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Pakistan's Fertilizer Sector

Structure, Policies, Performance, and Impacts

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ABSTRACT

The fertilizer industry in Pakistan, with US$3.74 billion per year in sales, now stands at a crossroads where, after an initial substantial contribution in boosting crop productivity, its future potential is being challenged. Fertilizer-responsive crop varieties, supplementary irrigation water, and a favorable policy environment in Pakistan have induced fast growth in fertilizer demand. On the supply side, the availability of gas at low prices along with a favorable investment environment resulted in the buildup of excessive manufacturing capacity. But recently, a shortage of gas and monopolistic behavior has led to underutilization and greater imports. Restrictive laws put fertilizer processing and marketing in a few hands, which has also affected its efficiency. Moreover, the yield response of fertilizer has tapered off and per hectare use is fast reaching its optimal level. The existing policy environment leads to higher costs, inefficient use, and a heavy burden on the government as it charges one-fourth of the market price for feedstock gas used in fertilizer manufacturing. In addition, the government imports urea and absorbs the difference in international and domestic prices.

We use an equilibrium displacement model, originally developed by Richard Muth in 1964, to estimate the potential impact of policy reform on a set of key commodities and markets. Simulations for several policy options suggest that removing the gas subsidy results in an increase in government revenue but losses to manufacturers, consumers, and farmers. Additionally, removing the gas subsidy and sales tax simultaneously on fertilizer reduces losses to farmers and manufacturers, but the government gain is nullified. Increasing the gas supply results in small benefits to consumers, manufacturers, and farmers, but government expenditure also increases due to increased gas subsidies. However, removing the gas subsidy and investing in agriculture research and development will result in the highest social benefit, where all major stakeholders benefit to some degree and the return to society is highest. The research and development investment could also result in the highest increase in agricultural productivity and a trade surplus, relative to the other simulations. Finally, removing the gas subsidy also makes sense because increased imports of fertilizer will occur in any case within a decade or so, and it is not wise to exhaust existing gas resources quickly through subsidies.

Keywords: fertilizer, urea, DAP, equilibrium displacement model (EDM), fertilizer prices, subsidies, Pakistan

ABBREVIATIONS

ASTI	Agricultural Science and Technology Indicators
CAN	calcium ammonium nitrate
CCP	Competition Commission of Pakistan
DAP	diammonium phosphate
EDM	equilibrium displacement model
FAO	Food and Agricultural Organization of the United Nations
FF	Fauji Foundation
FFBL	Fauji Fertilizer Bin Qasim Limited
FFC	Fauji Fertilizer Company Limited
FOB	free on board
GDP	gross domestic product
GIDC	gas input development charges
GST	general sales tax
HHI	Herfindahl-Hirschman Index
IFPRI	International Food Policy Research Institute
IRG	International Resource Group
K	potash
MMBTU	million British thermal units
MVCR	marginal value-cost ratio
N	nitrogen
NFC	National Fertilizer Corporation of Pakistan
NFDC	National Fertilizer Development Centre
NFML	National Fertilizer Marketing Limited
NP	nitrogen phosphate
NPK	nitrogen phosphorous potassium
P_2O_5	phosphorus pentoxide
P	phosphorous
PECA	Provincial Essential Commodity Act
PKR	Pakistani rupee (PKR 102 = US$1)
R&D	research and development
RHPS	Pakistan Rural Household Panel Survey
SFRI	Soil Fertility Research Institute

1. INTRODUCTION

Fertilizer has been one of the three key contributors to productivity growth in food staples since the Green Revolution that began in the 1960s in Pakistan, along with modern varieties and added irrigation water (Byerlee and Siddiq 1994). As farmers shifted from cultivation of traditional wheat varieties to higher-yielding, more fertilizer- and water-responsive modern varieties, yields increased fourfold between 1965 and 2013, but with rising population growth, per capita availability from domestic production increased from just 95 kg to 115 kg (Pakistan, MNFSR 2013). The corresponding increase in fertilizer nutrient use during this period—from almost nil in 1965 to 180 kg per ha in 2013 (NFDC 2014)—was an instrumental factor in these yield gains and corresponding improvement in food security, as per capita consumption of calories per day increased from 2,210 in 1965 to 2,428 in 2011 (FAO 2014).

But despite many gains attributed to increased fertilizer use, public policies designed to promote its production and use remained controversial. Successive governments have alternated between subsidizing its production, importation, and distribution; withdrawing these subsidies in a piecemeal manner; and reverting back when fertilizer prices escalated. This indicates its popularity among policymakers as a political input to be used to gain the support of the large farming population, as well as ensure food security in their own perception (CCP 2010).

As a result of these policies—alongside a host of other market and institutional factors, such as, for example, scale efficiencies in fertilizer processing and lack of institutional capacity to introduce new and more efficient fertilizer products and application methods—Pakistan now faces widespread misuse of fertilizer and corresponding resource degradation at the farm level, rigid oligopolies in the fertilizer industry, and untenable fiscal burdens for the government.

There is little empirical analysis on the impact of different policies in the fertilizer sector, especially in Pakistan. A few studies have looked at the role of fertilizer in productivity and resource degradation (Ali and Byerlee 2002; Rashid et al. 2013), estimated crop supply elasticities with respect to fertilizer prices (Ali 1990), determined demand elasticities of fertilizer (Quddus, Siddiqi, and Riaz 2008; Ayub 1975; Leonard 1969; Chaudhry and Javed 1976), and compared the impact of a fertilizer subsidy on consumer and producer surpluses with various other policy options (Abedullah and Ali 2001). While these estimates provide good information on the relationships between fertilizer prices, its use, and farm productivity, and how the benefits of increased productivity are distributed among various stakeholders, they fail to provide insight on the impacts of such options on macroeconomic parameters for policymakers, such as on fertilizer prices, crop production levels, the fertilizer and crop trade deficits, government revenues, and producers and manufacturers' cost and earnings. Here we used an equilibrium displacement model (EDM) to analyze these impacts so that policymakers can make informed decisions in adopting various options.

This paper explores the issues in the fertilizer sector in Pakistan in greater depth than other work by reviewing the state of the industry, including analyzing fertilizer availability in various regions for different crops and in selected microenvironments. Moreover, this study elaborates the institutional and regulatory framework, identifies main policy issues, and analyzes the impacts of these options on macroeconomic parameters in the economy. The remainder of this chapter proceeds as follows. Section 2 provides a literature review, followed by a brief history of the industry in terms of its processing, marketing, and regulatory framework in Section 3. The trends in fertilizer use at the country and regional levels, for various crops and under various microenvironments, are analyzed in Section 4. Section 5 explores yield responses with respect to fertilizer use under various control environments, and the optimal, or profit-maximizing levels, are estimated. Section 6 describes how the misuse of fertilizer can deteriorate resource quality and degrade productivity. Section 7 reviews the government interventions in fertilizer prices through taxes and subsidies, while Section 8 analyzes the international competitiveness of the industry. Section 9 develops an equilibrium displacement model and simulates the impacts of major government policy interventions. Section 10 concludes with recommendations aimed at improving the performance of Pakistan's fertilizer sector and its contribution to future agricultural productivity growth.

2. LITERATURE REVIEW

Most of the studies related to fertilizer in Pakistan are from an agronomic perspective, studying its response at the farm level (Ayub et al. 1999; Ayub et al. 2002; Shafi et al. 2007). Very few studies analyze the policy environment in the sector, encompassing the whole value chain of processing, marketing, trade, and application to crops. The only exception is the study by the Competition Commission of Pakistan (CCP 2010), which describes the policy and regulatory environment of the fertilizer sector in Pakistan. However, the study lacks a farm-level perspective and does not quantify the impact of the existing regulatory framework and policy interventions on various macroeconomic parameters and stakeholders. Moreover, the situation of the fertilizer sector has dramatically changed since 2008, the last year included in CCP 2010.

This study uses an EDM originally developed by Muth (1964) to quantify the potential impact of new policy interventions. The model can link the output of a sector to its various production factors, including qualitative variables such as research, extension, education, and advertising (Wohlgenant 1993; Piggott, Piggott, and Wright 1995). It can also link the production of a sector to its marketing and trade activities (Sumner and Wohlgenant 1985; Sumner 2005). A sector can be disaggregated to various subsectors, which can also be linked to account for cross-product interactions (say, meat, wool, skin, and so on, in the sheep industry) to any level researchers wish and data permit (Piggott, Piggott, and Wright 1995; Mounter et al. 2008). The researchers can set some production factors, or processing, marketing, and trade activities of various sectors, as exogenous, while others can be endogenous to the system. Harrington and Dubman (2008) have improved the power and flexibility of EDM by combining it with mathematical programming models.

The EDM has been utilized frequently to examine impacts of agricultural policies, including the impacts of new technologies in the Australian beef industry (Zhao et al. 2001), of the Australian sheep and wool industry (Mounter et al. 2008), for agriculture research's effects on multiple markets (Piggott 1992), and on the impact of environmental regulation on farm income (und Anwendung 1999). Additionally, it has been used to assess the effects of U.S. commodity polices on world prices and trade (Sumner and Wohlgenant 1985); examine water distribution policies (Pritchett et al. 2010; Alhashim 2013); analyze the impacts of advertising in the Australian beef, lamb, and pork industries in domestic and export markets (Piggott, Piggott, and Wright 1995); and very recently to examine the role of fertilizer subsidies in China (Li et al. 2014).

The impacts of policy variables to be examined, assumed to be exogenous, in this study are the subsidy on the price of natural gas used in urea manufacturing (normally called the feed price), the quantity of natural gas supplied for urea manufacturing, agricultural technology, and general sales tax (GST). The impact of these policy variables are analyzed for crop production, prices, and trade; the profit of farmers; the profit of urea processors; and the impact on consumers, processors, and government revenue.

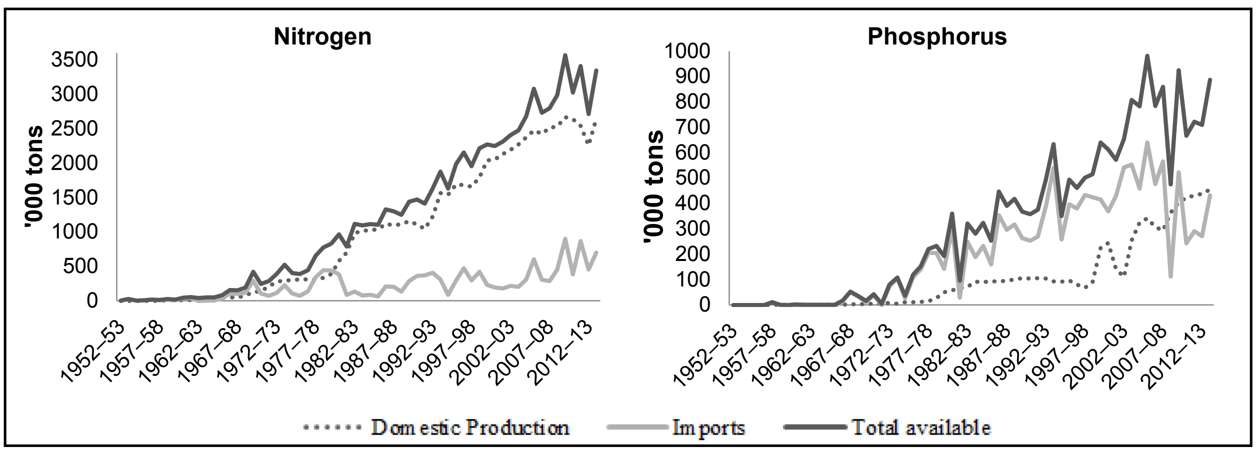
3. THE DEVELOPMENT OF PAKISTAN'S FERTILIZER INDUSTRY

Fertilizer Production and Imports

The initial introduction of fertilizer in Pakistan began in the 1950s, primarily through imports (Appendix Table A.1). Nitrogenous[1] chemical fertilizers were introduced through this channel in 1952, followed by phosphorus in 1959 and potassium in 1967 (NFDC 2014). But Pakistan initially perceived that its reserves of natural gas were large—an input to the Haber-Bosch process used to form ammonia, a key ingredient in nitrogen fertilizers such as urea—and thus conferred a comparative advantage in the production of fertilizer. Beginning in the late 1950s and early 1960s, the government pursued an import-substituting industrialization policy and made strategic manufacturing investments to build a domestic fertilizer industry. These included joint ventures with foreign companies, such as Pak-American Fertilizers (now Agritech, which was established in 1958) and Pakarab Fertilizers (established in 1973), as well as the establishment of domestic fertilizer plants, like that of the Fauji Fertilizer Company (FFC), established in 1978.[2] Upon nationalization of the fertilizer industry in 1973, production for all fertilizer companies was undertaken through the parastatal National Fertilizer Corporation (NFC).[3]

By the late 1960s, Pakistan's emerging domestic fertilizer industry, built on abundant gas supply, allowed the country to simultaneously increase the national supply of fertilizer and reduce the share of fertilizer imports, which consumed valuable foreign exchange reserves. Of course, large quantities of certain fertilizer products that are produced without natural gas (for example, diammonium phosphate [DAP] and potassium [K] compounds) still had to be imported, but domestic production capacity for both nitrogen and phosphate fertilizers nonetheless continued to increase (Figure 3.1). Fertilizer use gained momentum after 1970, when farmers began adopting high-yielding modern wheat and rice varieties in Pakistan's irrigated areas, with government promotion through subsidies and research support.

Figure 3.1 Historical trend in production, 1952/1953–2013/2014



Source: Authors' calculation based on NFDC (2014).

These policies led to the development of a sizable fertilizer industry in Pakistan. The value of fertilizer sales (estimated at domestic retail prices) was estimated at US$3.74 billion in 2014, up from just US$554 million in 1971 (both values in nominal terms). Approximately 76 percent of the fertilizer

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[1] "Fertilizer products" are a combination of three primary "fertilizer nutrients," which plants need in order to grow: nitrogen (N), phosphorus (P), and potash (K). For example, urea is 46 percent nitrogen, while DAP comprises 18 percent nitrogen and 46 percent phosphorus. Throughout this chapter, we use these terms distinctively.

[2] Company dates retrieved from Agritech 2014, FFC 2014, and PFL 2014.

[3] See Appendix B for more details.

consumed in Pakistan is produced domestically, with domestic production supplying 83 percent of the nitrogen, 51 percent of the phosphorus, and 47 percent of the potassium consumed nationally. The growth of domestic fertilizer production has been consistently higher than the growth of consumption for all nutrients since 1971, keeping import growth relatively low. For example, the production growth rate of nitrogen (6.15 percent) was greater than the offtake growth rate (5.54 percent), thereby keeping the import growth at 3.40 percent from 1971 to 2014, although trends in phosphorus and potash production and offtake were less dramatic (Appendix Table A.1).

The total domestic installed capacity of all types of fertilizer in Pakistan is currently estimated at 10 million metric tons, 69 percent of which is for urea and 31 percent for DAP and potash (the fertilizer product with the active nutrient potassium). In recent years, the industry has been operating below capacity, at approximately 75 percent of capacity in 2013–2014. During that time, urea production declined the most, with operating capacity estimated at 78 percent, while DAP production was running at almost full capacity (Table 3.1). Had there been no underutilization of capacity, installed capacity for production of urea would have been sufficient to meet domestic demand. However, DAP would remain short even with full utilization of its installed capacity by about 50 percent.

Table 3.1 Operating capacity of selected firms by type of fertilizer (%), 2013–2014

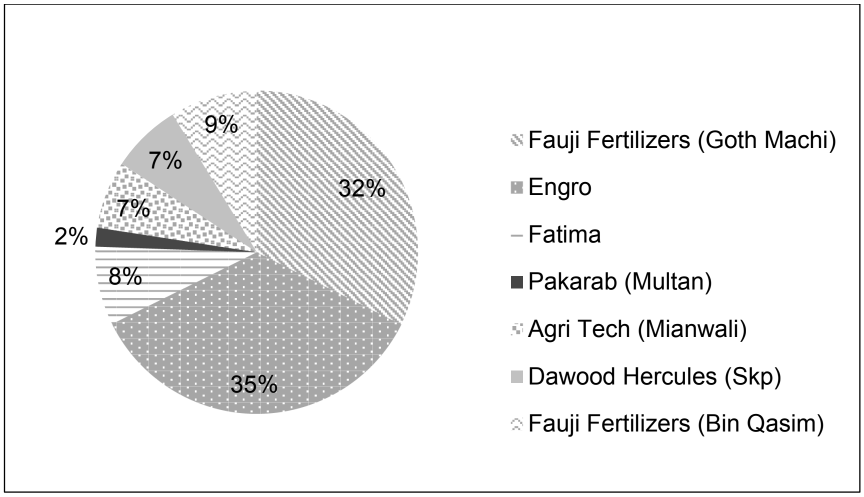
Firm	Urea	DAP	NPK	NP	CAN	Phosphate fertilizer	Total
Fauji Fertilizers (Goth Machi)	116.6	-	-	-	-	-	116.6
Engro	80.3	-	40.0	87.5	-	-	77.8
Fatima	71.4	-	-	101.7	124.4	-	95.5
Pak Arab	5.8	-	-	23.1	28.2	-	22.7
Agritech	31.7	-	-	-	-	-	31.7
Dawood Hercules	9.7	-	-	-	-	-	9.7
Fauji Fertilizers (Bin Qasim)	38.1	102.8	-	-	-	-	73.7
Others	-	-	-	-	-	21.0	21.0
Total	78.0	102.8	40.0	63.8	76.3	21.0	75.3

Source: Authors' calculation based on Pakistan, MNFSR (2013).
Note: DAP = diammonium phosphate; NPK = nitrogen phosphorous potassium; NP = nitrogen phosphate; CAN = calcium ammonium nitrate.

The production capacity and marketing power in the fertilizer industry in Pakistan is concentrated in a relatively few firms. The two big players, Fauji Fertilizers Company (FFC) (Gorth Machi) and Engro Fertilizer Limited, hold more than two-thirds of the total installed urea capacity (Figure 3.2). The estimated Herfindahl-Hirschman Index of industry concentration for urea manufacturing in Pakistan was 0.3742, in 2013–2014, indicating that the industry was highly concentrated.[4] The CCP has also arrived at similar conclusions.

[4] The Herfindahl-Hirschman Index (HHI) is calculated as the sum of the squared market share of each firm in the industry (Hannah and Kay 1977). The HHI can range from 0 to 1 approaches zero when a market consists of a large number of firms of relatively equal size, and increases both as the number of firms in the market decreases and as the disparity in size between those firms increases. An HHI more than 0.25 indicates high concentration. Because the HHI takes into account the relative size and distribution of the firms in a market, it is considered a better indicator of industry concentration than the four-firm concentration ratio.

Figure 3.2 Contribution of various firms to production capacity of urea, 2013–2014, in percent



Source: Authors' calculation based on Pakistan, MNFSR (2013).
Notes: Fauji Fertilizer Bin Qasim Limited is a subsidiary of Fauji Fertilizer Company Limited., and both are controlled by the Fauji Foundation.

With respect to DAP, the situation is slightly different. The Fauji Fertilizer Bin Qasim (FFBL) is also the only producer of DAP in the country, with about 54 percent of its demand met by that domestic producer, and with the rest being imported by a large number of smaller firms. As such, there is likely greater competition in the market for DAP, and domestic DAP prices tend to be more closely linked to its international price. But with this comes greater exposure to international price volatility and currency risk.

There is some evidence suggesting anti-competitive behavior in Pakistan's fertilizer industry. The firms benefit from the government's largess described above and have invested heavily in securing and maintaining market power. In 2012, the CCP fined FFC and Dawood Hercules Corporation Limited approximately 6 billion Pakistani rupees (PKR) for employing collusion tactics in an effort to manipulate the fertilizer market. Meanwhile, the return on equity in the industry is well above international comparators, suggesting the possibility of anti-competitive behavior that rewards investors. In Pakistan, the return on equity (taken as an average for the years 2004–2008) for the fertilizer industry was 33 percent, compared to 9 percent in China and 16 percent in India (CCP 2010).

Marketing

Initially, fertilizer was distributed through the agriculture extension wing of the provincial agriculture departments. There was no independent marketing system for agricultural inputs until the formation of the West Pakistan Agricultural Development Corporation in 1961 (Hussain 2011; Ul Hassan and Pradhan 1998). However, the West Pakistan Agricultural Development Corporation was abolished in 1972, when this responsibility was transferred to the provincial governments. Later, fertilizer marketing was the responsibility of the National Fertilizer Marketing Limited (NFML), a parastatal established in 1976 that carried the responsibility for distributing all domestic production from NFC companies as well as imports. After privatization of the manufacturing units of NFC, NFML's role has become restricted to the distribution of imported urea. Currently, domestically produced supply is marketed by private-sector processing companies through their registered dealers' networks.

Typically, fertilizer manufacturers supply products to dealers with a recommended maximum price, which is inclusive of the dealer's profit margin. Dealers procure fertilizer stocks—usually on a cash basis, but sometimes against a bank guarantee—and sell the product through their sales agent networks at prices determined by supply and demand. The existence of a competitive market is, however, subject to government intervention, sometimes ad hoc in nature and sometimes more structured. For example, during periods of short supply, according to interviewed dealers, the historical practice has been for the district coordination officer to call a meeting of all fertilizer dealers in a district to agree upon a price, even though deviations from this set price became the norm. More broadly, regulators have almost never been able to smooth out the supply or keep prices at reasonable levels whenever shortages have occurred—even despite the authority vested in regulators—mainly due to mismanagement of imports controlled by NFML (Nadeem Tariq, pers. comm.).

Regulations, Policies, and Institutions

The growth of fertilizer production and use in Pakistan gave rise to a series of policies designed to regulate the industry. First and foremost, from 1954 until the present, the government maintained control of the supply and allocation of natural gas to the fertilizer industry. The Provincial Essential Commodity Act (PECA), initially promulgated in 1971 and amended in 1973, placed fertilizer production and marketing under the direct regulatory purview of the federal government. At the provincial level, the Punjab Fertilizer (Control) Order of 1973 further strengthened the power of federal regulators by rendering provincial management of fertilizer subservient to PECA. Specifically, laws formulated and executed under PECA provide almost complete powers to the controller[5] in the management of prices, imports, and even the size of daily fertilizer transactions. Other policies that have been deployed over the past 40 years include subsidies on fertilizer importation and distribution, and sales tax exemptions on farmers' fertilizer purchases.

