-0.11	-0.13
Ayub, M.	Pakistan	1975	0.31	0.46
Chaudhry and Javed	Pakistan	1976	-1.21	N.A
Salam	Pakistan	1977	-0.52	-0.44
Hussain	Bangladesh	1982	-0.53 N	-0.71 N
			-0.41 P	-0.76 P
			-0.27 K	-0.47 K
Tariq	Pakistan	1992	-0.487 N	-0.4974 N
			-0.4141 P	-0.6627 P
			-0.2009 K	-0.2662 k
			-0.4189 NPK	-0.5741NPK
Gezahegn, A. and M. Tekalign	Nigeria	1995	-0.67	-
Dholakia and Majumdar	India	1995	-0.28	-

From Table 5.6 it can be seen that the results of present study, when compared with other studies on Pakistan, only agree with those of Leonard (1969) who found that own-price elasticity is -0.11. All other researcher in Pakistan found that demand for fertiliser is responsive to price changes namely Ayub (1976), Chaudhry and Javed (1976), Salam (1977) and Tariq (1992). It may be noted that all these studies, except Tariq (1992), on the demand for fertiliser, in Pakistan, were conducted in mid and late seventies. At that time farmers were not convinced about the use of fertiliser and the government was inducing the farmers to use more fertiliser with a substantial subsidy on it. Now-a-days the farmers are not only convinced about the use of fertiliser, but they regard it as an essential input. Therefore, they are less responsive to changes in fertiliser price.

In summary, it is concluded that subsidy from the fertiliser can be removed safely without affecting the demand for fertiliser adversely.

Chapter 6: Summary and Conclusions

6.1 Introduction

A summary of the whole study is presented in this chapter. It contains discreption of the main findings of the study. The conclusions and policy recommendations are also provided at the end of this chapter. Limitations of the study along with areas for future research are also outlined in the last section of this chapter.

6.2 Summary

Pakistan is under tremendous pressure of increasing its domestic food grain supplies. This pressure could be reduced either by horizontal or vertical expansion in the agricultural sector. Horizontal expansion is limited because of water availability and increasing population. In vertical expansion mechanization on a large scale is also limited because of small scale agriculture and surplus labour. So the most viable option is to concentrate on divisible technologies like seed-fertiliser and better pest management.

Among divisible technologies, increased use of chemical fertilisers offers one of the cheapest and quickest means of increasing productivity. Realising its importantance, the government of Pakistan introduced first chemical fertiliser in 1952-53 with a 100 percent subsidy. Since then the fertiliser use has been increasing. The main reasons for this increase included rapid expansion in domestic production, vast extension services, investment in rural infrastructure and subsidization of fertiliser. The subsidy bill on fertiliser was Rs. 26 million in 1971-72 which went up to Rs. 2400 million in 1981-82. The major reasons for increase in subsidy bill included increase in the use of fertilisers by the farmers, devaluation of Pak Rupee and increase in the cost of imported fertiliser. To cope with it, the government decided to gradually reduce subsidy from fertiliser in 1986-87. Thus, in 1986-87 subsidy was reduced from nitrogenous fertiliser and in 1993 from phosphatic fertiliser and in 1995 from potash fertiliser. As a result of the reduction in subsidy the fertiliser prices went up. In just six years the prices were doubled. The major objective of the present study has been to assess the impact of this increased price on the use of fertiliser nutrients by the farmers. In view of the objectives, the study was guided by the following hypothesis:

H_0 : Fertiliser subsidy has no significant impact on demand for fertiliser

H_A : Fertiliser subsidy has significant impact on demand for fertiliser

To achieve this end, separate demand functions for nitrogen, phosphate, potash and composite fertiliser were developed. Based on the economic theory and review of past studies it was decided to include one year lagged consumption of fertiliser nutrients, price of fertiliser nutrient, price of farm output, availability of credit for the purchase of fertiliser, time trend and acreage under major crops as explanatory variables. Time series data from 1967-1996 were collected on these variables. Box-Cox transformation was run, but it gave inconclusive results. Then the model was run in semi-log, double log and linear forms. Results from linear form were superior and were selected for analysis. The data was also analysed by using systems of equation approach. Single equation approach yielded better results and, therefore, was selected for further analysis.