The introduction of these policies, alongside the growth of fertilizer production and use, also led to the establishment of several key organizations aimed at promoting fertilizer use. Fertilizer research and development (R&D) was initially undertaken by the Directorate of Soil Fertility in the Research Wing of the Agriculture Department of the Government of West Pakistan, which was converted into provincially separate Soil Fertility Research Institutes in each province in 1971. Issues pertaining to economic policy, for example, concerning production, imports, pricing, subsidies, and regulations, were addressed by the National Fertilizer Development Centre (NFDC), which was established in 1977 by the Federal Planning and Development Division.

At the farm level, the Extension Wing of the Agriculture Department of the Government of West Pakistan was responsible for conveying recommendations for fertilizer use to farmers. Credit for fertilizer purchases was made available to farmers through a variety of formal and informal sources. Initially, the primary formal source of credit was the Agricultural Development Bank of Pakistan, now known as the Zarai Taraqiati Bank, established in 1961 to provide affordable financial services to rural Pakistan. Commercial banks, such as Habib Bank, Askari Bank, and Punjab Bank, began providing agricultural credit at market rates beginning in 1972 (MNFAL 2007c).

The rapid expansion of Pakistan's fertilizer production capacity—alongside increases in fertilizer imports, and the growth of the policy, market, and institutional infrastructure required to promote fertilizer use—led to significant yield gains in wheat and rice during the 1960s and 1970s, and also introduced new challenges to Pakistan's agricultural sector. First, relatively smaller subsidies for nutrients other than nitrogen led to a long-term pattern of unbalanced fertilizer use. Second, the regulators' strong hand over the fertilizer industry, as set forth in PECA, placed significant discretionary powers in the hands of regulators and made entry into the fertilizer industry difficult for those without strong political affiliations. Third, the public sector's extensive investment in the formation and management of Pakistan's fertilizer industry—from the pricing and allocation of natural gas to the distribution of fertilizers to farmers—created interest groups that made more market-oriented reforms difficult.

Another dimension of this problem has been the absence of new product testing and promotion until the first decade of 2000s. During the initial years of fertilizer introduction, provincial extension services played a major role in promoting fertilizer based on recommendations made by the Soil Fertility

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[5] For the management of prices, the controller is at the provincial agriculture department. For imports, the Commerce Ministry through NFML has the responsibility.

Research Institute (SFRI) for every crop. However, the emphasis of these demonstrations remained focused on the expansion of fertilizer use, meaning that few products or application methods were either tested or promoted. Meanwhile, SFRI had little success in formulating and disseminating new fertilizer recommendations—either general or site-specific—based on their R&D activities. These limitations in the research and extension system have exacerbated trends toward unbalanced use and resource degradation.

In recent decades, Pakistan's fertilizer industry has undergone several changes aimed at addressing many of these issues. After the gradual privatization of NFC's manufacturing units from 1996 to 2005, NFML's role has become restricted to the distribution of imported urea. In the 2013/14 Rabi season, even this role was reduced further when the government transferred the responsibility for the distribution of urea imports to domestic manufacturers. But subsidies are still central to the production and distribution of fertilizer, with the Ministry of Industry and Production deciding on the production subsidy by controlling the supply of gas to manufacturers, and the NFML deciding on the amount of fertilizer to be imported and the distribution subsidy to be applied.

In sum, the development of Pakistan's fertilizer industry has been both a success story and a source of difficulty for farmers, industrialists, and policymakers alike. The success story was driven by a number of key factors: a major technological shift initially in rice and wheat cultivation during the Green Revolution and later in cotton, sugarcane, and maize; Pakistan's perceived abundant endowment of natural gas at the time; and the willingness of policymakers and investors to build a domestic fertilizer industry from the ground up. But difficulties in sustaining this success have emerged in the form of unbalanced fertilizer use, poor management practices, poor allocation of public resources for R&D, and noncompetitive industrial practices. We examine these elements in the sections that follow.

4. FERTILIZER USE

To provide a better sense of how farmers actually use fertilizer in Pakistan, this section examines application rates at the country and cropping region levels.

Data in this section are drawn from three sources. First, fertilizer use across agro ecological zones and provinces is provided, at an aggregated level, from the NFDC.[6] Second, data on yield response and soil nutrient contents are drawn from SFRI, collected from laboratories present at the district levels in every province.[7] Third, household data are drawn from the first round of the Pakistan Rural Household Panel Survey (RHPS) conducted in 2012 (IFPRI/IDS 2014). RHPS data on fertilizer use, yields, and related variables are specifically drawn from a subsample of 942 agricultural households across three provinces surveyed in November 2012 under RHPS Round 1.5.

According to the NFDC data, total fertilizer offtake increased over 14 fold between 1970 and 2014 in Pakistan (Appendix Table A.1). The three-year average per hectare N use increased from 20 kg during 1970–1973 to 133 kg during 2011–2014, while phosphate fertilizer increased from 2 kg to 33 kg per ha in the same period. The total soil nutrient application increased from 17 kg per ha in 1970–1971 to 180 in 2013–2014 (Appendix Table A.2). The latest application rate is higher than that of India (141 kg/ha), but less than that in the neighboring Indian Punjab (229 kg/ha).[8] The highest increase in per hectare fertilizer use was recorded in 2009–2010, when the output–fertilizer price ratio jumped to a record level. Crop-Level Availability

Average per hectare availability of fertilizer for major crops was estimated by dividing fertilizer offtake by crop with its acreage for each year. The fertilizer nutrient offtake, as estimated from secondary data, varied among crops (Figure 4.1). The highest use was for sugarcane and, lately, cotton. Rice and maize have received the lowest application, and the use for these crops has in fact decreased since 1999. The highest fluctuation in per hectare fertilizer use was observed in sugarcane mainly because of its cyclical production and price fluctuation behavior. Despite relatively low per hectare application of fertilizer on wheat, it consumes over 50 percent of the total offtake in the country because wheat has the largest acreage. The large consumption requirement for wheat, which has a very rigid planting season in November, puts huge pressure on the fertilizer industry. The huge demand in a short period in combination with poor planning in the public sector to manage imports often creates seasonal shortages, especially for the Rabi season. A surprising increase in per hectare fertilizer use in cotton without corresponding increase in its yield clearly indicates inefficiency. Despite only a 14 percent share in cropped area, cotton now consumes 25 percent of all fertilizer in the country (Appendix Table A.3).

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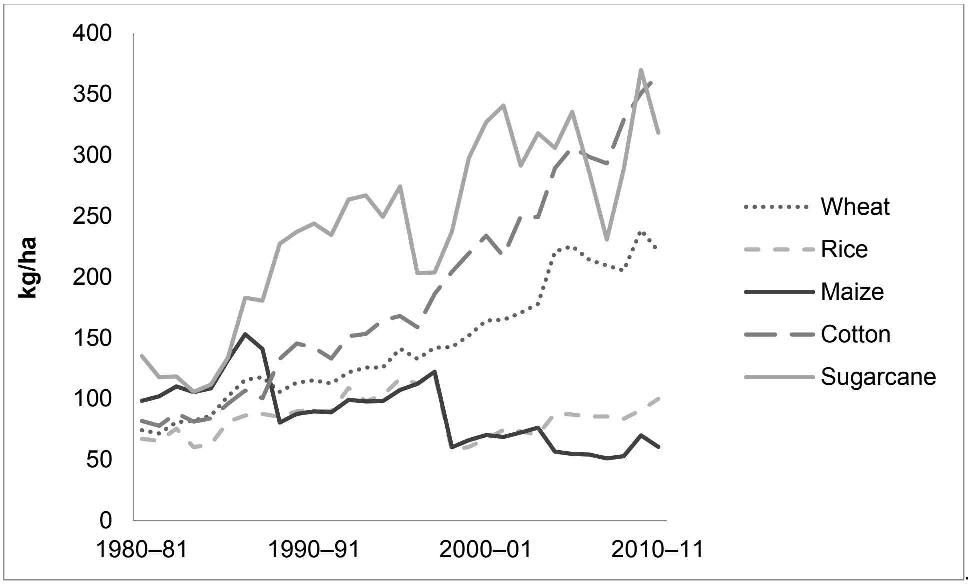
[6] All fertilizer traders in the country registered with the extension department are obliged to provide daily sale, price, and stock information to the extension wing of the provincial agriculture departments. The NFDC collects this information and also from importers and companies directly to verify these data. Daily prices of fertilizer products are collected from the Pakistan Bureau of Statistics. We used annual values for our analysis.

[7] These laboratories are engaged in research and development activities to increase agricultural production by improving plant nutrition management, together with a better use of other production factors. The Field Wings of SFRIs carry out experiments on farmers' fields every year for various crops and cultivars to evaluate optimum nutrient requirements and provide general and site-specific fertilizer recommendations.

[8] One reason for this low average use compared to Indian Punjab is that a larger area in the Pakistani Punjab is barani in northern and southern Punjab, where fertilizer use is significantly lower than the national average due to a lack of water.

Figure 4.1 Fertilizer use by crop, 1980–2011



Source: NFDC (2014).

Regional Variation

Per hectare fertilizer nutrient use by cropping region was also estimated from the district-level fertilizer offtake (Appendix Table A.4). Surprisingly, fertilizer consumption in Pakistan's province of Punjab, home of about 60 percent of Pakistan's agriculture, exhibited both the lowest level of nutrient use and the slowest growth rate between 1990–1991 and 2011–2012 (Table 4.1). The highest levels of nutrient use were found in Sindh, and the highest rate of growth was found in Baluchistan, which is the home of only 7 percent of agricultural output. Fertilizer use in barani areas in the northern and southern Punjab and Khyber Pakhtunkhwa are significantly lower than the national average, although the rate of increase in Khyber Pakhtunkhwa barani areas has been significantly higher than the national average. The highest growth in fertilizer use is observed in the Baluchistan horticulture region, followed by the wheat-cotton region of Sindh, while the lowest growth is observed in the wheat-cotton region of the Punjab.

Table 4.1 Fertilizer use by cropping region (kg/ha), 1990/1991 to 2011/2012

Cropping region	1990–1991	1995–1996	2000–2001	2005–2006	2010–2011	2011–2012	Annual growth rate (%)
Pakistan	**89**	**111**	**135**	**169**	**166**	**165**	**2.98**
Punjab	**90.7**	**114.9**	**107.4**	**150.7**	**158.7**	**157.4**	**2.66**
Barani	19.6	22.4	23.2	30.3	58.5	36.1	2.93
Mixed crop	70.0	103.1	94.1	134.2	136.52	137.2	3.26
Wheat-cotton	137.7	175.2	148.9	209.4	213.5	210.0	2.03
Wheat-rice	70.4	90.9	83.7	134.7	160.7	157.1	3.90
Wheat/gram-mung bean	67.9	66.7	80.4	107.2	112.2	115.4	2.56
Sindh	**88.0**	**134.7**	**154.9**	**208.8**	**246.9**	**296.5**	**5.96**
Mixed crops	136.3	123.0	151.3	179.1	154.6	325.8	4.24
Wheat-cotton	60.4	161.6	182.6	233.6	365.1	363.9	8.93
Wheat-rice	100.4	107.1	121.8	201.5	167.6	185.0	2.95
Khyber Pakhtunkhwa	**59.4**	**70.0**	**90.1**	**161.1**	**156.2**	**172.7**	**5.21**
Barani	16.8	20.1	24.9	129.4	110.9	69.2	6.99
Mixed crops	72.0	88.3	108.6	169.7	166.6	199.3	4.97
Baluchistan	**28.7**	**31.9**	**65.0**	**299.5**	**148.2**	**215.2**	**10.06**
Wheat-cotton	31.6	22.4	40.8	1496.8	65.4	109.2	6.09
Horticulture	26.8	43.1	100.5	325.44	256.0	352.6	13.06

Source: Authors' calculations based on NFDC (1998, 2002, and 2008).

Notes: All districts in a province having a common major kharif season (May–October), such as cotton, rice, or gram-mung bean, are merged into separate cropping regions. For example, the wheat-cotton region implies that the region is dominated by the cotton crop in kharif. The district where no crop dominates in kharif is called a mixed cropping region. Moreover, all districts in a province where 85 percent of the area depends on rain for irrigation are categorized as a barani region. In Baluchistan, horticulture regions consist of districts where horticulture cultivation in the valleys dominates. The data for 2010–2011 and 2011–2012 were collected from NFDC headquarters in Islamabad.

Fertilizer Use under Microenvironments

Overall, there was no significant difference in fertilizer nutrient applications across different soil types. Normally, lower levels of fertilizer nutrients are applied on poor land and the highest use is on most the fertile lands (Table 4.2). This is contrary to the higher recommended fertilizer doses for less fertile lands. However, this may be because those farming on poor lands have greater cash and credit constraints. Moreover, Table 4.2 indicates that 96 percent of farmers who have clay/clay loam soil use fertilizers, while, somewhat surprisingly, a mere 61 percent of the farmers who operate more than 12 acres of land use any type of fertilizer on their plots.

Table 4.2 Fertilizer use (kg/ha) in microenvironments, 2012

Type	Nitrogen	Phosphorus	Potassium	Overall	Fertilizer users (% of farmers)*
Fertilizer nutrient use	120.94 (1326)	38.24 (972)	0.54 (9)	159.72 (1326)	87.00
Soil type					
Sandy and sandy loam	117.56 (437)	37.12 (322)	0.37 (3)	155.05 (437)	89.73
Loam	121.48 (426)	38.56 (318)	1.01 (5)	161.06 (426)	90.25
Clay and clay loam	126.30 (463)	39.34 (334)	0.27 (1)	165.90 (463)	96.46
Land quality					
Highly fertile	127.44 (230)	39.42 (172)	1.14 (2.)	168.00 (230)	93.12
Moderate fertile	121.66 (1069)	38.47 (788)	0.43 (7)	160.55 (1069)	91.92
Poor/very poor fertile	77.70 (27)	23.83 (14)	0.00 (0)	101.54 (27)	93.10
Farm size					
Less than 12 acres	122.84 (1155)	37.37 (824)	0.56 (7)	160.77 (1155)	92.92
More than 12 acres	114.91 (171)	44.44 (150)	0.46 (2)	159.80 (171)	61.07**

Source: Authors' estimates based on IFPRI/IDS (2014).

Note: * This column reports the percentage of farmers using fertilizer within a given soil type, land quality, and so forth. Category. ** This low number is due to a high number of missing observations for this category. Parentheses represent frequencies of plots in each category.

5. YIELD RESPONSE AND OPTIMUM LEVELS

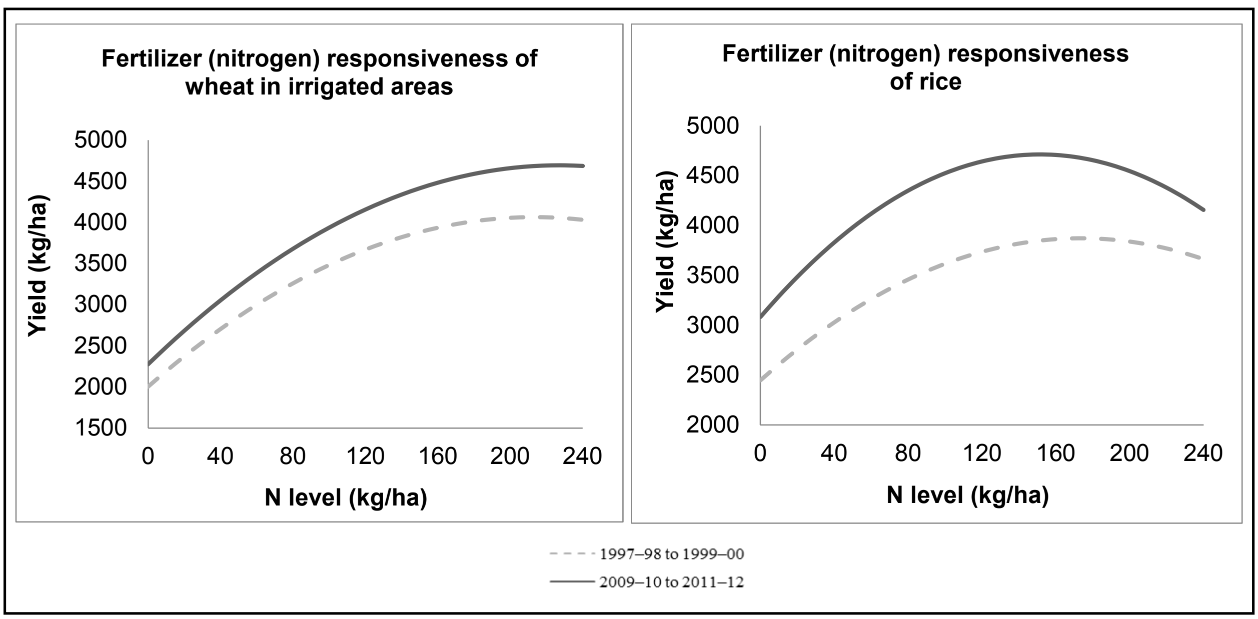
This section estimates the yield response with respect to fertilizer under experimental or optimal control, and separately, under farmers' conditions. The purpose is to quantify the contribution of fertilizer in crop production under various environments, keeping other inputs constant under an experiment situation or allowing them to vary under a farmer's control.

Response at Experiment Station

Yield responses of major crops to different fertilizer nutrient levels were estimated by using SFRI Punjab data collected from long-term controlled experiments on farmers' fields. Experiments were conducted separately for N and P, where the level of one specific nutrient (the one being examined) was set at five different levels while the other nutrients were fixed at recommended levels. The same layout was used every year, except the crop variety was changed to reflect the most common variety for that year. Other management practices, such as seed rate, number of irrigations, and so on, were kept at recommended levels. Data for three years at two selected intervals (1997/1998 to 1999/2000 and 2009/10 to 2011/2012) were combined to run the linear regression separately for N for wheat in irrigated areas and rice. (Cotton was also analyzed and a summary is reported below.)

The results indicate a positive relationship between yield and N levels, suggesting a significant increase in yield from increased N. However, the response turns negative at higher levels of N (because the squared term for N in the equation is negative). The N level at which the yield starts declining depends upon the crop and its variety, environment, and management practice. In the response function in Figure 5.1, during the latest period, the yield starts declining at about 230 kg per ha in the case of wheat and 160 kg per ha in the case of rice. This turning point is even lower in the earlier period, when different crop varieties were used. The responses were relatively weak in barani areas (not reported in the figure) compared to those in irrigated areas.

Figure 5.1 Yield response of fertilizer from experiment data



Source: Authors' calculations based on SFRI (2013a).

The results also indicate that the most recent period has a higher intercept than the earlier period for nitrogen in wheat and rice in irrigated areas, thereby indicating that the change in variety may be the primary reason for the upward shift in the yield response curve (Figure 5.1).[9]

Response under Farmers' Conditions

We also estimate a yield response function for wheat from the RHPS data. To do this, a semi-log estimation was conducted, where the log of per hectare yield was regressed on the quantities of various inputs and their squared terms, resource quality variables, climate-related variables, and district dummies (see Appendix Table A.5 for variable definitions). The production elasticities of all variable inputs were estimated at their mean values, keeping all other inputs constant (see Appendix Table A.6 for the mean and standard deviations).[10]

Results presented in Table 5.1 indicate the following. First, an obvious finding is that yield is significantly responsive to nitrogen use, but is also subject to decreasing marginal returns as captured in the squared term of nitrogen use. The estimate of the fertilizer production elasticity, at an average level of its use, suggests that a 1 percent increase in nitrogen use over the mean level (114.7 kg per ha) results in a 0.16 percent increase in wheat yield. However, the actual impact on productivity will be lower from gains in input use because the production elasticity declines significantly at higher levels (Figure 5.2). Interestingly, the elasticity is essentially flat for a large range lower than the average level, suggesting that decreasing its use (say, by removing the subsidy) will lead to reduced production and not affect fertilizer productivity more than the value at the mean level. These results have significant implications for using fertilizer subsidies as a tool to influence wheat productivity.

Surprisingly, the use of phosphorus, included as a dummy variable in the model, did not have a significant impact on yield. This may be due to the large number of observations that did not report any use of phosphorus; the little variation in its use across the sample; and its highly correlated use, whenever reported, with the use of nitrogen.

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[9] Similar trends were observed for nitrogen in cotton and for phosphorus in cotton, rice, and wheat. However, the earlier years were best approximated by linear functions, which was perhaps due to a narrow range of fertilizer levels used in the experiment.

[10] Previous literature mostly uses a log-log functional specification (Zuberi 1989). However, in our case the semi-log form fit better and gives more consistent results.