For nitrogenous fertiliser the value of R^2 was 0.9905 and there was no serial co-relation. It was found that the demand for nitrogenous fertiliser is positively and significantly influenced by the price of farm output, the time trend and the acreage under major crops. The variable of one year lagged consumption had a positive but statistically non-significant (at 5% level) coefficient. The coefficient of own-price of nitrogen has a negative sign and is statistically significant (at 5% level). Availability of credit for the purchase of nitrogen fertiliser has a positive but statistically non-significant (at 5% level) coefficient. The short-run own-price elasticity was -0.1216 which suggested that the demand for nitrogenous fertiliser was relatively price inelastic. This may be due to a long history of fertiliser use in Pakistan.

For phosphatic fertiliser value of R^2 was 0.9816 and there was no serial co-relation. The coefficients of price of farm outputs had a positive sign and was statistically significant (at 5% level). Availability of credit for the purchase of fertiliser and the time trend were found to be positive and statistically significant (at 1% level). One year lagged consumption of phosphate fertiliser was positive and statistically non-significant (at 5%

level). The own-price of phosphate had a negative but statistically non-significant (at 5% level) coefficient. Acreage under major crops had a positive and statistically non-significant (at 5% level) coefficient. The short-run price elasticity was -0.2062. It means that a one percent increase of phosphate prices will decrease its use only by 0.2062 percent or the demand for phosphate fertiliser is, like nitrogen fertiliser, price inelastic and any increase in its price will not decrease its use substantially.

In the case of potash fertiliser, one year lagged consumption of potash had a positive and statistically significant (at 1% level) coefficient. The coefficient of the own-price of potash has a negative sign and was statistically non-significant (at 5% level). The price of output and acreage under major crops had positive and statistically non-significant (at 5% level) coefficient. Availability of credit for fertiliser had a positive and statistically significant (at 1% level) coefficient. This may be because the potash fertiliser is costly and farmer buy it when additional funds in the form of loan are available. The time trend had a negative but statistically non-significant (at 5% level) coefficient. Short-run own-price elasticity was -0.0415 whereas the long-run own-price elasticity was -0.0479. It means that the demand for potash fertiliser is also price inelastic.

On overall basis or for composite fertiliser it was found that one year lagged consumption had a positive and non-significant (at 5% level) coefficient. The own-price of fertiliser had a negative and statistically significant (at 5% level) effect on demand for fertiliser. The price of farm output and the time trend had positive and statistically significant (at 1% level) coefficient. Credit availability for the purchase of fertiliser and acreage under major crops have positive but statistically non-significant (at 5% level) influence on demand for composite fertiliser. The short-run elasticity was found to be -0.1607. Lower value of short-run elasticity means that the fertiliser demand is not responsive to price.

The fertiliser demand is positively related to acreage under major crops. The corresponding values for nitrogen, phosphate, potash and composite fertiliser were 1.0886, 1.1272, 3.6509 and 0.8823, respectively.

6.3 Conclusions

Based on the results of the study the following conclusions are drawn:

- The time trend which measures the technological changes, experience of farmers with fertiliser use and extension services, is the most significant determinant of fertiliser demand in Pakistan.

- Price of farm output is the second most important determinant of fertiliser demand. It is positive and significant for nitrogen, phosphate and composite fertiliser.

- Availability of credit for the purchase of fertiliser is important determinant of demand for phosphate and potash.

- Acreage under major crops has positive but non-significant effect on fertiliser demand expect for nitrogenous fertiliser where it is positive and statistically significant.

- The fertiliser demand is inelastic to own-price in both short and long-run.

6.4 Policy implications and recommendations

From the results of the present study it is concluded that the demand for fertiliser is inelastic with respect to the own-price of fertiliser. Therefore, we conclude that fertiliser subsidy can be removed/reduced without reducing demand for fertiliser and hence output. Chaudhry and Javed (1976) also found that a 20.26 percent per annum increase in the price of nitrogenous fertiliser can be made with out affecting the fertiliser demand significantly.

In the present study the time trend was found to be the most important determinant of fertiliser demand. This points to the need of intensification on extension services. Extension services should particularly concentrate on the demonstration of fertiliser use which may be achieved by the establishment of *Model Farms*.

Prices of farm output have a positive and significant affect on fertiliser demand. It is generally understood that in Pakistan the prices of farm outputs are deliberately kept lower than the international prices. An increase in the prices of farm output will act as an additional income and incentive for the farmers to apply more fertilisers.

The demand for fertiliser is also positively affected by the availability of credit. An increase in the credit availability is, therefore, recommended. However, provision of credit to small farmers is likely to yield even better results.