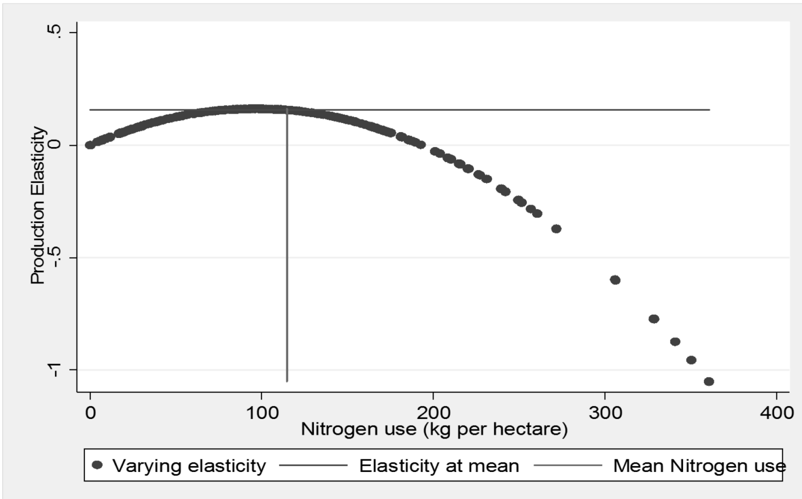
Table 5.1 Yield response function of wheat (kg/ha)

Variables	Log of Yield (kg/ha) of Wheat
Inputs (units/ha)	
Hired labor (hours)	0.000711***
	(0.000178)
$(\text{Hired labor})^2$	-1.23e-06***
	(4.32e-07)
Family labor (hours)	0.000162
	(0.000203)
$(\text{Family labor})^2$	-2.41e-07
	(4.18e-07)
Tractor usage (hours/ha)	0.0336***
	(0.0126)
$(\text{Tractor usage})^2$	-0.00172*
	(0.000986)
Total sprays (number)	0.109***
	(0.0294)
$(\text{Total sprays})^2$	-0.0323***
	(0.00739)
Nitrogen used (kg/ha)	0.00335***
	(0.00105)
$(\text{Nitrogen used})^2$	-1.74e-05***
	(6.63e-06)
Was phosphorous applied? (Yes=1, No=0)	-0.0396
	(0.0718)
Total seed used (kg/ha)	0.000727
	(0.00210)
$(\text{Total seed used})^2$	1.28e-06
	(1.25e-05)
Ground water irrigations (No)	0.00609
	(0.00987)
$(\text{Ground water irrigations})^2$	-0.000428
	(0.000912)
Canal water irrigations (Number)	0.0344***
	(0.00969)
$(\text{Canal water irrigations})^2$	-0.00305***
	(0.00106)
Resource Quality	
Is the soil highly fertile? (Yes=1, No=0)	0.237***
	(0.0822)
Other Factors	
Visit by extension agent (Yes=1, No=0)	-0.0308
	(0.0314)
District dummies	Yes
Constant	7.106***
	(0.127)
Observations	755
R-squared	0.555

Source: Authors' estimates based on IFPRI/IDS (2014).

Notes: Standard errors corrected for heteroskedasticity and are shown below the coefficients in parenthesis. * Significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent. Some insignificant results were not presented for the sake of brevity.

Figure 5.2 Production elasticity with respect to nitrogen use per hectare



Source: Authors' estimates using IFPRI/IDS (2014).
Notes: The elasticities are calculated at each observation of nitrogen use. The vertical line represents the mean value of nitrogen use (114.7 kg per hectare), whereas the horizontal line marks the elasticity (0.16) at the mean level.

In addition to the fertilizer and irrigation, all major inputs in wheat production were reflected, including hired labor, tractor services, seed, and irrigation. They are generally significant, with positive linear terms and declining squared terms, suggesting a positive but diminishing contribution to yield of each input. The production elasticities with respect to the inputs of canal water irrigation, hired labor, pesticide sprays, and tractor usage are 0.07, 0.06, 0.08, and 0.09, respectively.

Optimum and Actual Levels of Fertilizer Use

Optimal (profit-maximizing) values of fertilizer can be calculated from the response functions estimated from the SFRI data collected under experimental conditions, using fertilizer and commodity prices in 2011–2012. The optimal, or profit-maximizing, level of fertilizer is where the marginal value of the input is equal to the unit cost of the input, or the marginal value–cost ratio (MVCR) is equal to one.

For wheat and cotton, the respective optimal values of nitrogen are estimated to be 183.5 and 209.0 kg per hectare, more than 50 and 30 percent higher, respectively, than the average reported use of 119 and 123 kg per hectare (Table 5.2). The difference indicates a potential of fertilizer use if all socioeconomic and institutional constraints at the farm level are removed. For rice, the optimal value of nitrogen, 132.8 kg per hectare, is fairly close to the average of 123. However, the optimal value of nitrogen for wheat in barani conditions (not reported in the table) is much lower, at around 108 kg per hectare (SFRI 2013a). This reflects the sensitivity of yield response to fertilizer with a timely and sufficient availability of water.

Table 5.2 Fertilizer nutrient use (kg/ha) by crop, 2012

	Nitrogen (N)			Phosphorus (P)		
Crops	Actual	Optimal	Ratio (Actual/Optimal)	Actual	Optimal	Ratio (Actual/Optimal)
Wheat	119.4	183.5	0.65	43.9	114.8	0.38
Rice	123.0	132.8	0.93	36.0	208.8	0.17
Cotton	123.1	209.0	0.59	37.3	107.2	0.35

Source: Authors' calculation based on IFPRI/IDS (2014) and SFRI (2013a).
Notes: The optimal values are calculated by the authors using the nitrogen and phosphorus response equations estimated and provided by SFRI (2013a). The values of N and P (actual) are calculated using IFPRI/IDS (2014).

In addition, in Table 5.3, we use nitrogen coefficients estimated from the farm survey data in Table 5.1 to derive the MVCR ratio across different levels to find the value that equals 1.0, indicating optimum use. The MVCR ratio for nitrogen applied to wheat under the farmers' condition is one at around 126 kg per hectare when the subsidy is included (Table 5.3). This is almost equal to the actual level of 119 kg per hectare under the farmers' own set of resource-quality and socioeconomic constraints. This is lower than the optimal value of 183 kg /ha estimated from SFRI's experimental data obtained under controlled research environments. The optimum level of nitrogen use under farmers' conditions drops to 110 kg per ha, or by 8 percent, when the fertilizer price without a subsidy is used in the calculation[11] (Table 5.3). Using the production elasticity of 0.16,[12] this drop will bring a 1.3 percent reduction in wheat production, which costs farmers about PKR 11.8 billion through lower sales.

Table 5.3 Marginal value-cost ratio at different levels of fertilizer use with and without subsidy in wheat production in Pakistan, 2011–2012

Nitrogen level (kg/h)	MP (kg of wheat/kg of fertilizer)	MP*PR (PKR/kg of fertilizer)	Cost of nitrogen with subsidy (PKR/kg)	Subsidy on nitrogen (PKR/kg)	Cost of nitrogen without subsidy (PKR/kg)	MVCR (with subsidy)	MVCR (without subsidy)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
70	6.0	137.3	74.7	18.1	92.8	1.8	1.5
100	4.5	103.8	74.7	18.1	92.8	1.4	1.1
110	4.03	92.6	74.7	18.1	92.8	1.3	1.0
120	3.5	81.4	74.7	18.1	92.8	1.1	0.9
126	3.2	74.7	74.7	18.1	92.8	1.0	0.8

Source: Authors' estimates based on IFPRI/IDS (2014), Pakistan, MNFSR (2013), and HDIP (2013)

Note: PKR = Pakistani rupees. MP = Marginal productivity of fertilizer in column (2) derived from the estimated production function by taking its first derivative and evaluating it at the mean value of all other inputs, where PR (is the price of output in column (3). VCR = Value cost ratio in columns (7) and (8) are estimated as the value of marginal productivity in column (3) divided by the per unit cost of fertilizer with subsidy in column (4) and without subsidy in column (6), respectively.

[11] We assume here that the subsidy given on fertilizer processing (calculated in a later section) is completely passed on to farmers, and reduction in the subsidy on 1 kg of fertilizer will increase its price by an equal amount. These assumptions will be tested in a following section.

[12] This is the elasticity at the mean value of nitrogen use, which is valid to use to look at the yield effect for the reduction of fertilizer use from 126 kg to 110 kg, given the small changes in elasticities seen in Figure 5.2.

6. FERTILIZER USE INEFFICIENCIES

Next, we explore the issue of inefficiency in fertilizer use. Many researchers (Rashid et al. 2013; Sankaram and Rao 2002; Bumb and Baanante 1996) have pointed out the negative implications for the misuse of fertilizer on long-term sustainability of agricultural production. The process through which it happens is explained in Rashid et al. (2013), borrowed from the United Nations Environment Program. The misuse of fertilizer can result in environmental damage, soil degradation, increased deforestation, and depletion of the natural resource base. Fertilizer use produces most efficient results when fertilizer-responsive varieties are used and it's most dissolvable form is placed nearest to the root zone of the plant, in the right proportions and at the appropriate time. Also, the best productivity comes when the land is precisely prepared, and other inputs such as water are available and applied in a timely manner. While general and site-specific recommendations for fertilizer use along these lines are available in Pakistan (SFRI 2013a), few farmers pay much attention to them. The reasons for this are complex and range from exogenous constraints, such as the unavailability of surface irrigation or rainfall, to more internal constraints, such as the unavailability of cash and labor, or the effort and drudgery associated with adhering precisely to recommended practices.

That said, fertilizer policies and investments in Pakistan have tended to overlook the promotion of fertilizer practices that can improve its efficiency. For example, fertilizer subsidies have been primarily allocated to the promotion of urea, despite the fact that its use is quickly reaching its optimal level (as the data suggest), while other nutrients—namely, phosphorus and potassium—are both underutilized by farmers and were overlooked, until recently, by the subsidy policy. Meanwhile, extension agents tend to place limited emphasis on educating farmers on practices that can improve fertilizer-use efficiency, such as timeliness of application, application methods, and appropriate combinations of different fertilizers.

The balanced use of fertilizer is very important in improving its efficiency. Haerdter and Fairhurst (2003) show that the recovery of N increases from 16 percent within a traditional NP fertilization program to 76 percent in a balanced NPK application. Also, the recovery of P improves with balanced fertilization—namely, from 1 percent using NP to 13 percent with NPK—and the recovery of K increases from 22 percent with a nitrogen potassium application to 61 percent with NPK fertilization. In Pakistan, the recommended ratio of N: P is 1:0.5 (NFDC 2014), while the optimal level for K is to be determined, as its use in the country is very small. However, the average use of P and the N: P proportion are far from optimal (Appendix Table A.2). In fact, the ratio of N: P has dropped from its peak of 1:0.37 in 2006–2007 to 1:0.20 in 2011–2012. The ratio of N: K reached its peak at 1:0.036 in 1985–1986 but then gradually decreased to 1:0.007 in 2013–2014. The unbalanced use of fertilizer, which deteriorates the release of all nutrients, including those used in abundance, has not only serious implications for nutrient-use efficiency and agricultural productivity but also for the environmental sustainability and quality of produce (Concepcion 2007; Gruhn, Goletti, and Yudelman 2000).

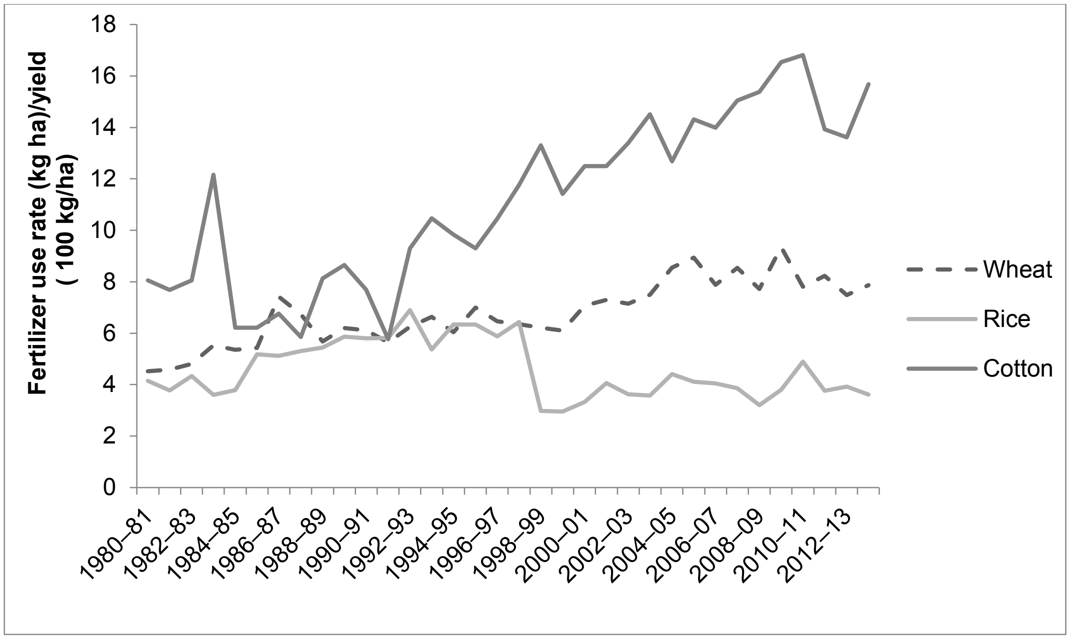
Fertilizer-use efficiency (defined as fertilizer nutrient use [in kg] divided by yield [in 100 kg per hectare]) has declined in Pakistan for both wheat and cotton, as more fertilizer per unit of yield has been required over time (Figure 6.1). Possible explanations include increasing resource degradation, such as salinity, water logging, or decreases in organic matter and other nutrient contents in the soil, which we will discuss further below. In only a few cases, since the Green Revolution, have technological changes, such as the introduction of new, more fertilizer-responsive varieties or a change in soil and water management practices, helped address this problem.[13]

Production of 100 kg of wheat in 1980–1981 required 4 kg of fertilizer nutrient, but by 2014, the same amount of wheat production required 7.9 kg of fertilizer nutrient. A similar trend is observed in cotton, although fertilizer-use efficiency in rice has remained largely unchanged. As a result of declining

[13] An exception is the introduction of a new basmati rice variety, which was introduced in 1996 after an increasing trend in fertilizer requirements were observed. This new variety led to a onetime jump in nutrient-use efficiency in rice, indicating the importance of continuous introduction of new varieties to maintain fertilizer-use efficiency (Ali and Flinn 1989).

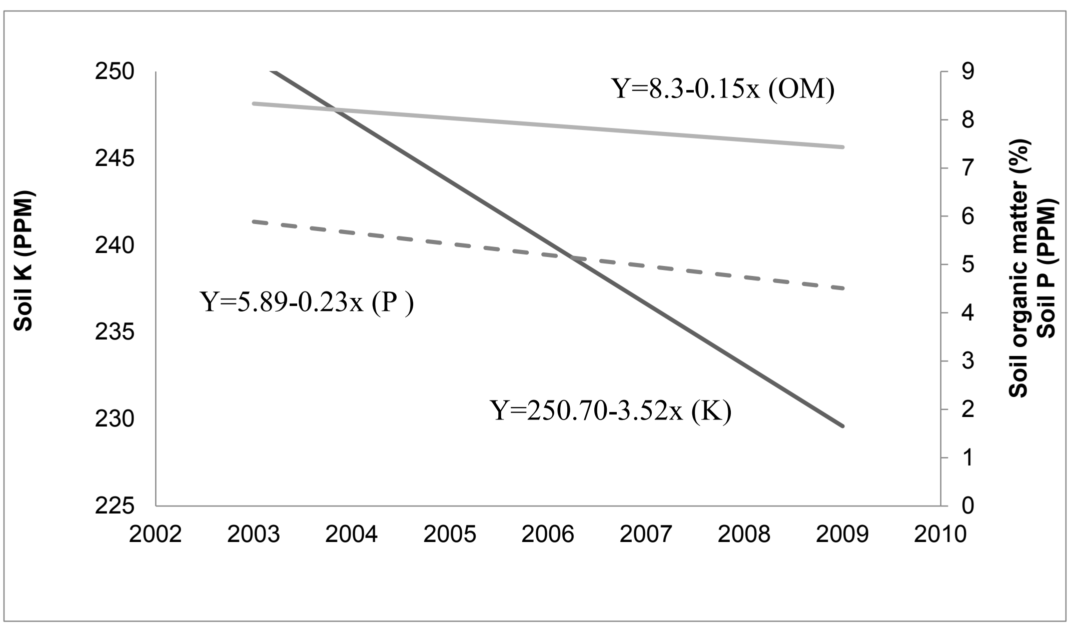
fertilizer and water partial productivities, growth in total factor productivity slowed and later stagnated. Pakistan's total factor productivity growth has gone from being among the best in the world in the 1980s to the lowest among such Asian comparators as China, India, and Sri Lanka (Ahmed and Gautam 2013).

Figure 6.1 Ratio of fertilizer use/yield, 1980–2014



Source: Authors' calculation based on NFDC (2014), Pakistan, MNFSR (2013), MNFAL (2007a), and MNFAL (2007b).

Figure 6.2 Nutrient depletion in Punjab, Pakistan, 2003–2009



Source: SFRI (2013b).
Note: PPM = parts per million.

Failure to use fertilizer appropriately can lead not only to inefficiencies at the farm level but also cause resource degradation on a wider scale (Ahmed and Gautam 2013; Ali and Byerlee 2002). Both over- and underutilization of fertilizer and poor management of resources have damaged not only the environment but also soil resources (Conway and Pretty 1991; Bumb and Baanante 1996; NRC 1989). Research from other parts of the world has found that an imbalance of urea with P and K has resulted in excessive soil mining, which caused yield stagnation (Concepcion 2007). In developed countries, applications of fertilizer nutrients led to environmental contamination of water supplies and soils (Gruhn, Goletti, and Yudelman 2000).

In Pakistan, the absence of farming practices that adjust nutrient applications to land resources has resulted in over-mining of several essential soil micronutrients, such as phosphorus, iron, zinc, and potassium. The underutilization of micronutrients and reduction in the application of farm manure has decreased organic matter content to threateningly low levels (Figure 6.1).

7. PRICING BEHAVIOR AND GOVERNMENT INTERVENTIONS

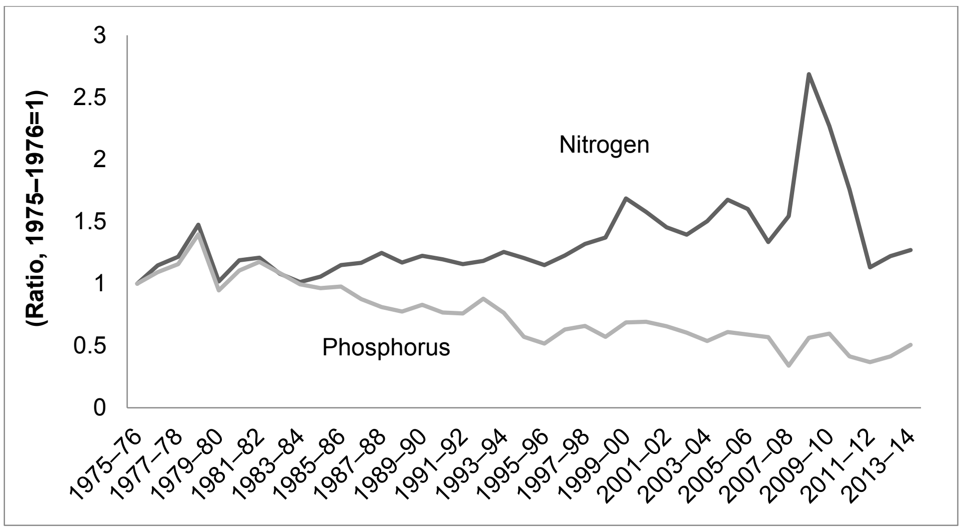
Relative Prices

This section examines the input prices of fertilizer compared to major outputs, the extent of government interventions in the fertilizer industry, and international and regional competitiveness to show the costs of these interventions.

Fertilizer prices—in real terms and relative to output prices—have evolved in Pakistan as follows. The grain output prices (weighted average of wheat and rice) increased more than the N price, implying that one unit of N purchases more grain in 2014 than in 1976. A similar decrease in real fertilizer prices is observed in other Asian countries like India, Bangladesh, and Indonesia, but the decline is lowest in Pakistan (Rashid et al. 2013).

However, the opposite was true for P (Figure 7.1). In terms of input-output prices, farmers did not lose overtime and their profitability did not shrink due to increased nitrogen prices. However, the decline in fertilizer-use efficiency in Pakistan, as discussed earlier, does have a detrimental effect on the profitability of fertilizer use.

Figure 7.1 Output price to N price ratio, 1975–2014



Source: Authors' estimates from NFDC (2014), Pakistan, MNFSR (2013), MNFAL (2007a, 2007b, and 2007c).

Fertilizer Policy

The fertilizer policy of 2001 is built around the provision of a gas subsidy to the manufacturing of urea. It states:

> It is the intent of this policy to provide investors in new fertilizer plants in Pakistan a gas price that enables them to compete in the domestic market with fertilizer exporters of the Middle East so that indigenous production is able to support the agricultural sector's requirement by fulfilling fertilizer demand.

Clearly, the policy encourages import substitution to meet demand from indigenous sources. Differential and low rates of gas were offered to new plants to encourage investment, which is currently being availed by Engro and Fatima Fertilizer. More important, the fertilizer policy ignores the distribution, demand, and utilization sides, particularly of farmers' and traders' interests. Thus, the policy fails to offer incentives to enhance efficiency in fertilizer distribution and application, and encourage more efficient and new products.

Fertilizer Subsidies

Gas Subsidy

Public subsidies for the production and distribution of fertilizer have evolved over time. The most significant subsidy comes through the provision of natural gas to urea producers, and approximately 16 percent of the total gas consumed in the country was used by the fertilizer industry (HDIP 2013). The government subsidizes fertilizer manufacturing through a dual gas price policy: one price exists for the fuel stock applicable to the general use of gas, while another, which is far lower than the market price although closer to the Middle East price, is for gas used in fertilizer manufacturing. The subsidy is made available to all urea producers, although issues with access to gas for smaller producers do exist.[14]

In Pakistan, over the 2005–2014 period, feedstock prices were lower than Middle East prices for five nonconsecutive years and vice versa for the remaining five years. On average, the Pakistani and Middle Eastern prices are insignificantly different. On the contrary, these prices are substantially lower than the U.S. gas prices, which can be seen as a proxy for international prices (Appendix Table A.7). The fuel stock prices are comparable with other sectors in the Pakistan economy, except for the energy sector, where the prices are lower. Thus, fuel stock prices can be taken as an opportunity cost for the feedstock gas.

We estimated the production subsidy on fertilizer manufacturing by taking the firm-level difference in fuel stock and feedstock prices and multiplying it with the respective amount of gas used in each firm. Following this approach, the total value of the production subsidy during 2013–2014 is estimated as PKR 48 billion, which has gradually increased from PKR 2.11 billion in 1995–1996 (Table 7.1). While the prices of fuel stock increased by over seven times, the growth in the feedstock price was less than three during the period. The difference in fuel and feedstock prices grew more than 15 times, which when multiplied by a 40 percent increase in feed gas consumption, resulted in an expansion of the gas subsidy by over 22 times over the period (Table 7.1).

There were clearly two upward shifts in the production subsidy shown in Table 7.1, one in 2002, when it jumped by four times, and the other in 2008, when it increased by 1.7 times. The later jump overlapped with the start of the ongoing crisis of gas shortages in the country. Some shortage of gas to the expanded fertilizer sector, comparing 2014 to 2007, is apparent from the gas supply data in Table 7.1. (However, a more severe shortage was observed in the cement industry, where it declined about 39 percent, and in the power sector, where 4 percent less gas has been supplied since 2006.) The effect of the gas shortage on the fertilizer industry is obvious from its underutilized capacity.[15]

[14] The approval of plant installment from the Production Ministry was linked to the gas that could be supplied. Some smaller firms (with the exception of FFC, Fatima Fertilizer, Engro Fertilizer Limited, and Agritech) complained about facing 35 to 50 days of shortage in a year. No schedule of gas supply was provided, which deterred companies from making operational plans. This increased their fixed and operational costs (Mr. Nadeem Tariq on August 15, 2013).

[15] Capacity expanded due to new plants of Engro in 2010 and capacity enhancement of FFC in 2009.

Table 7.1 Trends in production subsidy, 1995–2014

Year	Gas prices (RS/MCF) feedstock	Fuel stock	Difference in price	Gas consumed (billion MCF)	Total production subsidy* (Billion PKR)
1995–1996	44.2	67.6	23.4	90.2	2.11
1996–1997	47.7	77.7	29.9	90.0	2.69
1997–1998	52.7	77.7	25	88.2	2.20
1998–1999	49.5	80	30.5	100.6	3.07
1999–2000	56.9	88.1	31.2	105.7	3.30
2000–2001	63.9	117.2	53.2	106.0	5.64
2001–2002	70.8	95.6	24.7	110.0	2.72
2002–2003	76.1	170.4	94.4	112.8	10.64
2003–2004	79.6	175.7	96.1	116.1	11.16
2004–2005	61.2	185.7	124.5	119.9	14.93
2005–2006	110.8	229.2	118.4	124.2	14.71
2006–2007	124.7	256.7	132.0	122.8	16.20
2007–2008	124.7	256.6	132.0	128.1	16.90
2008–2009	120.3	341.2	220.9	129.6	28.63
2009–2010	132.3	360.4	228.1	140.5	32.05
2010–2011	138.7	375.2	236.5	140.7	33.29
2011–2012	161.8	492.4	330.6	135.0	44.62
2012–2013	116.3	460.0	343.7	116.7	41.37
2013–2014	123.4	488.2	364.8	128.3	48.04

Source: Authors' estimates based on HDIP (2013). Gas consumption figures for the sector were obtained from HDIP (2013), NFDC (1998), NFDC (2008), and NFDC (2014).

Note: RS/MCF = Rupees per Million Cubic Feet; MMBTU = million British thermal units; PKR = Pakistani rupees. * The production subsidy on fertilizer is calculated as the difference between fertilizer feedstock and fuel stock prices per MMBTU, multiplied by the amount of feedstock gas used by each firm and then aggregated for the sector. The conversion from million cubic feet (MMCFT) to MMBTU was done at the rate of 1 MMCFT = 950 MMBTU for Sui Southern Gas Company Limited and SNGPL and at the rate of 1 MMCFT = 750 MMBTU for Mari Gas.

The subsidy to each firm depended upon the gas field from which their gas was sourced until 2010 (after which prices were constant irrespective of the gas field) and on the installation date of the plant. The largest beneficiary of the subsidy was Fauji Fertilizer, which received a subsidy of PKR 29 billion in 2011–2012 (Table 7.2).

Table 7.2 Subsidy on fertilizer manufacturing through natural gas pricing, 2013–2014

	Prices (PKR/MMBTU)		Gas consumption[1]	Subsidy[2]
Fertilizer firm	Fuel stock	Feedstock	Billion MBTU	(Million PKR)
Sui Southern Gas Company Limited				
Fauji Fertilizer-Bin Qasim	488.23	123.41	12325	4497
Sui Northern Gas Pipelines Limited				
Pak Arab	488.23	123.41	3034	1107
Dawood Hercules	488.23	123.41	1446	527
Pak American	488.23	123.41	3367	1228
Engro Chemicals ENVEN	488.23	73.17	3729	1548
Mari Gas Limited				
Engro Chemicals	488.23	123.41	28931	10554
FFC	488.23	123.41	55044	20081
Fatima Fertilizer	488.23	73.17	20468	8495
Total			128344	48038

Source: Authors' calculation based on NFDC (2014).

Note: PKR = Pakistani rupees; MMBTU = million British thermal units; FFC = Fauji Fertilizer Company Limited. 1 The consumption of gas for each firm was reported after adjusting for the difference in pressure of each field. 2 For the procedure to estimate production subsidy on fertilizer, see the note in Table 7.1.

Distribution Subsidy

In addition to domestic production subsidies, the government subsidizes the importation and distribution of fertilizers in an attempt to maintain domestic prices at a reasonable level. NFML intervenes in the market when the difference in domestic and international prices becomes significant and domestic supply falls short of demand, and does so by importing higher-priced fertilizer and selling it at the lower domestic price. Normally, this intervention is limited to imported urea, but for the first time ever in 2007–2009, the government intervened in the DAP market through a subsidy on imported DAP.[16] Beginning in 2014, the government allowed the private sector to import urea and sell it at the domestic price, while the NFML covers the price difference, including transportation and handling charges.[17] Either way, NFML's intervention in the market is costly for the government (Table 7.3).

Table 7.3 Subsidy on fertilizer distribution (billion PKR)

Year	Subsidy on imported urea (billion PKR)	Imports of Urea (000 tons)	Subsidy on other P&K fertilizer (billion PKR)	Total distribution subsidy
2004–2005	1.85	307	-	1.85
2005–2006	4.54	825	-	4.54
2006–2007	2.05	281	13.7	15.75
2007–2008	2.74	181	17.4	20.14
2008–2009	17.23	905	26.50	43.73
2009-2010	12.87	1524	0.50	13.37
2010–2011	8.41	694	0	8.41
2011–2012	9.55	1075	-	9.55
2012–2013	10.50	833	-	10.50
2013–2014	4.53	1200	-	4.53

Source: Authors' calculation based on NFDC (2014).

Note: P&K = phosphorous and potassium; PKR = Pakistani rupees. Subsidy figures for urea are calculated as import quantity multiplied by the difference between international and domestic prices. The international price is taken as the cost, insurance, and freight price (inclusive of $30 freight charges and general sales tax). The figures for 2011–2014 are collected from the NFDC in Islamabad. The subsidy for P and K is taken from NFDC (2008, 2014).

The total production and distribution subsidy in the fertilizer sector during 2013–2014 amounts to PKR 53 billion (Appendix Table A.8), which is about 20 percent of the existing fertilizer price in PKR per ton (Appendix Table A.9 and 10). It is about 0.21 percent of the national gross domestic product, 0.87 percent of the agricultural gross domestic product, and 6 percent of the annual development expenditure of the country during the year (Appendix Table A.8). The fertilizer subsidy was about ten times the R&D expenditure in agriculture during 2009, the latest year when such expenditure data are available.

In order to conduct a further analysis of the benefits of the subsidy to farmers, we utilize the data discussed above to compare the international price with the production subsidy removed with the actual domestic retail price. If the domestic price is higher than the international price sans subsidy, then it might be more effective to subsidize imports rather than domestic production.

Taxes

General Sales Tax

The government also intervenes in the fertilizer market through its tax policies. In 2001, the federal government exempted urea from the general sales tax (GST), but withdrew the exemption in 2011, along with the taxes on other agricultural inputs that had been exempted. The government charges the tax at the factory gate and manufacturers pass it on to farmers at the retail level through sales agents. If all such

[16] The government has also announced the subsidy on DAP sales for 2014–2015; however, no clear distribution mechanism for the subsidy has been defined (Khan 2014).

[17] However, the standard operating procedures (SOPs) for the mechanism have not been developed yet.

proceeds are honestly submitted, we estimate the total GST revenue (offtake of urea and DAP multiplied by their respective price and the tax rate) from urea and DAP at approximately PKR 50 billion during 2013–2014. It may appear that the government has evened out the burden due to the production subsidy using the GST collection, although farmers see little of the benefit side because, as discussed in the next section, little of the production subsidy is passed on to them while they pay 100 percent of the GST.

Gas Input Development Cess (GIDC)

The government tried to impose 20 percent GIDC on all gas consumers in 2013, except for domestic household consumers. However, the Peshawar High Court struck down the cess in 2014; that decision was maintained by the Supreme Court of Pakistan in its decision on August 22, 2014 (SCP 2014). In response, the government of Pakistan issued an ordinance in October 2014 to impose the GIDC since 2011 to overcome legal lacuna in the earlier bill. The industry again went to the court and got a decision in their favor. Consequently, the government of Pakistan moved a GIDC bill to legislators, which was approved by the National Assembly and Senate during 2015. As a result, PKR 300 per MMBTU was imposed on feedstock while PKR 150 per MMBTU was levied on fuel stock. However, the amount of subsidy to the fertilizer sector still remains substantial.

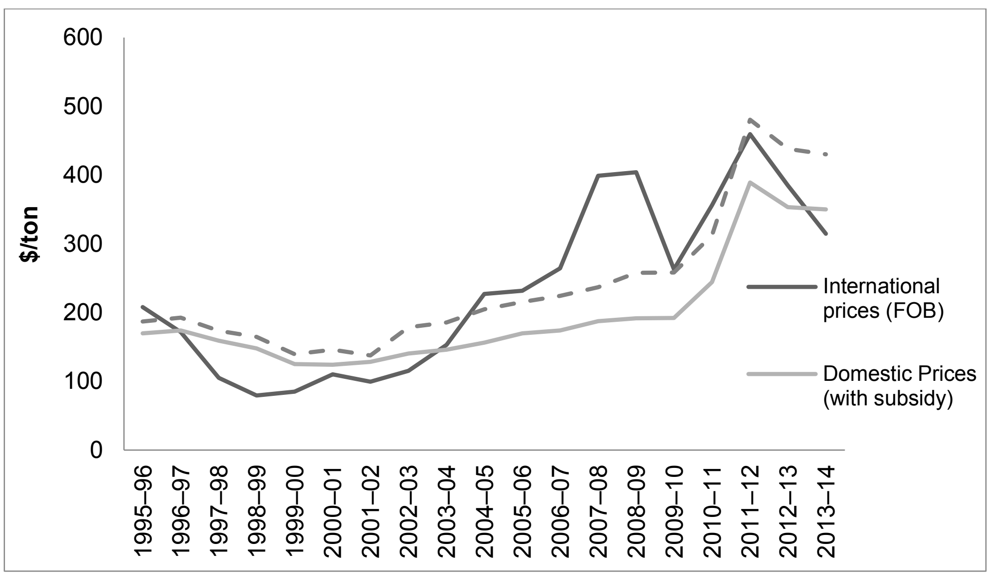
8. COMPETITIVENESS AND PROFIT OF THE INDUSTRY

International Competitiveness

Given the extent of subsidies found in Pakistan's fertilizer industry, it is worth asking whether the industry is actually competitive in the international market for fertilizer. One way to evaluate the competitiveness of the sector is to compare international and domestic prices, both with and without subsidies. The government provides a distribution subsidy on imported urea to meet the gap in supply and demand at existing prices, which are set lower than the international market price. Thus, direct comparison of domestic prices without the production subsidy and international prices provides an indication of competitiveness in the domestic fertilizer sector.

The domestic price of urea (with the gas subsidy) remained higher than the free on board (FOB) international prices until 2004, with the relationship reversing afterward (Figure 8.1). Until 2004, fertilizer imports required subsidies because local prices were not high enough to cover the shipment, loading/unloading, and in-country transport costs. During 2005–2013 the domestic prices were lower and the difference in the two was large enough to cover port and other handling charges, thus creating opportunity for exports, especially to neighboring countries for which transportation costs are lower. This opportunity is unlikely to be explored in the presence of a subsidy as long as domestic demand remains unmet. Until then, exports will exist primarily through informal smuggling channels to Afghanistan.[18]

Figure 8.1 International versus domestic urea prices with and without subsidies, 1995–2014



Source: Authors' estimates based on NFDC (2014).
Note: FOB = freight on board.

The trend once again reversed during 2013–2014, when domestic prices became higher than the international prices despite the gas subsidy on manufacturing, thereby indicating that the sector has once again become uncompetitive with respect to the international market.[19] Again, domestic prices are kept lower than international prices (after adjusting for freight and in-country distribution charges) through a public–private sector interface, so that imports remain blocked.

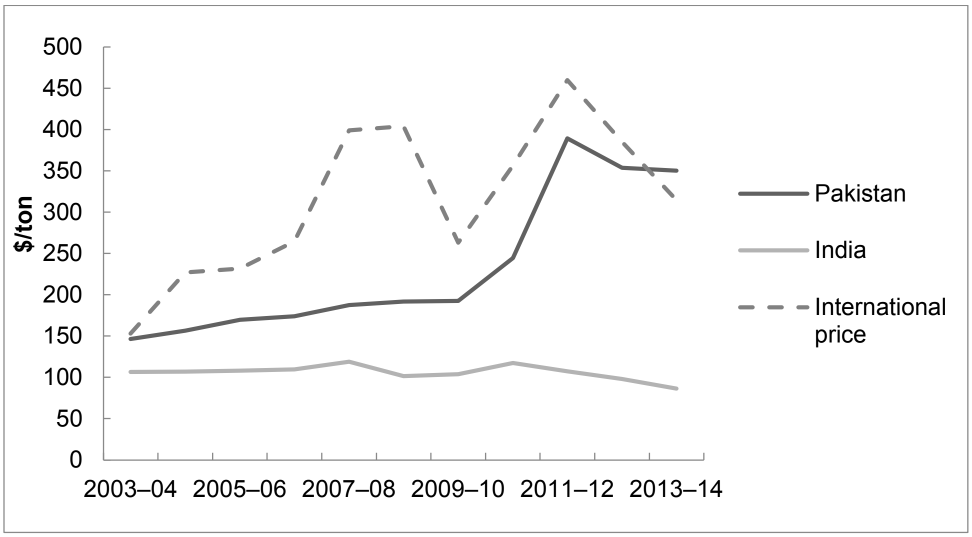
[18] The incentive to smuggle urea into India does not exist because of India's higher subsidy rates: India's retail nitrogen prices with a subsidy remained far lower than Pakistan's over the period 1995–2012.

[19] One encouraging dimension of the price setting was that shocks in international fertilizer prices during 2007 and 2008 were absorbed without any panic in the domestic market.

So what happens when we make the same comparisons without the gas subsidies? To examine this, we adjust the domestic price of urea to account for the gas subsidy by adding the per-unit subsidy to the price. Our analysis indicates that the domestic, unsubsidized price of urea remained higher than the international price during 1996–2004, but during 2005–2011 the prices became almost equal, except for two years during 2007–2009, when international prices reached their peak. During 2011–2014, the situation reversed again and domestic prices became higher than international prices. This suggests that during 1996–2004 and during the last three years, removal of the gas subsidy would have made urea producers uncompetitive in the international market.[20] In summary, during the last 20 years, the fertilizer manufacturing sector without subsidies was competitive with the international market for only six years.

When fertilizer prices are compared between India and Pakistan, keeping the subsidy intact in both countries, Indian prices were far lower than Pakistani prices, suggesting a higher subsidy at the retail level in India (Figure 8.2).

Figure 8.2 Comparison of Indian and Pakistani prices of urea with subsidies, 2003–2014

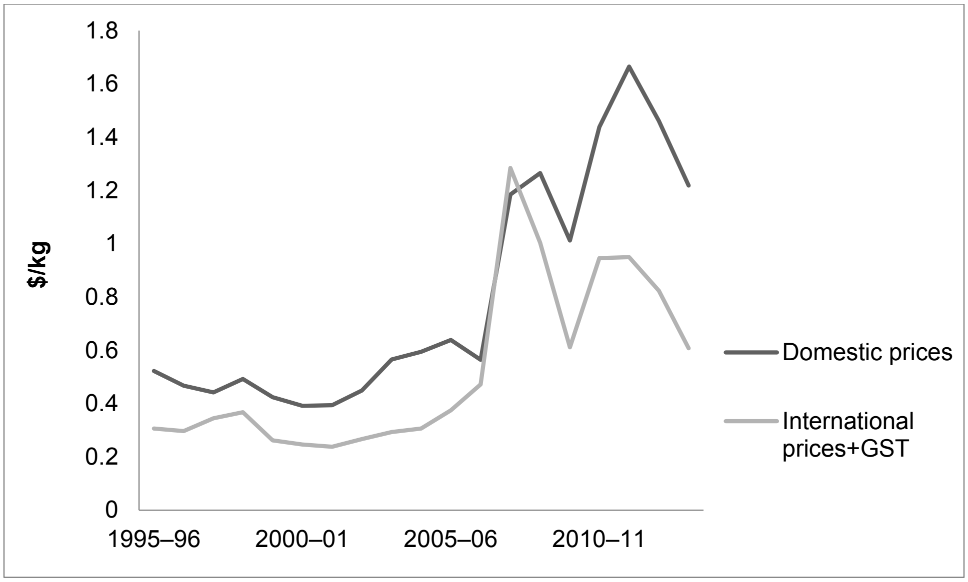


Source: Authors' estimates based on NFDC (2014), DoP (2012), and HDIP (2013).

The domestic phosphate prices followed the international price trend as the former remained higher than the latter, with the difference almost equivalent to transport and shipping costs, except during the peak international price period, when the government provided a subsidy on phosphate fertilizer (Figure 8.3). However, this trend changed after 2010, when domestic prices became much higher than international prices, and the gap increased over time. This may indicate increased price manipulation on the part of DAP manufacturers and importers.

[20] Our analysis shows that Pakistan is not competitive with international market, while the CCP (2010) and IRG (2011) studies concluded the reverse. The conclusion in both of these studies is based on the 2008 and 2009 international and local price situation, while our conclusion is based on the period 1995–2012. In our study, the normalized prices, after adding back the subsidy in domestic prices, are also lower than international prices during 2007, 2008, and 2009.

Figure 8.3 International versus domestic phosphorus prices



Source: Authors' estimates based on NFDC (2014) and HDIP (2013).
Note: GST = general sales tax.

Who Benefits from Production Subsidies

How much of the production subsidies are passed on varies from year to year depending upon the difference between local and FOB prices (both with subsidy and GST). To make both of the prices comparable, we added both the subsidy and the GST to the international prices (Table 8.1).

The positive values indicate years in which local prices remained higher than international prices, after accounting for the subsidy and GST in the latter, indicating that the manufacturers failed to transfer all subsidies to farmers, and vice versa for years with negative values. The values are especially negative for 2007 and 2008, when international prices were extremely high.

The difference is positive for the last year, 2013–2014, suggesting that the industry received more in subsidy than it returned in taxes. For 2013–2014, the difference in prices multiplied by the production level was over Rs. 46 billion. Therefore, fertilizer prices during that year would have been 21 percent lower than the existing market prices had all subsidies that manufacturers received on feed gas been passed on to farmers. Summing up all values in the last column of Table 8.1 over the period of 1995–2014 gives us a positive value of PKR 49 billion, the money fertilizer industry owes to the farmers.

Table 8.1 Subsidy not passed on to farmers

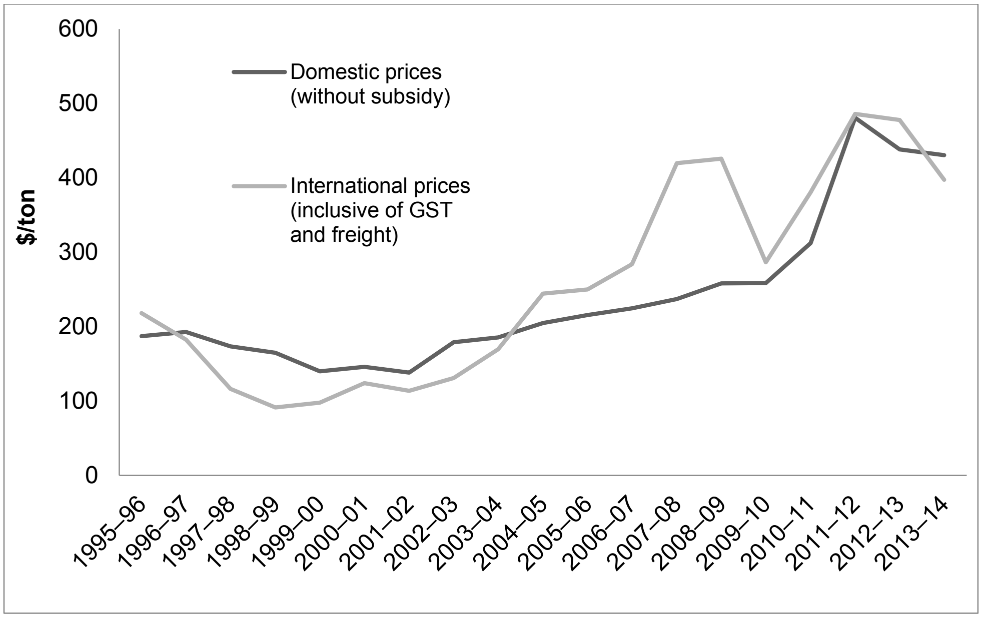
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Year	International prices of urea^ $/ton	Production subsidy (US$/ton)	International prices± (1) - (2)	Domestic prices of urea including GST and subsidy ($/ton)	Subsidy not passed on ($/ton) (4) - (3)	Total urea produced (000 tons)	Subsidy not passed on billion PKR) (5) * (6)
1995–1996	208.2	21.38	186.819	169.80	-17.016	3681	-2.10
1996–1997	171.6	23.62	147.981	173.87	25.894	3655	3.69
1997–1998	105	17.66	87.340	159.27	71.935	3610	11.22
1998–1999	79.35	21.03	58.325	147.89	89.569	3903	16.36
1999–2000	84.9	17.98	66.922	125.17	58.245	4434	13.37
2000–2001	110.2	41.05	69.152	124.23	55.083	4465	14.37
2001–2002	99.35	55.38	43.974	128.28	84.311	4639	24.03
2002–2003	115.5	58.03	57.468	140.51	83.046	4766	23.15
2003–2004	153.15	46.87	106.284	146.25	39.961	4940	11.37
2004–2005	226.95	46.73	180.220	156.37	-23.846	5159	-7.36
2005–2006	231.6	45.65	185.948	169.74	-16.209	5383	-5.22
2006–2007	264.4	90.19	174.211	173.83	-0.382	5276	-0.12
2007–2008	399.15	62.57	336.579	187.38	-149.199	5463	-50.98
2008–2009	404.1	68.67	335.432	191.60	-143.836	5504	-62.15
2009–2010	263.1	117.02	146.078	192.36	46.281	5802	22.50
2010–2011	356.2	83.29	272.914	244.44	-28.474	5743	-13.98
2011–2012	459.75	94.21	365.538	389.18	23.644	5524	11.53
2012–2013	450.333	86.89	363.447	350.41	-13.035	4909	-6.21
2013–2014	367.965	82.94	285.030	361.68	76.654	5735	45.72

Source: NFDC (2014).