6.5 Limitations of the study

The present study is limited in several respects. Some of the limitations of the study are listed below:

- The study is limited to analyzing the impact of fertiliser subsidy on its use from 1967-1996. This does not provide a full view of the impact of the policy on food production in Pakistan.
- The fertiliser subsidy may have different impact on small, medium and large farmers. The present study could not look at this aspect.
- Level of education and distance from road/market are also important determinants of fertiliser demand. The data on these variables could come only from a field survey. Time and resource limitations of the present study prevented from getting such field data.

6.6 Areas for future research

On the basis of findings and limitations of the present study following future research studies are proposed:

- It is suggested that a study based on field data should be conducted. Such a study should look into the non-institutional factors of fertiliser demand such as level of education, distance from road/market and age.

- A study which looks into the impact of increased fertiliser prices on small, medium and large farmers is suggested.
- A study on regional fertiliser demand functions is also suggested.

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Appendix 1: Research data

Yn	Pn	Yp	Pp	Yk	Pk	Y	P	Po	Lf	Acreage
177.44	0.026699	12.78	0.02493	0.21	0.01795	190.43	0.026571	9.492086	1.322626	16.94
203.52	0.026283	38.64	0.024542	2.48	0.0186	244.64	0.02593	9.16029	0.930016	16.24
272.56	0.026458	33.8	0.023572	1.34	0.017865	307.7	0.026103	8.641421	1.071907	16.44
251.5	0.025027	30.5	0.022297	1.2	0.016899	283.2	0.024699	8.403585	0.95057	16.62
341.2	0.027296	37.3	0.021294	0.7	0.016139	379.2	0.026685	8.287916	0.726246	16.6
346.2	0.035186	48.7	0.024183	1.3	0.014714	396.2	0.033766	7.344886	1.967997	16.93
341.9	0.046142	57.8	0.026597	3.2	0.018112	402.9	0.043116	5.374336	4.740342	18.28
362.9	0.036414	60.5	0.027297	2.1	0.014294	425.5	0.035008	4.020877	4.042434	17.37
445.3	0.031087	102.5	0.024444	2.8	0.0128	550.6	0.029757	3.29493	4.83	18.02
511.1	0.026452	118.2	0.017894	2.5	0.011452	631.8	0.024791	2.71563	5.582893	18.21
550.9	0.023637	156.8	0.0166	5.9	0.009628	713.6	0.021975	2.167513	6.789509	18.49
684.27	0.021321	188	0.015568	7.6	0.008718	879.87	0.019983	1.885527	7.573753	19.3
806.2	0.028429	228.5	0.01953	9.6	0.008437	1044.3	0.026298	1.985638	8.640934	19.22
843	0.025302	225.6	0.017382	9.6	0.007509	1078.2	0.023486	1.81028	9.792879	19.33
832.6	0.026712	265.3	0.015802	21.8	0.007395	1119.7	0.023751	1.659936	10.99039	19.78
952.69	0.0303	259.81	0.024198	25.6	0.008711	1238.1	0.028573	1.608011	14.18305	20.13
914.32	0.027962	293.79	0.022331	28.5	0.008039	1236.6	0.026165	1.33263	17.64056	19.99
934.8	0.026021	350.07	0.020781	24.67	0.007481	1309.5	0.024271	1.550135	21.40085	19.92
1128.4	0.024821	408.87	0.019823	33.33	0.00892	1570.6	0.023183	1.504076	24.42799	20.28
1332.3	0.024816	392.89	0.022441	42.62	0.008781	1767.8	0.023902	1.511978	30.25098	20.9
1282.1	0.024245	390.41	0.024325	45.03	0.009913	1717.5	0.023887	1.450296	22.078	19.52
1324.9	0.026843	382.43	0.024114	24.53	0.010776	1731.9	0.026013	1.274748	16.30681	21.82
1467.6	0.028383	388.5	0.026661	40.07	0.015103	1896.2	0.02775	1.282912	12.0152	21.46
1471.6	0.026555	398.02	0.032366	32.75	0.018793	1902.4	0.027637	1.398722	14.74621	21.82
1462.6	0.024015	488.2	0.029269	23.3	0.016995	1974.1	0.025231	1.495025	14.07745	21.72
1635.3	0.022986	464.24	0.026649	24.07	0.020116	2123.7	0.023755	1.374532	13.97282	22.44
1659.4	0.021172	428.4	0.024671	23.17	0.018078	2110.9	0.021848	1.214169	11.86184	21.87
1738.1	0.020954	494.45	0.03418	16.54	0.015996	2166.2	0.023428	1.329484	15.46762	22.14
1988.8	0.021488	359.4	0.037638	25.6	0.024508	2373.8	0.021538	1.244165	15.83129	22.14

For definitions refer to Page 51.