Notes: GST = general sales tax. PKR = Pakistani rupees. FOB inclusive GST. ±FOB, inclusive GST minus subsidy. We converted the domestically available nitrogen to urea by dividing by 0.46. Annual average exchange rates were used to convert values in US$ into PKR. GST of 17 percent was imposed from 2012–2013 onward. Numbers in parenthesis represent column numbers. International prices with subsidy (3) are calculated by subtracting the production subsidy (2) from the international prices (1). The difference in domestic price of urea (4) and subsidized international price of urea (3) reflects the amount of subsidy that is not passed on to farmers (5). The total amount of subsidy on urea (7) is calculated by multiplying (5) with (6).

To see the cost of the fertilizer subsidy policy to society, we made both the domestic and the international markets free of any subsidy. But we took the retail prices, instead of the wholesale domestic prices, and cost, insurance, and freight rather than FOB international prices, and added the unit cost of the production and distribution subsidies to domestic retail prices, which was calculated as the total subsidy divided by the total fertilizer offtake, not just domestic production. However, we maintained the GST on both domestic and international prices and added distribution charges to the international prices (Figure 8.4).

Figure 8.4 Year-to-year urea fertilizer prices: Domestic versus international, 1996–2013



Source: Authors' estimates based on NFDC (2014) and HDIP (2013).
Note: GST = general sales tax.

Again, for the last year, the domestic price remained higher than the international price, as defined in this section. Only for two years are domestic prices significantly lower than international prices. Adding up the difference between the domestic prices and the international prices (as defined in this section) over the period gave us a positive subsidy of PKR 49 billion. This implies that we allowed the fertilizer sector to consume 16 percent of a scarce resource—gas—and in return did not get any benefit over the long run. If all fertilizer had been imported during this period, without any subsidy on the domestic fertilizer, then the nation would have saved 16 percent of its gas resources, as well as PKR 49 billion in subsidies, even with the unusual fertilizer price hike during 2009 and 2010. The domestic fertilizer prices would not have been significantly different except for the two years when fertilizer prices were extraordinarily high.

Industry Profit

One logical question emerging from the above discussion is, how has the industry's profit behaved since the increase in the gas subsidy in 2008, which has been accompanied by insufficient gas supply to the industry? To analyze this further, we utilize profit-and-loss statements (from industry annual reports) to decompose net sales from fertilizer into various cost items during for the period 2003–2012.[21]

The results depicted in Figure 8.5 indicate that, since 2008, the share of raw material costs increased from 19 percent to 38 percent of total costs. However, this has been accompanied by an increase in the profit margin from 23 percent in 2003 to 30 percent in 2013, with a peak of 42 percent in 2011 (Table 8.2). However, it is not clear whether this increase in industry profit percentage is due to improvement in the efficiency of the industry depicted by the decrease in sales costs or due to the shortage of gas, which resulted in a sharp increase in prices as both phenomena happened simultaneously beginning in 2008. More analysis is needed to separate the effects of these two phenomena on industry profit. This will be done in the following sections.

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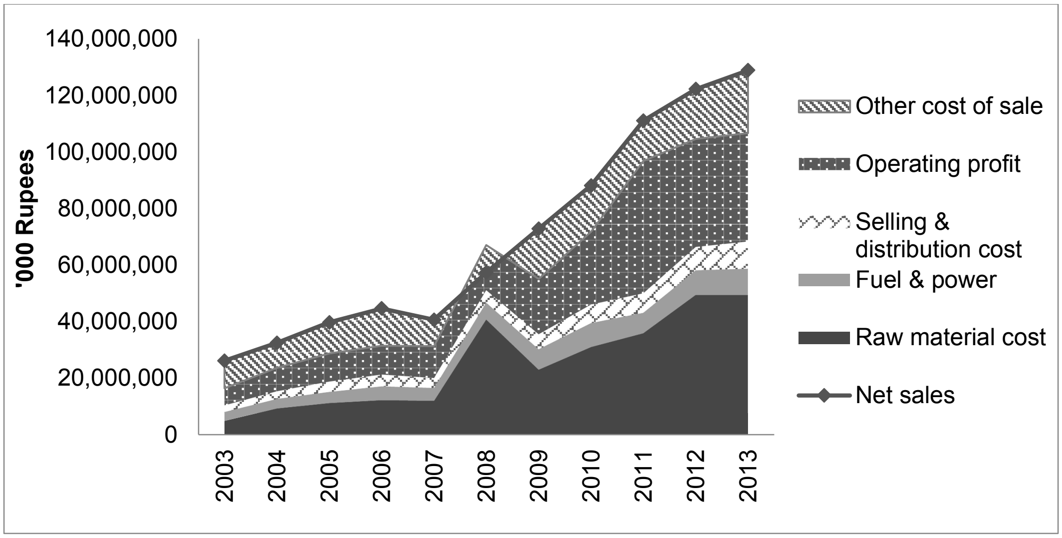
21. We completed the series only for FFC and FFBL, which cover over 50 percent of fertilizer industry. Consistent data over time for the Engro, another big player in the industry, were not available.

Figure 8.5 Trend in cost and profit structure of fertilizer industry: Fauji Fertilizer Bin Qasim Limited and Fauji Fertilizer Company Limited, 2003–2013



Source: Authors' estimates based on data collected from FFBL (2005, 2006, 2008, 2010, 2012, 2014) and FFC (2004, 2006, 2008, 2010, 2012, 2014) annual reports.

Table 8.2 Cost structure and profit (%) in fertilizer industry: Fauji Fertilizer Bin Qasim Limited and Fauji Fertilizer Company Limited, 2003–2013

Cost item/profit	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Fuel and power	12	10	10	11	11	10	10	10	7	7	7
Distribution cost	9	8	9	9	9	8	7	7	6	7	7
Raw material cost	19	29	28	28	30	71	32	35	32	40	38
Other cost of sale	37	27	28	30	23	-17	24	18	13	14	17
Operating margin with subsidy	23	26	25	23	28	28	27	29	42	31	30
Operating margins less subsidy	-4.5	-1.3	-0.2	-0.5	1.4	1.2	1.5	7.2	19.5	N/A*	N/A*
Operating margins less 50% subsidy	9.2	12.2	12.4	11.1	14.6	14.5	14.1	18.2	30.8	N/A*	N/A*
Return on equity	25%	30%	36%	39%	44%	41%	53%	63%	92%	66%	66%

Source: Authors' estimates based on data collected from FFBL (2005, 2006, 2008, 2010, 2012, and 2014) and FFC (2004, 2006, 2008, 2010, 2012, and 2014) annual reports.

Notes: *Data for subsidy not available for the years 2012 and 2013.^ This is estimated by adding up returns and shareholders' equity for both firms.

Additionally, to gain perspective on these figures, we compare the profitability of these two main players in Pakistan's fertilizer market with those of companies in the region. Table 8.3 from the competition report indicates that the return on equity (ROE) during the same time (2004–2008) for these two firms was much higher, estimated at approximately 38 percent,[22] and has grown much higher since.

[22] The CCP estimated the return on equity (ROE) for the Pakistani fertilizer industry at 33 percent, slightly different from our estimates of 38 percent across the same period because it included all firms in the sector while ours included just FFC and FFBL.

A possible explanation, at least with reference to India, is that gas prices for feedstock are provided at a relatively higher rate to Indian firms and the large chunk of the subsidy is provided at the retail level in the form of a price ceiling.

Table 8.3 Profitability comparisons

Region	Average return on equity margin
SAFCO	30%
MENA	31%
China	9%
India	16%
Pakistan	33%

Source: CCP (2010).
Note: SAFCO = Saudi Arabian Fertilizer Company; MENA = Middle East and North Africa. ** Average for four years (2004–2008).

9. IMPACT OF POLICY INTERVENTIONS

In this section, we use an EDM to estimate the impact of exogenous policy shocks on the market for urea and DAP as well as on major crops: cotton, rice, wheat, and other crops. The analysis allows us to identify winners and losers from each intervention, thereby enabling policymakers to make more informed decisions regarding the fertilizer industry.

The model uses parameters derived from demand and supply equations for the input (urea and DAP) and output (that is, cotton, rice, wheat, and other crops) markets.[23] For each crop, we assume that the supply of the output is a function of the respective endogenously determined output price, the prices of its substitute (or complement) outputs, and fertilizer prices. In addition, technology is included as an exogenous trend variable in all output supply equations. The demand of crops is a function of its price, the price of substitutes (or complements), and consumer income (which is an exogenous variable) (Appendix C).

The urea and DAP demand equations are a function of their respective prices and the quantity of production of all four crops. The urea supply equation is a function of the factory price of urea and the quantity of natural gas available, which is an exogenous variable. The DAP supply equation similarly is a function of its own factory price, the price and quantity of natural gas (with smaller coefficients compared to the urea equation), and the price and quantity of phosphorous (exogenous variables).

Moreover, marketing margins from the producer to retailer, both in input and output markets, are assumed to be fixed, that is, changes in producers' and retailers' prices occur in the same proportions. Additionally, the model allows us to see the impact of the GST, which acts as a wedge between producer and consumer prices in both markets. Improvements in input or output market efficiencies can be studied by changing this wedge.

Both input and output markets are cleared by equating domestic demand plus exports with total supply plus imports, which allows international trade to balance any deficit or surplus produced in the domestic market. Input and output trade is a positive function of the domestic price of the respective commodity for exports and negative for imports. The distinction between the international price and the domestic price is established by the fixed import duty/tariff/transport cost, which is exogenously determined.[24]

The supply and demand sides of these input and output markets are combined by substituting the demand equation into the market clearing equation. Each equation in this linear system is then totally differentiated and manipulated, so that all variables are converted into proportionate changes and elasticities (see Appendixes D and E). The equations are then entered into the general algebraic modeling system software to estimate the impact of exogenous shocks on the endogenous variables.

A large number of own and cross price elasticities in the supply and demand equations are required: input price elasticities with respect to input quantities; processing elasticities with respect to gas and phosphorous prices; and international supply elasticities of inputs and outputs with respect to world market prices are needed to estimate the model. These are taken from various sources or based on our own best judgment (Appendix Table F.1).[25]

An important assumption of the model is that the elasticities that define the relationships between and across different exogenous and endogenous variables are constant. Technologies for input processing and crop production are assumed to be constant in a given policy scenario. The model also assumes no limitations on inputs, such as total cropland, irrigation water, or, as in the case of this paper, the quantity of natural gas. In addition, the natural environments are also assumed to be at an average normal level.

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[23] We do not differentiate between the basmati and non-basmati rice varieties in our model mainly because of the non-availability of the data on different elasticities for each variety.

[24] This again implies that the world price has the same proportionate change as the domestic price, unless we conduct a simulation utilizing the wedge between these prices.

[25] When the data on certain elasticities are not reliable or do not exist, we simulate the results at different levels and select the intuitively more logical results.

We simulate the results for six scenarios: (1) removing the gas subsidy; (2) exempting GST on fertilizer; (3) removing the gas subsidy and GST simultaneously; (4) removing the gas shortage in fertilizer manufacturing; (5) providing subsidy on the retail price of DAP and combining it with the removal of the gas subsidy; and (6) investing in R&D and combining it with the removal of the gas subsidy scenario. We simulate the results in each scenario with two import elasticities, of α_k at 1 and 5, to judge how ease of importing will affect the outcomes. The results of all scenarios (in percentage changes) with import elasticity of 1 are presented in Table 9.1, and the actual and percentage changes are compared to the base scenario of 2013–2014 in Appendix Table F.2.

Table 9.1 Results of the EDM with low import elasticity of urea and DAP, α=1 (in percentage changes)

Variables	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
		Fertilizer market				
Domestic supply of urea	-14.11	2.44	-11.67	5.68	-13.92	-11.63
Domestic supply of DAP	-7.12	1.92	-5.2	3.57	-3.91	-6.54
Import supply of urea	10.21	3.05	13.25	-4.1	10.45	13.3
Import supply of DAP	4.48	4.8	9.28	-2.27	12.5	5.92
Demand of urea	-9.5	2.55	-6.94	3.82	-9.29	-6.9
Demand of DAP	-0.47	3.57	3.1	0.22	5.5	0.6
Farmer price of urea (inclusive GST)	10.21	-13.95	-3.75	-4.1	10.45	13.3
Farmer price of DAP (inclusive GST)	4.48	-12.2	-7.72	-2.27	-17.5	5.92
Factory price of urea (exclusive GST)	10.21	3.05	13.25	-4.1	10.45	13.3
Factory price of DAP (exclusive GST)	4.48	4.8	9.28	-2.27	12.5	5.92
Import cost of fertilizer	15.22	8.72	24.51	-6.34	25.62	20.18
		Output market				
Overall pressure on output prices	0.07	-0.1	-0.04	-0.03	0.03	-0.44
Overall trade surplus	-0.51	0.78	0.27	0.21	-0.2	4.58
Total crop production gain	-0.3	0.47	0.16	0.13	-0.12	2.15
Fertilizer expense for farmers	1.22	-10.82	-8.5	-1	-4.38	5.85
Production revenue	-0.28	0.44	0.15	0.12	-0.11	2.01
Overall farmer benefit	-0.51	2.14	1.46	0.29	0.54	1.43
Gas expense	242.43	2.41	252	5.57	243.83	251.87
Fertilizer revenue	-4.82	5.83	0.81	1.32	-2.07	-0.13
Overall manufacturer benefit	-32.31	6.21	-27.12	0.85	-29.41	-28.15
Production subsidy (urea)	-100	2.41	-100	5.57	-100	-100
Distribution subsidy	15.98	3.04	13.25	-6.12	16.37	21.03
Tax revenue from fertilizer sales	1.22	-100	-100	-1	-34.63	5.85
All subsidies	23.55	102.47	10.85	103.2	46.41	24.58
Consumer crop demand	-0.27	0.42	0.15	0.11	-0.11	1.9

Source: Authors' results.
Notes: EDM = equilibrium displacement model. Parentheses represent percentage changes.

Policy Scenario 1: Removing the Subsidy on Natural Gas

To completely remove the subsidy on natural gas, the government must exogenously increase the price of the fuel stock by 297 percent. The first important impact from this policy is a rise in the factory cost, which shifts the supply curve back. This increases the factory price of fertilizer and reduces its domestic supply. However, the higher domestic price creates incentives for importers, and thus imports increase depending upon the import elasticity (which reflects how easy it is to import). In the low import-elastic supply of scenario 1, the equilibrium factory price of urea increases by over 10 percent, while it increases by only 4 percent in the case of high import elasticity of scenario 5. The price of DAP fertilizer also increases in both scenarios but to a far lesser extent, because one unit of DAP requires less than one-half of ammonia produced from natural gas than does the same amount of urea. Farmgate prices of urea and DAP (including GST) increase parallel to their factory prices, as the difference between the two is only a constant wedge. The increased cost of urea and DAP processing reduces domestic supply and increases imports, and higher farmgate prices lower demand (except in the high import elasticity scenario, where imports increase more than the decrease in domestic supply).

The changes in the fertilizer market trigger dynamic responses in the crop markets, which induce impacts on government, farmers, and manufacturers. The lower demand of fertilizer reduces crop output, depending upon the output supply elasticity with respect to fertilizer price.[26] This creates pressure on output prices. The farmers lose from lower crop production and higher fertilizer prices, but benefit from higher output prices and lower fertilizer demand. In the scenario of low import elasticity, farmers' overall loss is about PKR 11 billion, or 0.5 percent of the original value of farm production. However, this loss can be mitigated and turned into a profit of PKR 15 billion if imports are made flexible enough, reflected in the high import elasticity scenario that we run. Although crop outputs still decrease and output prices increase, both are moderated because of the higher imports of fertilizers, and farmer losses from lower output sales are reduced from PKR 7 billion to PKR 3 billion. On the other hand, expenses on fertilizer decrease by PKR 19 billion because of the lower increase in fertilizer prices and the higher decrease in its demand. Thus, the moderating effect of a higher import elasticity or facilitation in imports can be used to lower the impact on farmers of reduced gas subsidies.

The government is the biggest net beneficiary, as gas subsidies are reduced by PKR 46 billion. There will be a small change in GST and the distribution subsidies, and the net gain to the government would be around PKR 42 billion in the high import elasticity scenario and 46 billion in the low import elasticity scenario.

The decrease in crop production also affects international crop trade. Compared to 2013–2014, the generally higher commodity prices provide incentives to international traders to export more commodities or reduce imports from Pakistan. This causes increased imports of cotton and a reduction in the exports of rice, wheat, and other crops, creating a trade deficit in these markets by PKR 1 billion. The trade loss can be reduced when the import elasticity of fertilizer is increased.

The manufacturers will be the biggest losers in this scenario, as their profit declines by PKR 46 billion in the case of low import elasticity and PKR 58 billion in the case of high import elasticity. The cost of gas used in fertilizer processing increases by PKR 38 and PKR 35 billion, respectively, while revenue from fertilizer sales decreases by over PKR 8 and PKR 23 billion, respectively. The greater loss to manufacturers in the case of a liberal import scenario is because more imports are brought into the country.

With the increase in output prices, consumers' demand for agricultural commodities will decrease by PKR 7 billion, although the reduction will be only PKR 2 billion if fertilizer imports are more liberally imported. The society as a whole would lose by about PKR 5 billion in this scenario.[27]

In this simulation, we assumed the elasticity of fertilizer supply with respect to the price of natural gas as 0.1 and 0.025 for urea and DAP, respectively. Because this elasticity may be argued as being low, we also simulated the impacts with an increased elasticity of 0.4 percent and 0.1, respectively. This further increases the manufacturers' loss, from PKR 46 and PKR 58 billion in the scenarios of low

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[26] The crop supply elasticities with respect to fertilizer prices used in our EDM are from Haile, Kalkuh, and von Braun (2014). This is an international study and has reported low crop supply elasticities for Pakistan compared to those in relatively older Pakistani studies. One reason for the high elasticities in earlier studies may be the low use of fertilizer at the time of estimation. In addition, using high elasticities from the Pakistani literature blows up the effects of any policy intervention on crop production to unbelievable levels.

[27] The net social gain to society was estimated as change in the value of crop demand + government revenue + farmers' benefit + manufacturers' benefit.

and high import elasticity to PKR 70 and PKR 116 billion, respectively, mainly because of the greater decline in revenue from fertilizer sales.

Policy Scenario 2: Removal of General Sales Tax (GST)

The removal of the 17 percent GST on prices of urea and DAP will immediately reduce its cost to farmers, which will shift their demand functions outward. With this intervention, different reactions occur in all the markets, and the final outcome again depends upon the import elasticity.28 In our model, the eventual decline in urea and DAP prices at the farmgate level was around 14 percent and 12 percent, respectively. This also increases fertilizer demand, which pushes the factory prices of urea and DAP upward by 3 percent and 5 percent, respectively, as imports start competing with domestic manufacturers. This increases the domestic supply of urea and DAP by about 2 percent.29 When the import elasticity is enhanced, the reduction in prices at the farmgate can be further induced nearer toward the full-scale reduction in GST. This, however, will reduce the impact on factory gate prices, and thus domestic supply will be further cut back as imports are encouraged.

The production of all three crops increases by only PKR 11 billion. The trade surplus in these crops increases by PKR 1 billion. Overall, the greatest beneficiaries of the removal of GST would be farmers, as they save nearly PKR 37 billion in fertilizer cost, and their revenue from crop production also increases by about PKR 11 billion. Urea and DAP manufacturers also gain PKR 8 billion because of the higher factory prices and greater demand. However, their gains are reduced to PKR 3 billion if high import elasticity is assumed, as some of the fertilizer demand is captured by importers. The government revenue will be affected, as it loses tax revenue equal to PKR 50 billion. Another beneficiary of GST removal from fertilizer is the consumer, as the crop demand increases by 0.4 percent, or PKR 10 billion.

Policy Scenario 3: Removal of Gas Subsidy and GST Simultaneously

Some policymakers would like to see the fertilizer sector without any tax, but also without production subsidies, which we analyze in this simulation. This essentially means shifting the supply curve of fertilizer downward (because its manufacturing costs would go up) and its demand curve upward (because the GST on fertilizer to farmers would be dropped). The net results depend upon supply and demand elasticities. Under the assumed elasticities in our model, the demand for urea decreases despite the decrease in urea prices. However, for DAP the demand and prices move in the opposite direction. The factory prices and fertilizer supply both increase, although the response is relatively low.

The factory price of urea and DAP increases by 13 percent and 9 percent, but their farmgate prices decrease by 4 percent and 7 percent, respectively, because farmers do not have to pay the GST. This decreases the supply of urea and DAP by 12 percent and 5 percent, respectively, mainly because of the increased manufacturing cost as the gas subsidy is removed. This will also increase the imports of fertilizer by 24 percent, or PKR 21 billion, in both the high and the low import elasticity scenarios, which can be reduced to some extent by increasing the import elasticity of fertilizer. This change in policy leaves the government with little change in revenue, despite its loss of PKR 50 billion from the GST, because it receives PKR 47 billion from the removal of the gas subsidy.

The 7 percent and 3 percent decrease in the demand for urea and DAP, respectively, lowers crop production and creates upward pressure on prices, which costs the economy PKR 4 billion, without much change in the trade deficit of the crops. Farmers gain PKR 33 billion from this scenario from increased output prices and lower fertilizer prices. The farmers' return from a completely open policy, however, can

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[28] Here we first explain the results with a low import elasticity of 1, and then generalize the impact with a high import elasticity of 5.

[29] Although the model assumes that additional inputs, including gas, will be freely available to produce any quantity of fertilizer (as well as crops), alternatively, small increases in fertilizer supply, as assumed in this scenario, may arise through enhanced efficiency even if additional gas is not available. Also, encouraging imports of gas is another source of new supply, even though the domestic outlook is not good.

be improved to PKR 70 billion with a higher import elasticity of fertilizer. Manufacturers are the greatest losers in this scenario, as their gas expenses increase, which is further intensified with the higher import elasticity because demand will be captured by importers. The social cost of this reshuffling from the removal of all taxes and subsidies would be PKR 5 billion, which can be turned into a social profit of PKR 20 billion when the higher import elasticity is assumed.

Policy Scenario 4: Removal of Gas Shortage

The fertilizer industry as of 2013–2014 was operating at around 72 percent of installed capacity. One of the key factors impacting the future and viability of the industry will be the availability of natural gas to the sector.[30]

In this scenario, we assume that surplus gas is available and we increase the amount of natural gas supplied to the fertilizer industry by 28 percent, keeping all other exogenous effects constant.[31]

The policy scenario would shift the supply curve outward and decrease the prices of urea and DAP by 4 percent and 2 percent, respectively, both at the farm and the factory level, while increasing the equilibrium quantity of domestic supply by about 6 percent and 4 percent, respectively. As domestic prices decrease, imports become less competitive and decline by 4 percent and 2 percent, respectively (the decrease in fertilizer prices and imports are greater under the high import elasticity scenario, due to a larger increase in domestic availability as well as demand). Domestic demand increases by 4 percent and 0.2 percent, respectively. The quantities of domestically produced wheat, cotton, rice, and other crops increase and put downward pressure on their prices. Given the base values in 2013–2014, the domestic production of all crops increases by about PKR 3 billion, while trade surplus of these crops increases insignificantly.

Farmers would gain by nearly PKR 6 billion; half of this comes from an increase in the value of crop production (despite a decrease in their prices) and the remaining half from low fertilizer cost due to its lower price. Urea manufacturers will see an increase in revenue by PKR 2 billion, but half is consumed by an increase in processing cost. Consumers will also gain by PKR 3 billion. The government subsidy on gas will increase by PKR 2 billion.

Although the policy of removing the gas shortage benefits all stakeholders, except the government, the extent of the benefits is relatively small. Moreover, the policy relies on the utilization of a scarce economic resource in the country. It is estimated that, with the existing rate of utilization, the most extensive recoverable gas reserves available to the fertilizer sector, from the MARI field, will be exhausted within 16 years.[32] This suggests that the government should start planning now for a gradual shift from domestic supply to imports, either of fertilizer or of natural gas for the production of fertilizer, which is inevitable anyway, rather than promoting excessive utilization of a scarce resource.

Policy Scenario 5: Subsidizing DAP and the Removal of the Gas Subsidy

In professional circles, low use of phosphorus has always been a concern. Therefore, subsidy on phosphorus is vehemently argued (Chaudhary et al. 2008). We evaluate here the impact of 17 percent reduction in prices through GST and an additional 13 percent subsidy on the retail prices of DAP. This, in fact, implies 30 percent reduction in the base-scenario wedge between factory and farmgate prices. Ultimately, this policy decreases the price of DAP at the farmgate level by about 22 percent, which increases farmers' demand by about 6 percent and increases factory prices by 8 percent. This increases the overall crop production by about 0.2 percent, worth PKR 4 billion, which creates a small downward

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[30] These analyses with our EDM model do not take into account the fast depleting supply of natural gas in Pakistan and the cost to other sectors if gas is allocated from those to fertilizer.

[31] The model, however, will only reflect utilization of gas, which is needed by the firm to meet equilibrium demand.

[32] According to data from the Ministry of Petroleum and Natural Resources, the recoverable reserves of gas from MARI fields as of December 31, 2014, was 3,382 billion cubic feet and the utilization rate during 2014 was 211 billion cubic feet, giving the remaining life to the field not more than 16 years. This is also recognized by IRG (2011) in its report on page 17.

pressure on crop prices and an infinitesimal expansion in the trade surplus. The cost of imports of DAP due to the policy is PKR 8 billion. This scenario benefits farmers by PKR 24 billion, as it decreases fertilizer costs by PKR 20 billion and increases crop revenue by PKR 4 billion, but it costs the government PKR 30 billion (PKR 13 billion in terms of a 13 percent subsidy on DAP and PKR 17 billion in terms of GST foregone). The manufacturers also gain from the policy, at PKR 4 billion, as they capture expanded demand for DAP from enhanced production. However, if manufacturers fail to expand DAP production due to factors like a shortage of gas or phosphate raw material, the importers will fill the gap, as shown in the higher import elasticity scenario. In that case, imports of DAP increase, resulting in a further decrease in the DAP price at the farmgate and a smaller increase in the factory gate price. In the higher import elasticity scenario, benefits to farmers increase through higher crop output, while the manufacturers' benefit decreases due to a lower expansion in DAP production.

If the policy of subsidizing DAP is combined with the policy of removing the gas subsidy, then the former is able to partially balance the depressing effect of the latter on crop production and trade surplus. In addition, farmers' negative profit under the gas subsidy policy (with low import elasticity) turns positive when it is combined with subsidizing the DAP at 30 percent. However, the government surplus decreases from PKR 42 billion in the gas subsidy policy to PKR 14 billion in the DAP subsidy policy.[33]

Policy Scenario 6: Investing in R&D and Combining it with the Removal of the Gas Subsidy

There is very little investment in agricultural R&D in Pakistan. This has dried up the flow of innovations to farmers and, as a result, the productivity-based growth has lagged behind compared to other developing countries, like China, India, Brazil, and Turkey (Ahmed and Gautam 2013). Essentially, we have created a fiscal space for the government to increase R&D investment by eliminating the production subsidy in Scenario 1. Here, we assume that 25 percent of this savings, about PKR 12 billion, will go to R&D in the crop sector, implying a 150 percent increase in the current R&D budget for agriculture of PKR 8 billion in 2011–12 (ASTI-PARC 2012). We assume this brings about a modest increase of 3 percent in crop productivity across the board, by shifting the supply curve outward after a five-year lag.[34]

The shift in the supply curve of the crop sector induced by R&D will drive the fertilizer sector as well, while the opposite is true in the earlier scenarios. Another important difference is that, unlike earlier scenarios, there is a significant time lag between the investment in R&D and returns through enhanced productivity, which we capture by calculating the net present value with returns starting five years after the investment.[35]

For the first year of benefits, when the new technologies generated through R&D produce a 3 percent increase in crop productivity, the shift in the supply curve will increase crop production and lower prices. More fertilizer is required to produce the greater crop output, which will shift the fertilizer demand curve upward. More fertilizer demand increases its farm and factory prices, and induces fertilizer manufacturing and imports. If, somehow, the domestic manufacturers cannot expand production capacity sufficiently, importers will fill the gap (which happens under the high import elasticity scenario).

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[33] These benefits include only the effect of DAP on crop productivity, and not the productivity impact due to an interaction of P with N, which are vehemently argued to be strong in some literature (Mahmood-ul-Hassan, Rashid, and Akhtar 1993).

[34] This productivity increase might come from improved high-yielding varieties; development and promotion of appropriate input application machinery; improvement in the timing of delivery of inputs, including fertilizer, credit, water, and information; and development of new crop management models that not only improve productivity but also reduce post-harvest losses. We assume that technological innovations are neutral to fertilizer-use efficiency, thus we observe a general 10 percent shift in the overall supply curve, rather than an increase in fertilizer coefficient in production function.

[35] We assume here a five-year lag period between the time the investment in R&D is made and the return (including additional costs) from the investment starts flowing. The fifth-year values of additional fertilizer costs and income due to the shift in crop supply curve are reported in Scenario 6 in Appendix Table F.2. After the fifth year, we assume gradually declining growth in crop productivity from 3 percent in the first year to 2.5 percent, 2.0 percent, 1.5 percent, 1.0 percent, and 0 percent in the subsequent years. We then discounted these benefit streams at a 15 percent rate.

Although the import bill for fertilizer increases, more crop supply reduces output prices and generates a higher trade surplus, which is more than enough to compensate for the higher import bill of fertilizer. We generated results for the remaining four years, assuming that the crop productivity increases by a lesser percentage in each consecutive year (by 2.5 in the second, 2.0 percent in the third year and so on) until the technology gets completely exhausted.

The discounted values of benefits of an R&D investment to farmers are PKR 59 billion in the case of low import elasticity, and PKR 54 billion in the case of high import elasticity. Despite assuming a modest gain of 3 percent in crop productivity through tripling the R&D investment, the gains to farmers as well as to society are the highest compared to any other scenario. Despite having a similar cost (~PKR 12 billion), the benefits due to this policy are more than double when compared to the case of providing a subsidy on phosphate fertilizer.

Another advantage of this scenario is that, except for the government, all other stakeholders, including manufacturers, benefit from this intervention. The manufacturers benefit through the increased fertilizer price as well as its expansion in production. Consumers benefit from the reduced output prices and expansion in the production of agricultural commodities. International competitiveness increases, with improvement in the trade surplus. Additional production brings new jobs and businesses into the agriculture sector.

The 25 percent investment in R&D is capable of mitigating or reducing all negative impacts of removing gas subsidies when both policy scenarios are combined. The combined intervention reduces the urea demand by only 7 percent compared to 10 percent (in the case of low import elasticity) when only gas subsidies are removed. Crop production gains become highly positive, at PKR 52 billion, instead of the negative PKR 7 billion when the removal of the gas subsidy is applied by itself. Although government revenue declines by PKR 12 billion, farmers' gains substantially increase from PKR -11 billion with the individual policy of gas subsidy removal to PKR 32 billion when both policies are combined. Similarly, crop trade becomes positive in the combined policy instead of negative in the individual policy.

Table 9.2 shows the beneficiaries of all interventions discussed above. For instance, investment in enhancing agricultural productivity while removing subsidy on feedstock gas will have positive outcomes for consumers due to higher crop production, increase in farmers' benefits, and rise in government revenues, and will benefit society overall.

Table 9.2 Summary of policy interventions (α=1)

Intervention	Consumer	Farmers	Manufacturer	Government	Social benefit
Removing subsidy on feedstock gas				(shaded)	
Removing GST	(shaded)	(shaded)	(shaded)		(shaded)
Removing subsidy and GST	(shaded)	(shaded)			
Increasing quantity of natural gas		(shaded)	(shaded)		(shaded)
Subsidizing DAP and removing gas subsidy	(shaded)	(shaded)		(shaded)	
Investing in R&D and removing gas subsidy	(shaded)	(shaded)		(shaded)	(shaded)

Source: Authors' calculations.
Notes: GST = general sales tax; DAP = Shaded boxes represent benefits to each stakeholder.

10. POLICY RECOMMENDATIONS AND CONCLUSIONS

Historically, Pakistan has offered a favorable setting for growth in fertilizer uptake and increased agricultural production. The rich alluvial soils, an extensive canal irrigation system supplemented by tube wells, and the historically rapid adoption of fertilizer-responsive wheat and rice varieties have created conditions to generate rapid increases in fertilizer demand beginning in the mid-1960s. On the supply side, Pakistan's perceived large natural endowment of gas has aided in the rapid construction of a domestic fertilizer industry, because, at that time, policymakers thought sufficient gas existed. That perception has proved to be false, as evidenced by the serious shortage of gas in the country, and gas fields used in fertilizer processing will exhaust in about 16 years (IRG 2011).

Additionally, the general policy emphasis on building domestic production capacity and promoting urea use among farmers occurred at the expense of more balanced use of other nutrients, such as phosphate and potassium, resulting in a long-term trend of declining fertilizer-use efficiency and growing resource degradation. Meanwhile, policies to encourage the industry have resulted in a high concentration of capacity in the hands of a small number of manufacturers, and evidence of anti-competitive behavior is emerging (CCP 2010). Despite policies to encourage the industry and government's effort to control price shocks through subsidies, the price of phosphorus remains highly dependent on price fluctuations in international markets due to Pakistan's high dependence on imported DAP.

Pakistan's fertilizer industry, valued at an estimated PKR 3.74 billion in 2013–2014, has been operating at approximately 75 percent of capacity in recent years, despite subsidies on both production and distribution. Adding these two sources together, the total subsidy burden comes to about PKR 53 billion, or 14 percent of the fertilizer market value in 2013–2014. The subsidies are highly skewed toward urea, while other nutrients remain subject to international price trends.

Various policies, regulations, and organizations oversee the pricing, quality, promotion, manufacturing, importation, and distribution of fertilizer in Pakistan. The elaborate marketing rules provided sweeping and discretionary powers to controllers (extension wings of provincial agricultural departments), which, according to the regulations themselves, included stopping or limiting sales, sealing stocks, and fixing prices, among others. Such powers, along with the control of the gas supply and prices, limited entry into fertilizer processing and marketing, inducing an oligopolistic cartel (CCP 2010, and our analysis).

The NFDC brings various stakeholders together for issue resolution and policy formulation. However, less attention appears to be given to policies that promote a balanced use of fertilizer, environmentally friendly products, and efficient application methods. The provincial Soil Fertility Research Institutes do a good job in analyzing farmers' soil and water samples to evaluate the nutrient and productivity status of their lands, and thus to advise them in adjusting nutrient application according to site specificity. However, plot-level data collected by IFPRI/IDS (2014) suggests that this had almost no impact, as we found that farmers did not adjust fertilizer use enough to be consistent with the SFRI recommendations, thus using urea and phosphate fertilizers in a 2:1 ratio, or applying more fertilizer on poor and saline soils.

An equilibrium displacement model was developed by specifying the fertilizer market, three major agricultural product markets, and an "other" cop market. Each market was cleared by linking it with international markets through trade. The overall equilibrium was induced by equating supply and demand. Using the specified model, we simulated effects of government policies on the fertilizer and output markets, including trade, by looking at gains to consumers and producers. Our results suggest that removing the gas subsidy and GST simultaneously on fertilizer would increase government revenue but would have minimal impact on fertilizer prices, supply and demand, and crop production if trade is freely allowed. Increasing the gas supply would benefit only consumers, as agriculture output prices decrease, but it would not benefit farmers or manufacturers, as their profits would be squeezed. In fact, fertilizer manufacturers, in the wake of reduced profit, would use less than the full amount of gas provided, and the fertilizer supply curve would shift backward. The reduction of GST alone would most significantly benefit consumers.

Basic changes in the philosophy and direction in fertilizer processing, marketing, and use are required to exploit the full potential of the industry without damaging the environment and to safeguard the sustainability of agricultural resources. Hence, we make a series of recommendations in the next paragraphs.

With respect to fertilizer manufacturing, the policy emphasis should move away from expansion based on subsidies to full utilization and modernization of existing capacity, thereby improving efficiency and preparing the industry for an era with fewer subsidies and more international competition. Our findings also suggest that the production subsidy on gas should be removed because it will not harm farmers or consumers to a great extent if free imports of urea are allowed and combined with other policy options. It will also prepare the industry for an era of severe gas shortage within the country, which will happen in any case within the next 15 years, possibly enabling it to substitute domestic gas with imported liquefied natural gas.

Although it is tempting to leave this adjustment process to the market, by lifting all subsidies and allowing unrestrained imports, the lack of infrastructure needed to deliver natural gas, both domestically and from imports, may make this unlikely to work in the medium term. (It may, however, be an ultimate goal.) Thus, the sector should be closely guarded with antitrust laws, and approaches to distributing gas in ways closer to market outcomes, such as diverting more to efficient firms, need to be considered. As it is unlikely that pure market outcomes can be effective in the near term, a broad fertilizer policy should be considered to address issues of *all* stakeholders. A Fertilizer Board consisting of a broad group of stakeholders could help monitor the performance of the fertilizer sector, including pricing, import strategies, and other provisions of the policy.

The redesign of incentives for the industry needs to reflect several dimensions in the outlook for world and domestic fertilizer and natural gas markets. We compared domestic fertilizer prices without subsidies to that of international prices and found the former higher than the latter during most of the year, suggesting that the fertilizer industry does not have much opportunity to sell its product in international markets. Also, a key issue here is the outlook for natural gas, which may disappear locally, and so questions to be examined carefully are whether Pakistan can continue to run its fertilizer plants with imported gas, or whether importing fertilizer directly makes more sense. Given the limited natural gas, it seems unlikely for Pakistan to become an exporter, even though the CCP analysis makes some suggestions along these lines.

On the fertilizer marketing side, the policy focus should change from controlling fertilizer markets, the existing norm, to freeing the market, which will improve marketing efficiency. First, laws need to be rationalized and regulators should only be allowed to interfere within clear parameters of market failure. Second, antitrust laws should be enforced in marketing at district levels as well, and standards for animal manure, micronutrients, plant growth promoting rhizobacteria, and so on, should be developed and strictly enforced.

In terms of fertilizer promotion among farmers, our results clearly show that future policy and investment emphasis should be on improving fertilizer-use efficiency rather than promoting higher per hectare use of fertilizer. This will require assessments of the capacity of agricultural extension and soil fertility labs to provide more advanced consulting to farmers. For example, can there be computer-based models developed to synchronize fertilizer use with resource quality in line with plot-specific needs? These could also provide efficient fertilizer application methods, such as placement, fertigation, or machinery, which could be standardized for local conditions. Other ways to enhance efficiency, which can be examined for their economic value, include more efficient fertilizer materials, such as plant growth promoting rhizobacteria, slow-release fertilizer, animal and chicken manure, and micronutrients, as well as more efficient crop varieties, especially for barani areas.

Finally, issues of inventory management, fertilizer stocks, and the relationship of the domestic industry to the international market should be considered in further research. Analyses of reasons that intermittent shortages of fertilizer occur would be valuable, and causes might be due to poor import planning or allocation issues of public-sector supplies at the local level. Questions that might also be considered include the costs and usefulness of fertilizer stocks (perhaps held in the private sector but paid for by the government) to help counter sudden international shocks in fertilizer prices, and strategic trade negotiations to minimize fertilizer subsidies jointly with India rather than entering in fertilizer-subsidy war with India, which is not beneficial to either country.

In summary, there is opportunity to strengthen the fertilizer industry in Pakistan and, in turn, strengthen the prospects for sustainable agricultural production with continued productivity growth. However, the policy and investments required in order to move the entire fertilizer sector—manufacturers, dealers, farmers, policymakers, and the civil service—in the right direction are challenging.

APPENDIX A: SUPPLEMENTARY TABLES

Table A.1 Fertilizer production, offtake, import, and stock (000 tons) by nutrient, 1970–2014

	Offtake				Production				Import				Stock*			
Fiscal year	N	P	K	Total	N	P	K	Total	N	P	K	Total	N	P	K	Total
1970–1971	251.5	30.5	1.2	283.2	140.1	4.5	0.0	144.7	107.8	38.6	5.0	151.4	131.5	42.7	6.1	180.3
1971–1972	344.0	37.2	0.7	381.9	215.1	4.9	0.0	220.0	73.0	0.0	0.0	73.0	75.7	10.3	5.4	91.4
1972–1973	386.4	48.7	1.4	436.5	274.5	8.2	0.0	282.8	115.6	72.1	0.0	187.7	79.4	41.9	4.0	125.3
1973–1974	341.9	58.1	2.7	402.7	300.1	4.2	0.0	304.3	225.0	104.3	6.3	335.6	262.5	92.3	7.6	362.5
1974–1975	362.8	60.6	2.1	425.5	296.3	10.6	0.0	307.0	106.5	26.1	0.8	133.3	302.5	68.4	6.3	377.2
1975–1976	441.6	103.6	2.9	548.1	316.5	10.6	0.0	327.1	73.5	109.2	0.0	182.7	250.9	84.6	3.4	338.9
1976–1977	511.0	117.9	2.4	631.3	309.3	11.9	0.0	321.2	137.1	140.1	2.5	279.6	186.2	118.7	3.5	308.4
1977–1978	549.9	156.3	6.0	712.2	312.5	15.0	0.0	327.5	341.8	204.8	2.1	548.7	290.6	182.1	-0.4	472.3
1978–1979	684.3	188.0	7.6	879.8	334.0	27.0	0.0	361.0	443.9	205.6	9.9	659.4	384.2	226.7	1.9	612.8
1979–1980	806.0	228.5	9.6	1044.1	388.9	49.8	0.0	438.6	440.8	142.4	13.8	596.9	407.9	190.4	6.1	604.3
1980–1981	842.9	226.9	9.6	1079.5	579.7	57.7	0.0	637.4	386.7	302.3	22.0	711.0	531.3	323.5	18.5	873.3
1981–1982	830.6	225.2	21.7	1077.5	699.2	66.9	0.0	766.1	88.8	28.5	15.6	132.8	488.8	193.7	12.3	694.8
1982–1983	952.7	265.3	25.7	1243.6	987.3	71.3	0.0	1058.6	133.3	249.3	21.5	404.1	656.7	249.0	8.1	913.8
1983–1984	914.3	259.8	28.5	1202.6	1015.3	91.8	0.0	1107.1	79.4	189.1	27.2	295.7	837.1	270.1	6.9	1114.1
1984–1985	934.9	293.9	24.7	1253.4	1028.7	90.0	0.0	1118.7	86.5	233.1	21.3	340.9	1017.5	299.3	3.5	1320.2
1985–1986	1128.1	349.8	33.2	1511.1	1041.7	93.3	0.0	1135.0	66.3	159.3	40.3	266.0	997.3	202.1	10.6	1210.0
1986–1987	1332.5	408.9	42.5	1783.9	1120.1	93.3	0.0	1213.3	210.2	354.0	46.2	610.4	995.1	240.5	14.3	1249.9
1987–1988	1281.7	393.5	45.1	1720.2	1097.1	95.2	0.0	1192.3	204.6	295.8	57.1	557.6	1015.2	238.1	26.3	1279.5
1988–1989	1324.8	390.6	24.5	1740.0	1113.8	100.5	0.0	1214.3	134.2	317.5	9.4	461.1	938.3	265.5	11.1	1214.9
1989–1990	1467.9	382.5	40.1	1890.4	1156.4	105.1	0.0	1261.5	285.5	262.9	41.5	590.0	912.3	251.1	12.6	1175.9
1990–1991	1471.6	388.5	32.8	1892.9	1110.6	104.6	0.0	1215.2	360.6	252.9	54.6	668.1	911.8	220.1	34.4	1166.2
1991–1992	1462.6	398.0	23.3	1883.9	1043.8	105.5	0.0	1149.3	369.9	269.8	10.1	649.7	862.8	197.4	21.2	1081.4

Table A.1 Continued

	Offtake				Production				Import				Stock*			
Fiscal year	**N**	**P**	**K**	**Total**	**N**	**P**	**K**	**Total**	**N**	**P**	**K**	**Total**	**N**	**P**	**K**	**Total**
1992–1993	1635.4	488.2	24.1	2147.6	1227.3	104.8	0.0	1332.1	409.6	388.9	14.9	813.5	864.4	202.9	12.0	1079.3
1993–1994	1659.4	464.3	23.2	2146.8	1565.9	92.9	0.0	1658.9	310.5	540.9	33.5	884.9	1081.4	372.5	22.4	1476.3
1994–1995	1738.1	428.4	16.6	2183.1	1544.1	92.1	0.0	1636.2	87.7	258.4	12.8	358.8	975.1	294.6	18.6	1288.3
1995–1996	1990.9	494.5	29.7	2515.0	1693.4	96.1	0.0	1789.5	297.9	397.2	39.0	734.1	975.5	293.4	27.9	1296.8
1996–1997	1985.1	419.5	8.4	2413.0	1681.5	80.7	0.0	1762.2	472.9	381.0	24.3	878.1	1144.8	335.7	43.7	1524.2
1997–1998	2075.1	550.9	20.0	2646.1	1660.5	67.5	0.0	1728.0	297.7	433.5	17.6	748.8	1028.0	285.7	41.3	1354.9
1998–1999	2097.0	465.0	21.3	2583.3	1795.2	90.7	0.0	1885.9	421.8	425.0	37.2	884.8	1147.9	336.4	57.2	1542.3
1999–2000	2217.8	597.2	18.5	2833.4	2039.6	223.5	0.0	2263.2	233.0	416.0	13.8	662.8	1202.8	378.8	52.5	1634.9
2000–2001	2264.2	675.8	23.1	2963.1	2053.8	243.8	0.4	2298.1	194.0	369.1	16.5	579.6	1186.4	315.9	46.4	1549.5
2001–2002	2285.3	624.5	18.8	2928.6	2134.0	142.7	8.9	2285.6	178.5	429.5	17.7	625.7	1213.5	263.6	54.2	1532.1
2002–2003	2349.1	650.2	20.5	3019.8	2192.4	111.1	11.5	2315.0	215.7	542.4	7.9	766.0	1272.6	266.9	53.1	1593.4
2003–2004	2526.7	673.5	21.8	3222.0	2272.5	253.9	12.9	2539.3	204.2	553.5	6.4	764.1	1222.6	400.8	50.6	1674.8
2004–2005	2796.4	865.1	32.5	3694.0	2373.1	324.8	20.1	2718.0	309.7	458.2	16.9	784.8	1109.0	318.7	55.1	1483.6
2005–2006	2926.6	850.5	27.0	3804.2	2476.0	341.4	14.7	2832.2	603.4	639.8	25.1	1268.3	1261.8	449.4	67.9	1779.9
2006–2007	2649.7	978.8	43.1	3671.6	2426.8	307.9	11.9	2746.5	307.6	476.2	12.1	795.9	1346.4	254.8	48.8	1650.7
2007–2008	2924.6	629.7	26.9	3581.2	2513.0	294.0	16.0	2822.0	286.7	565.7	23.9	876.3	1221.5	484.8	61.8	1767.8
2008–2009	3034.9	651.2	25.3	3711.4	2532.0	364.0	10.0	2907.0	456.6	111.5	0.0	568.1	1175.2	309.1	4s6.5	1531.5
2009–2010	3476.3	860.4	23.8	4360.5	2669.0	403.0	10.0	3082.0	900.8	522.4	20.9	1444.1	1268.7	374.1	53.6	1697.1
2010–2011	3133.5	767.0	32.3	3932.8	2642.0	423.0	12.0	3076.0	383.2	243.5	18.0	644.7	1160.4	273.6	51.3	1485.0
2011–2012	3206.5	633.2	21.2	3860.9	2541.0	431.0	10.0	2983.0	871.0	291.0	15.0	1177.0	1365.9	362.4	55.1	1784.1
2012–2013	2853.5	746.9	20.8	3621.2	2257.5	438.6	7.5	2703.6	456.4	271.2	6.8	734.5	1226.3	325.3	48.6	1601.0
2013–2014	3184.0	881.0	23.6	4089	2644.0	455.0	11.0	3110.0	703.0	432.0	14.0	1149.0	1389.3	331.3	50.0	1771.0
Growth (%)	5.54	6.32	5.54	5.65	6.15	9.41	6.81	6.39	3.4	5.5	2.47	3.95	4.98	4.05	6.29	4.75

Source: NFDC (2014).
Note: N = nitrogen; P = phosphorus; K = potassium. Stock = Production + import + previous year's stock consumption.

Table A.2 Fertilizer use rate (kg/hectare), 1970–2014

Fiscal year	N	Moving average	P	Moving average	K	Moving average	Total	Moving average	P/N	K/N
1970–1971	15		1.83	-	0.07		17		0.12	0.005
1971–1972	21		2.24	-	0.04		23		0.11	0.002
1972–1973	23	20	2.88	2	0.08	0	26	22	0.13	0.003
1973–1974	19	21	3.18	3	0.15	0	22	24	0.17	0.008
1974–1975	21	21	3.49	3	0.12	0	25	24	0.17	0.006
1975–1976	25	22	5.75	4	0.16	0	30	26	0.23	0.006
1976–1977	28	25	6.47	5	0.12	0	35	30	0.23	0.004
1977–1978	30	28	8.45	7	0.32	0	39	35	0.28	0.011
1978–1979	35	31	9.73	8	0.39	0	46	40	0.28	0.011
1979–1980	42	36	11.85	10	0.5	0	54	46	0.28	0.012
1980–1981	44	40	11.81	11	0.5	0	56	52	0.27	0.011
1981–1982	43	43	11.67	12	1.13	1	56	55	0.27	0.026
1982–1983	47	45	13	12	1	1	62	58	0.28	0.021
1983–1984	46	45	13	13	1	1	60	59	0.28	0.022
1984–1985	47	47	15	14	1	1	63	62	0.32	0.021
1985–1986	56	50	17	15	2	1	75	66	0.3	0.036
1986–1987	64	56	20	17	2	2	85	74	0.31	0.031
1987–1988	66	62	20	19	2	2	88	83	0.3	0.03
1988–1989	61	64	18	19	1	2	80	84	0.3	0.016
1989–1990	69	65	18	19	2	2	89	86	0.26	0.029
1990–1991	69	66	18	18	2	2	89	86	0.26	0.029
1991–1992	69	69	19	18	1	2	88	89	0.28	0.014
1992–1993	77	72	23	20	1	1	101	93	0.3	0.013
1993–1994	76	74	21	21	1	1	98	96	0.28	0.013
1994–1995	79	77	19	21	1	1	99	99	0.24	0.013
1995–1996	88	81	22	21	1	1	111	103	0.25	0.011
1996–1997	87	85	18	20	0.4	1	105	105	0.21	0.005
1997–1998	91	89	24	21	1	1	116	111	0.26	0.011
1998–1999	91	90	20	21	1	1	112	111	0.22	0.011

Table A.2 Continued

Fiscal year	N	Moving average	P	Moving average	K	Moving average	Total	Moving average	P/N	K/N
1999–2000	97	93	26	23	1	1	124	117	0.27	0.01
2000–2001	103	97	31	26	1	1	135	124	0.3	0.01
2001–2002	104	101	28	28	1	1	133	131	0.27	0.01
2002–2003	106	104	29	29	1	1	136	135	0.27	0.009
2003–2004	116	109	31	29	1	1	147	139	0.27	0.009
2004–2005	122	115	38	33	1	1	161	148	0.31	0.008
2005–2006	130	123	38	36	1	1	169	159	0.29	0.008
2006–2007	115	122	42	39	2	1	159	163	0.37	0.017
2007–2008	125	123	27	36	1.2	1	153	160	0.22	0.01
2008–2009	128.2	123	28	32	1.1	1	157	156	0.22	0.009
2009–2010	146.1	133	36	30	1	1	183	164	0.25	0.007
2010–2011	132.4	136	32	32	1.4	1	166	169	0.24	0.011
2011–2012	137	139	27	32	0.9	1	165	171	0.2	0.007
2012–2013	122	130	32	30	0.9	1	155	162	0.26	0.007
2013–2014	140	133	39	33	1	1	180	167	0.28	0.007

Source: NFDC (2014).
Note: N = nitrogen; P = phosphorus; K = potassium.

Table A.3 The use of fertilizer nutrient in major crops, 1980–2014

	Share of fertilizer use (%)				Fertilizer use rate (kg/ha)		
Year	Wheat	Rice	Cotton	Other crops	Wheat	Rice	Cotton
1980–1981	48	12	16	24	74.2	67.0	81.9
1981–1982	48	12	16	24	71.6	65.5	77.9
1982–1983	48	12	16	24	80.7	75.5	88.0
1983–1984	50	10	15	25	81.9	60.2	81.3
1984–1985	50	10	15	25	86.3	62.7	83.8
1985–1986	50	10	15	25	102.1	81.2	95.9
1986–1987	50	10	15	25	115.8	86.4	106.8
1987–1988	50	10	15	25	117.7	87.6	100.5
1988–1989	47	10	20	23	105.8	85.2	132.9
1989–1990	47	10	20	23	113.2	89.7	145.5
1990–1991	47	10	20	23	112.5	89.6	142.0
1991–1992	47	10	20	23	112.4	89.8	132.9
1992–1993	47	10	20	23	121.6	114.6	151.5
1993–1994	47	10	20	23	125.6	97.9	153.1
1994–1995	47	10	20	23	125.6	102.8	164.6
1995–1996	47	10	20	23	141.1	116.3	167.8
1996–1997	45	10	21	24	132.7	112.4	158.8
1997–1998	45	11	21	24	142.0	120.4	186.2
1998–1999	45	5	23	26	142.4	57.3	204.1
1999–2000	45	5	23	26	151.8	60.6	219.4
2000–2001	45	5	23	26	164.3	67.1	233.8
2001–2002	45	5	23	26	164.9	74.5	217.2
2002–2003	45	5	23	26	170.5	73.0	249.7
2003–2004	45	5	23	26	177.9	70.4	249.0
2004–2005	50	6	25	19	221.0	88.0	289.3
2005–2006	50	6	25	19	225.2	87.1	306.5
2006–2007	50	6	25	19	214.0	85.3	298.5
2007–2008	50	6	25	19	209.4	85.4	293.1
2008–2009	50	6	25	19	205.1	75.2	329.0
2009–2010	50	6	25	19	238.7	90.7	351.0
2010–2011	50	6	25	19	220.9	99.8	365.6
2011–2012	50	6	25	19	223.2	90.1	340.5
2012–2013	50	6	25	19	209.1	94.1	314.5
2013–2014	50	6	25	19	226.2	87.9	364.3
Growth	0.06%	-2.59%	1.75%	-0.81%	3.52%	0.45%	4.97%

Source: NFDC (2014).

Table A.4 The crop-based ecoregional classification in Pakistan

Crop region	Punjab	Sind	KPK	Baluchistan
Wheat-maize, groundnut (Barani)	Attock, Rawalpindi, Islamabad, Jehlum, Chakwal		Hangu, Tank, Bannu, Karak, Lakki Marwat, F.R. Bannu, F.R. D.I. Khan, F.R. Kurrum, N. and S. Waziristan, Orakzai Agency, Kurrum Agency	
Mix crops	Gujrat, M. B. Din, Sargodha + Khushab Faisalabad + T. T. Singh Jhang Lahore + Kasur	Sukkur, Shikarpur, Hyderabad, Badin	D. I. Khan, Haripur, Mansehra, Kohat, Abbot Abad, Shanglapur, Battagram, Charsadda, Nowshehra, Mardan, Peshawar, Swabi, Mahmand Agency, F. R. Peshawar, F. R. Kohat, F. R. Masehra, Khyber Agency	
Wheat-cotton	Sahiwal, Vehari, Okara, Pakpatten, Multan, Khanewal, Lodhran, Bhawalpur, Bhawalnagar, R. Y. Khan	Khairpur, Nawabshah, N. Feroz Sanghar, Tharparkar, Mirpukhas		Sibbi, Jhal Magsi, Jafar Abad, Nasir Abad, Tumbo, Karachi
Wheat-rice	Sialkot + Narowal Gujranwala + Hafizabad Sheikhupura	Jacobabad + Karachi Larkana Dadu Thatta		
Wheat/gram-mung bean	Mianwali + Bhakkar Muzaffargarh + Layyah D. G. Khan + Rajanpur			
Horticulture				Loralai, Kalat, Khuzdar, Zhob, Pishin, Quetta, Bolan, Mastung, Killa Saifullah, Ziarat, Lasbella, Gawadar, Tubat, Pangoor
Mountainous				Kohlu, Musa Khel, Kila Abdullah, Barkhan, Dera Bugti

Source: SSD-PARC (1980).

Note: KPK = Khyber Pakhtunkhwa.

Table A.5 Definition of variables

Variable name	Variable definition
Dependent variable	
Yield of wheat (kg/ha)	Production of wheat per hectare
Input variables	
Nitrogen used (kg/ha)	Total kilogram of nitrogen consumed
Tractor usage (hours/ha)	Total number of hours for which tractors were used
Family labor (hours/ha)	Number of hours for which family labor was used
Hired labor (hours/ha)	Number of hours for which hired labor was used
Number of pesticide sprays (no)	Total number of sprayings
Total seed used (kg/ha)	Total seed or seedlings used
Ground water irrigations (number)	Number of groundwater irrigations applied on plot
Canal water irrigations (number)	Number of canal water irrigations applied on plot
Age of the household head (years)	Age in years of household head
Average education of household (years)	Average number of education years of entire household
Indicator variables (Yes=1, No=0)	
Access to extension services	Household had access to extension service
Seed was registered after 2005	Seed used by farmer was registered after 2005
Loss experienced during harvesting	Household experienced loss in production during harvesting of crop
Loss due to natural disaster	Household experienced loss in production due to flood, drought, and frost
Loss due to pests	Household experienced loss in production due to pests
Did the plot experience salinity?	Presence of salinity on plot reported by respondent
Was the plot fertile?	Quality of soil as reported by respondent
Manure application	Manure was applied during the rabi 2011–2012 season

Source: Authors' definitions.
Notes: Each of the values was standardized by the cultivated land size in hectares.

Table A.6 Summary statistics on agricultural output, input uses, and household demographics

Variable	Mean	SD
Agricultural output		
Yield of wheat (kg/ha)	2760.3	1061.8
Inputs		
Canal water irrigations (number)	2.73	4.12
Groundwater irrigations (number)	4.66	5.41
Hired labor (hours/ha)	97.37	154.1
Family labor (hours/ha)	130.4	139.7
Pesticide sprays (number)	1.02	1.10
Nitrogen used (kg/ha)	114.7	57.60
Age of household head (years)	47.17	12.67
Average education level of household (years)	6.43	8.47
Tractor usage (hours/ha)	8.01	4.39
Total seed used (kg/ha)	141.2	40.95
Extension, loss, seeds, and soil health (yes percent given)		
Was phosphorous applied?	0.83	0.38
Was manure applied?	0.26	0.44
Did the plot experience salinity?	0.05	0.22
Is the soil highly fertile?	0.96	0.20
Loss was experienced during harvesting	0.06	0.24
Crop was affected by pest or disease	0.04	0.19
Loss due to a natural disaster	0.20	0.40
Visit by extension agent	0.20	0.40
Seed was registered before 2005	0.61	0.50

Source: Authors' estimates based on IFPRI/IDS (2014).
Note: These are for 755 observations that are used to estimate the yield response function.

Table A.7 Feedstock gas prices ($/MMBTU) for fertilizer manufacturers in Pakistan, the Middle East, and the USA

Year	Pakistan	Middle East	Henry Hub, USA
2004–2005	1.0	1.1	6.3
2005–2006	1.9	1.4	8.9
2006–2007	2.1	1.3	6.9
2007–2008	2.0	1.7	8.3
2008–2009	1.5	2.7	5.9
2009–2010	1.6	1.1	4.3
2010–2011	1.6	1.4	4.2
2011–2012	1.8	1.9	3.2
2012–2013	1.2	2.0	3.8
2013–2014	1.2	2.1	4.3
Average	1.6	1.7	5.6

Source: Data retrieved from HDIP (2014), EIA (2014), and HC Securities & Investment (2010).

Table A.8 Total P subsidy to the fertilizer industry (million USD)

Year	Production subsidy	Distribution subsidy			Total subsidy	% of GDP	% of Ag. GDP	% of ADP
		Urea	Other (P&K)	Total				
2004–2005	13.34	1.52	0.00	1.52	14.86	NA	NA	NA
2005–2006	13.13	3.60	0.00	3.60	16.73	0.20	0.94	4.58
2006–2007	14.53	1.69	13.70	15.39	29.92	0.32	1.49	6.90
2007–2008	15.23	2.49	17.40	19.89	35.12	0.33	1.47	7.77
2008–2009	25.60	15.91	26.50	42.41	68.01	0.52	2.27	14.16
2009–2010	28.47	10.57	0.50	11.07	39.54	0.27	1.14	6.45
2010–2011	29.39	6.39	0.00	6.39	35.78	0.20	0.78	7.07
2011–2012	36.29	8.41	0.00	8.41	44.70	0.22	0.94	6.11
2012–2013	35.59	1.63	0.00	1.63	37.22	0.17	0.69	4.79
2013–2014	41.32	11.35	0.00	11.35	52.67	0.21	0.87	6.20

Source: Authors' calculation based on NFDC (2014).

Note: GDP = gross domestic product; Ag. = agriculture; ADP = Annual Development Program (Provinces); P&K = phosphorus and potassium.

Table A.9 Proportion of subsidy in price for urea, 2004/2005–2013/2014

Year	Subsidy on domestic production±	Subsidy on imported urea ±	Total subsidy ±	Urea produc-tion^	Imported urea^	Total urea supply^	Domestic prices#	Average production subsidy#*	Average import subsidy #**	Total subsidy #***	Propor-tion+	Import subsidy / domestic price (%)	Total subsidy/ domestic prices (%)
2004–2005	222.9	30.88	253.78	4610.7	307.0	4917.7	156.4	48.3	100.6	51.6	31%	64%	33%
2005–2006	219.3	75.79	295.09	4803.9	825.0	5628.9	169.7	45.7	91.9	52.4	27%	54%	31%
2006–2007	239.7	33.88	273.58	4731.7	281.0	5012.7	173.8	50.7	120.6	54.6	29%	69%	31%
2007–2008	243.5	43.76	287.26	4925.1	181.0	5106.1	187.4	49.4	241.8	56.3	26%	129%	30%
2008–2009	326.1	219.47	545.57	4921.7	905.0	5826.7	191.6	66.3	242.5	93.6	35%	127%	49%
2009–2010	339.7	153.53	493.23	5154.9	1525.0	6679.9	192.4	65.9	100.7	73.8	34%	52%	38%
2010–2011	343.7	98.38	442.08	4994.0	635.0	5629.0	244.4	68.8	154.9	78.5	28%	63%	32%
2011–2012	410.9	108.11	519.01	4686.0	1449.0	6135.0	389.2	87.7	74.6	84.6	23%	19%	22%
2012–2013	366.8	108.22	475.02	4364.0	761.0	5125.0	350.4	84.0	142.2	92.7	24%	41%	26%
2013–2014	397.2	43.54	440.74	4932.0	1155.0	6087.0	361.7	80.5	37.7	72.4	22%	10%	20%

Source: Authors' calculation based on NFDC (2014).

Note: ± Million $; ^000 tons; #$/ton; +Production subsidy /domestic price. * Estimated on domestic production only. ** Estimated on imported urea only. *** Estimated on production plus import.

APPENDIX B: FIRMS IN THE FERTILIZER INDUSTRY IN PAKISTAN

The first urea and calcium ammonium nitrate (CAN) combined plant was established in the private sector by Pak Arab in 1958. Lyall Chemicals and Fertilizer Limited installed its first single super phosphate plant in 1967 and Engro Chemical Pakistan (Ltd.) added a urea capacity in 1968. During 1972, total installed capacity was 534 thousand tons of N and 15 thousand tons of phosphorus pentoxide (P_2O_5), while 215 thousand tons of N and 4 thousand tons of P_2O_5 were produced and 73 thousand tons of N were imported (capacity was greater than demand). Thus, the production capacity of fertilizer was growing faster than demand and the sector was competing with imported material, although the gas used as a raw material was supplied by the government at a subsidized rate. The government then decided to intervene in the sector at this point and created the National Fertilizer Corporation (NFC). The major firms engaged in fertilizer production are described below.

National Fertilizer Corporation (NFC)

The NFC was the first major public-sector initiative incorporated in 1972 with the objectives of keeping fertilizer prices at reasonable and affordable levels, developing domestic manufacturing, and ensuring availability through an intensive market network. Later, the government took further initiatives to form joint ventures with regional partners. In 1972 NFC became the major shareholder in Pak Arab Fertilizers and Lyall Chemicals and Fertilizer Limited. It established the Pak Saudi urea plant with a capacity of 774 thousand tons in 1982. NFC decided to sell all of its share in the fertilizer manufacturing industry in 1984 and gradually withdrew from fertilizer production.

Fauji Fertilizer Company (FFC)

By the late 1970s, Fauji Fertilizer Company (FFC) was formed through a joint venture between Fauji Foundation (FF) and Haldor Topsoe A/S of Denmark. The company evolved into a dominant player in the market. Later in 2000, the group expanded into the DAP business by setting up Pakistan's first and the only DAP plant in the form of FFC-Jordan Fertilizer Company, later renamed as Fauji Fertilizer Bin Qasim (FFBL).

The company commenced operations in 1982 with an annual urea capacity of 570 thousand tons, which was gradually increased to 635 thousand tons. In 2002, FFC acquired the Pak Saudi Fertilizer Limited urea plant from NFC under the government's privatization program. This pushed the company capacity to 1.9 million tons. Further expansion activities have enhanced the company's urea capacity to 2.58 million tons. Apart from manufacturing, the company also has an extensive marketing network comprising 3,258 dealers spread across the country. Presently, Fauji Foundation (FF) holds a 44 percent stake in the company.

As a joined venture between FFC, FF, and Jordan Phosphate Mines, Co., a new plant, Fauji Fertilizer Bin Qasim Ltd. (FFBL), was built at a cost of $68 million in 1993. It is the only DAP producer in the country, and it also manufactures superior quality granular urea. However, the plant ran into a series of crises in its early years due to technical, financial, and managerial reasons. As a result, its DAP plant was mothballed in 2001 due to accumulated losses of Rs. 6.5 billion. In 2003, Jordan Phosphate Mines, Co. sold its stake, and the company resumed production after a lapse of two years. The company currently has annual urea and DAP capacities of 645 thousand tons and 670 thousand tons, respectively. Presently, a 51 percent stake is held by FFC and 17 percent is held by FF (Agricultural Statistics of Pakistan 2011–2012).

Engro Chemical Pakistan Ltd.

Engro has gradually achieved the status of the largest player in the urea industry, while also being the first company to establish a urea plant in the country. The company was initially established as Esso Pakistan Fertilizer Company Ltd. in 1965 with 75 percent shares held by Esso. With an initial investment of $43 million, the plant had a capacity of 173 thousand tons. With Esso becoming Exxon, the company was renamed as Exxon Chemical Pakistan Ltd. In 1991, Exxon decided to divest its fertilizer business on a global basis, which resulted in an employee-led buyout of Exxon's 75 percent stake in the company. Since then, the company has evolved into a dynamic and well-diversified conglomerate. The holding company has become the biggest domestic urea producer by way of its expansion of 1.3 million tons in 2010, costing over $1 billion. In addition, it has a nitrogen phosphorous potassium (NPK) capacity of 160 thousand tons. The company also has a share of 21 percent within the marketing segment of the fertilizer sector in the country.

Dawood Hercules Chemical Ltd.

The Company was incorporated in 1968 as a joint venture between the Dawood Group and Hercules, Inc. USA. The plant had an initial capacity of 345 thousand tons of urea, which was enhanced to 445 thousand tons as a result of revamp activities during 1981–1991. DHCL markets its products through Dawood Corporation Ltd. (DCL), though its activities are confined to Punjab and NWFP. During 2008, DCL maintained a share of 8.2 percent in the overall fertilizer marketing activities in the country. The company is primarily held by the Dawood Group, and it also holds a 41 percent stake in Engro Chemical Pakistan Ltd.

Fatima Fertilizer Company Limited

The Company is the newest player in the sector, and entered the urea, CAN, and nitro phosphate (NP) markets during 2010 and 2011. With a total project cost of Rs59 billion, the company is jointly owned by the Fatima Group and Arif Habib Group, while Pak Arab Fertilizer holds a 50 percent stake in the company. The company has 500 thousand tons of urea production capacity and is the market leader in CAN, NP, and NPK production. The fertilizer complex is a fully integrated production facility, capable of producing urea, CAN, NP, and NPK at Sadiqabad, Rahim Yar Khan. Fatima and Pak Arab are the only producers of CAN and NPK in the country. They introduced the concept of balanced fertilizer use by introducing such products rather than leaving it on the farmers. The complex has been allocated 110 million cubic feet per day of gas from the dedicated Mari Gas fields (CCP 2010).

APPENDIX C: INITIAL EQUATIONS FOR THE EQUILIBRIUM DISPLACEMENT MODEL

The crop market is estimated as

$$Q_i^s = f\left(P_i^f, P_j^f, P_k, T_i\right) \text{ and} \tag{1}$$

$$Q_i^d = h(P_i, P_j, C_i), \tag{2}$$

where *Q* is the quantity of *i*th output (*i*=1,2,3,4 crops, that is, cotton, rice[36], wheat, other crops); P_i is *i*th domestic commodity price at equilibrium, where supply and demand curves cross each other; and P_j is the price of all other commodities, where $j \neq i$, P_k is the domestic price of fertilizer *k* (*k*=u, p fertilizer, that is, urea, DAP), *T* is an exogenous technology variable or constant shifter in *i*th crop production, C_i is the income of the consumer for the *i*th crop, and the superscripts *s* and *d* represent domestic production and domestic demand, respectively.

The market clearing equation and the trade equations for the crop market are estimated as

$$Q_i^d = Q_i^s + I_i, \tag{3}$$

$$I_i = l(P_i), \tag{4}$$

$$P_i = P_i^f(1 + t_i), \tag{5}$$

$$P_i^f = P_i^w(1 + z_i), \tag{6}$$

where I_i is the quantity of import supply of *i*th commodity; P_i^f is the factory price of *i*th commodity; t_i is the general sales tax on *i*th crop; P_i^w is the world price of the *i*th crop; and z_i is the import duty/tariff/transport cost, which establishes the difference between the world price and the domestic price.

The fertilizer market is estimated as

$$Q_k^s = m(Q_g, P_g, P_k^f, Q_{po}, P_{po}) \text{ and} \tag{7}$$

$$Q_k^d = r(P_k, Q_i^s), \tag{8}$$

where Q_k and P_k are quantity and prices of *k*th fertilizer, respectively; P_k^f is factory price of *k*th fertilizer; and the superscript *s*, *d*, *w, g,* and *po* are for supply, demand, world, natural gas, and phosphate, respectively.

The market clearing equation, along with a set of trade equations for the fertilizer market, is given as the following identity

$$Q_k^d = Q_k^s + I_k, \tag{9}$$

$$I_k = v(P_k), \tag{10}$$

$$P_k = P_k^f(1 + t_k), \tag{11}$$

$$P_k^f = P_k^w(1 + z_k), \tag{12}$$

[36] We do not differentiate between the basmati and non-basmati rice varieties in our model mainly because of data constraints. Further, we focused on urea in our model because it is the most pervasively used fertilizer and also the most heavily subsidized.

where Q_k^d and Q_k^s are the quantity demanded and supplied of *k*th fertilizer, respectively. I_k is the import of fertilizer and t_k is the general sales tax on fertilizer. P_k^w is the world price of fertilizer and z_k is import duty/tariff/transport cost and represents the difference between the domestic and the world price.

APPENDIX D: TRANSFORMATION OF EQUATIONS

The following shows how linear equations are transformed to provide elasticities and marginal impacts. We transform the following equation for wheat:

$$Q_i^s = f(P_i^f, P_j^f, P_u, P_p, T_i). \tag{13}$$

$$Q_1^s = \zeta_1 + \zeta_2(P_1^f) + \zeta_3(P_2^f) + \zeta_4(P_3^f) + \zeta_5(P_4^f) + \zeta_6(P_u) + \zeta_7(P_p) + \zeta_8 T_1 + u_1, \tag{14}$$

where Q_1^s, domestic production of wheat, is a function of P_1, the price of wheat, and shifters are P_2, P_3, and P_4, which are the price of rice, cotton, and other crops, respectively; P_u is the price of urea; P_p is the price of DAP; and T is technology adoption.

Total differentiation of equation (14) yields

$$dQ_1^s = \frac{\partial Q_1^s}{\partial P_1^f} dP_1^f + \frac{\partial Q_1^s}{\partial P_2^f} dP_2^f + \frac{\partial Q_1^s}{\partial P_3^f} dP_3^f + \frac{\partial Q_1^s}{\partial P_4^f} dP_4^f + \frac{\partial Q_1^s}{\partial P_u} dP_u + \frac{\partial Q_1^s}{\partial P_p} dP_p + \frac{\partial Q_1^s}{\partial T_1} dT_1. \tag{15}$$

Multiplying both sides by $\frac{1}{Q_1^s}$ and expanding the right-hand side by $\frac{P_1^f}{P_1^f}, \frac{P_2^f}{P_2^f}, \frac{P_3^f}{P_3^f}, \frac{P_4^f}{P_4^f}, \frac{P_u}{P_u}, \frac{P_p}{P_p}, \frac{T_1}{T_1}$, respectively, yields:

$$\frac{dQ_1^s}{Q_1^s} = \frac{\partial Q_1^s}{\partial P_1^f}\frac{dP_1^f}{Q_1^s}\frac{P_1^f}{P_1^f} + \frac{\partial Q_1^s}{\partial P_2^f}\frac{dP_2^f}{Q_1^s}\frac{P_2^f}{P_2^f} + \frac{\partial Q_1^s}{\partial P_3^f}\frac{dP_3^f}{Q_1^s}\frac{P_3^f}{P_3^f} + \frac{\partial Q_1^s}{\partial P_4^f}\frac{dP_4^f}{Q_1^s}\frac{P_4^f}{P_4^f} + \frac{\partial Q_1^s}{\partial P_u}\frac{dP_u}{Q_1^s}\frac{P_u}{P_u} + \frac{\partial Q_1^s}{\partial P_p}\frac{dP_p}{Q_1^s}\frac{P_p}{P_p} + \frac{\partial Q_1^s}{\partial T_1}\frac{dT_1}{Q_1^s}\frac{T_1}{T_1}. \tag{16}$$

Equation (16) can rewritten as

$$EQ_1^s = \eta_1 EP_1^f + \sigma_{12} EP_2^f + \sigma_{13} EP_3^f + \sigma_{14} EP_4^f + \varphi_{1,1} EP_u + \varphi_{1,2} EP_p + \vartheta_1 ET_1, \tag{17}$$

where operator E represents a marginal change.

The tax equation is given as

$$P_1^f(1 + t_1) = P_1. \tag{18}$$

We derive equation (18) by first taking its total differentiation, which yields the following equation:

$$dP_1 = P_1^f d(1 + t_1) + (1 + t_1) dP_1^f, \tag{19}$$

where $d(1 + t_1) = dt_1$, and multiplying both sides by $\frac{1}{P_1}$ yields

$$dP_1/P_1 = (P_1^f dt_1/P_1) + ((1 + t_1) dP_1^f)/P_1. \tag{20}$$

Substituting $P_1^f = P_1/(1 + t_1)$ and $P_1 = P_1^f(1 + t_1)$ on the right-hand side yields

$$dP_1/P_1 = (P_1 dt_1/(1 + t_1)P_1 + ((1 + t_1) dP_1^f)/P_1^f(1 + t_1). \tag{21}$$

Assuming the initial tax rate=0, $dt_1 = t_1$ and $\frac{t_1}{1+t_1} = t_1$, equation (21) can be rewritten as:

$$EP_U = t_u + EP_u^f. \tag{22}$$

APPENDIX E: FINAL EQUATIONS FOR EQUILIBRIUM DISPLACEMENT MODEL

The input and output markets are first reduced by substituting the demand equation in the market clearing equation (equation [3]). Each equation in this linear system is then totally differentiated and manipulated so that all variables are converted into proportionate changes and elasticities, where the operator *E* applied to any variable is the proportionate change in that variable and all the other notations represent elasticities, as explained in Appendix Table F.1. These transformed equations are entered in the general algebraic modeling system with their respective elasticities to estimate the impact of exogenous shocks on the endogenous variables. The final reduced and transformed equations are as follows:

$$EQ_i^s = \eta_i\left(EP_i^f\right) + \sum_{j=1}^{j\neq i, j=3} \sigma_{ij}\left(EP_j^f\right) + \sum_{k=1}^{k=2} \varphi_{ik}(EP_k) + \vartheta_i ET, \tag{23}$$

$$EQ_i^s = \gamma_i(EP_i) + \sum_{j=1}^{j\neq i, j=3} \delta_{ij}\left(EP_j\right) + \mu_i EC_i - a_i EI_i, \tag{24}$$

$$EI_i = \beta_i\, EP_i, \tag{25}$$

$$EP_i^f = EP_i^w + z_i, \tag{26}$$

$$EP_i = EP_i^f + t_i, \tag{27}$$

$$EQ_k^s = v_k EP_k^f + \rho_k EQ_g + \xi_k EP_g + \lambda_k EQ_{po} + \varsigma_k EP_{po}, \tag{28}$$

$$EQ_k^s = \tau_k EP_k + \sum_{i=1}^{4} \partial_{ki}(EQ_i) - b_k EI_k, \tag{29}$$

$$EI_k = \alpha_k\, EP_k, \tag{30}$$

$$EP_k^f = EP_k^w + z_k, \tag{31}$$

$$EP_k = EP_k^f + t_k. \tag{32}$$

APPENDIX F: EQUILIBRIUM DISPLACEMENT MODEL TABLES

Elasticities were drawn from previous literature whenever possible. According to our research, elasticities on fertilizer manufacturing were not available, and are based on feedback from industry professionals.

Table F.1 Values of elasticities used in the EDM model

Descriptor	Symbols	Elasticity	Descriptor	Symbols	Elasticity
			Crop market		
	Demand elasticity			***Supply elasticity***	
Own price elasticity			Own price elasticity		
Wheat	γ_1	-0.400	Wheat	η_1	0.228
Rice	γ_2	-0.537	Rice	η_2	0.407
Cotton	γ_3	-0.300	Cotton	η_3	0.715
Other crops	γ_3	-0.800	Other crops	η_4	0.500
Cross price elasticity wheat			Cross price elasticity wheat		
Rice	δ_{12}	-0.098	Rice	σ_{12}	0.173
Cotton	δ_{13}	-0.02	Cotton	σ_{13}	-0.151
Other crops	δ_{14}	-0.01	Other crops	σ_{14}	-0.100
Cross price elasticity rice			Urea	φ_{11}	-0.0525
Wheat	δ_{21}	0.098	DAP	φ_{12}	-0.0175
Cotton	δ_{23}	0	Cross price elasticity rice		
Other crops	δ_{24}	-0.02	Wheat	σ_{21}	0.136
Cross price elasticity cotton			Cotton	σ_{23}	-0.098
Wheat	δ_{31}	0	Other crops	σ_{24}	-0.150
Rice	δ_{32}	0	Urea	φ_{21}	-0.0225
Other crops	δ_{34}	0	DAP	φ_{22}	-0.0075
Cross price elasticity other crops			Cross price elasticity cotton`		
Wheat	δ_{41}	-0.01	Wheat	σ_{31}	0
Rice	δ_{42}	-0.02	Rice	σ_{32}	-0.329
Cotton	δ_{43}	0	Other crops	σ_{34}	-0.15
Income elasticity			Urea	φ_{31}	-0.0375
Wheat	μ_1	0.376	DAP	φ_{32}	-0.0125
Rice	μ_2	0.85	Cross price elasticity other crops		
Cotton	μ_3	0.1	Wheat	σ_{41}	-0.1
Other crops	μ_4	1.1	Rice	σ_{42}	-0.15
Import elasticity			Cotton	σ_{43}	-0.15
Wheat	a_1	-1	Urea	φ_{41}	-0.0075
Rice	a_2	-1	DAP	φ_{42}	-0.0025
Cotton	a_3	1	Technology elasticity		
Other crops	a_4	-1	Rice	ϑ_1	1
	Trade elasticity of crops		Cotton	ϑ_2	1
Wheat	β_1	-5	Wheat	ϑ_3	1
Rice	β_2	-5	Other crops	ϑ_4	1
Cotton	β_3	5			
Other crops	β_4	-5			

Table F.1 Continued

Fertilizer Market					
Demand Elasticity			***Supply Elasticity***		
Own price elasticity			Own Price Elasticity		
Urea	τ_1	-0.3	Urea	v_1	0.8
DAP	τ_2	-0.5	DAP	v_2	0.4
Cross elasticity of urea with supply of crops			Input Elasticity in Urea		
Wheat	∂_{11}	0.82	Quantity of natural gas	ρ_1	0.32
Rice	∂_{12}	0.368	Price of natural gas	ξ_1	-0.075
Cotton	∂_{13}	0.486	Quantity of phosphate	λ_1	0
Other crops	∂_{14}	0.65	Price of phosphate	ς_1	0
Cross elasticity of DAP with supply of crops			Input Elasticity in DAP		
Wheat	∂_{11}	0.41	Quantity of natural gas	ρ_2	0.16
Rice	∂_{12}	0.184	Price of natural gas	ξ_2	-0.03
Cotton	∂_{13}	0.243	Quantity of phosphate	λ_2	0.4
Other crops	∂_{14}	0.15	Price of phosphate	ς_2	-0.3
Import Elasticity					
Urea	b_1	1			
DAP	b_2	1			
Trade elasticity of fertilizer					
Urea	α_1	1 and 5			
DAP	α_2	1 and 5			

Source: Ali (1990); Nazli, Haider, and Tariq (2012); and authors' own judgment assumptions.

Note: EDM = equilibrium displacement model; DAP = diammonium phosphate.

Table F.2 Results of the EDM

		Base values	Scenario 1		Scenario 2	
Variables	**Units**		**α=1**	**α=5**	**α=1**	**α=5**
			Fertilizer market			
Domestic supply of urea	Tons	**4932000**	-695899(-14.11)	-956431(-19.39)	120177(2.44)	42787(0.87)
Domestic supply of DAP	Tons	**694000**	-49405(-7.12)	-57709(-8.32)	13323(1.92)	4340(0.63)
Imports supply of urea	Tons	**1155000**	117884(10.21)	208091(18.02)	35180(3.05)	62625(5.42)
Imports supply of DAP	Tons	**933000**	41779(4.48)	69336(7.43)	44780(4.8)	72929(7.82)
Demand of urea	Tons	**6087000**	-578015(-9.5)	-748340(-12.29)	155356(2.55)	105412(1.73)
Demand of DAP	Tons	**1627000**	-7625(-0.47)	11627(0.71)	58103(3.57)	77268(4.75)
Farmer price of urea (inclusive GST)	PKR/ton	**36540**	3729(10.21)	1317(3.6)	-5099(-13.95)	-5816(-15.92)
Farmer price of DAP (inclusive GST)	PKR/ton	**72800**	3260(4.48)	1082(1.49)	-8882(-12.2)	-11238(-15.44)
Factory price of urea (exclusive GST)	PKR/ton	**31231**	3188(10.21)	1125(3.6)	951(3.05)	339(1.08)
Factory price of DAP (exclusive GST)	PKR/ton	**62222**	2786(4.48)	925(1.49)	2986(4.8)	973(1.56)
Import cost of fertilizer	Billion PKR	**98**	15(15.22)	15(15.45)	7(8.72)	7(8.3)
			Output market			
Overall pressure on output prices	PKR/ton	**-**	(0.07)	(0.03)	(-0.10)	(-0.12)
Overall trade surplus	Billion PKR	**129**	-1(-0.51)	0(-0.18)	1(0.78)	1(0.92)
Total crop production gain	Billion PKR	**2591**	-7(-0.3)	-3(-0.11)	11(0.47)	13(0.54)
Fertilizer expense for farmers	Billion PKR	**341**	4(1.22)	-18(-5.19)	-37(-10.82)	-46(-13.4)
Production revenue	Billion PKR	**2591**	-7(-0.28)	-3(-0.1)	11(0.44)	13(0.51)
Overall farmer benefit	Billion PKR	**2250**	-11(-0.51)	15(0.67)	48(2.14)	59(2.62)
Gas expense	Billion PKR	**16**	38(242.43)	35(222.31)	0(2.41)	0(0.85)
Fertilizer revenue	Billion PKR	**158**	-8(-4.82)	-23(-14.4)	9(5.83)	3(2.01)
Overall manufacturer benefit	Billion PKR	**142**	-46(-32.31)	-58(-40.72)	9(6.21)	3(2.14)
Production subsidy (urea)	Billion PKR	**47**	-47(-100)	-47(-100)	1(2.41)	0(0.85)
Retail subsidy (DAP)	Billion PKR	**-**	0(0)	0(0)	0(0)	0(0)
Distribution subsidy	Billion PKR	**11**	2(15.98)	2(20.2)	0(3.04)	0(5.42)
Tax revenue from fertilizer sales	Billion PKR	**50**	1(1.22)	-3(-5.19)	-50(-100)	-50(-100)
All subsidies	Billion PKR	**58**	-45(23.55)	-44(24.41)	1(102.47)	1(101.29)
Investment in R&D	Billion PKR	**-**	0	0	0	0
Total change in government revenue	Billion PKR	**-**	46	42	-51	-50
Consumer crop demand	Billion PKR	**2433**	-7(-0.27)	-2(-0.1)	10(0.42)	12(0.49)
Eventual social benefit [3]	Billion PKR	**-**	**-18**	**-3**	**16**	**24**

Table F.2 Continued

Variables	Units	Base values	Scenario 3		Scenario 4	
			α=1	α=5	α=1	α=5
		Fertilizer Market				
Domestic supply of urea	Tons	**4932000**	-575722(-11.67)	-913644(-18.52)	280126(5.68)	384742(7.8)
Domestic supply of DAP	Tons	**694000**	-36081(-5.2)	-53370(-7.69)	24789(3.57)	29011(4.18)
Imports supply of urea	Tons	**1155000**	153064(13.25)	270716(23.44)	-47358(-4.1)	-83669(-7.24)
Imports supply of DAP	Tons	**933000**	86559(9.28)	142265(15.25)	-21180(-2.27)	-34961(-3.75)
Demand of urea	Tons	**6087000**	-422658(-6.94)	-642928(-10.56)	232767(3.82)	301073(4.95)
Demand of DAP	Tons	**1627000**	50478(3.1)	88895(5.46)	3610(0.22)	-5950(-0.37)
Farmer price of urea (inclusive GST)	PKR/ton	**36540**	-1369(-3.75)	-4499(-12.31)	-1498(-4.1)	-529(-1.45)
Farmer price of DAP (inclusive GST)	PKR/ton	**72800**	-5622(-7.72)	-10156(-13.95)	-1653(-2.27)	-546(-0.75)
Factory price of urea (exclusive GST)	PKR/ton	**31231**	4139(13.25)	1464(4.69)	-1281(-4.1)	-452(-1.45)
Factory price of DAP (exclusive GST)	PKR/ton	**62222**	5773(9.28)	1898(3.05)	-1412(-2.27)	-466(-0.75)
Import cost for fertilizer	Billion PKR	**98**	21(24.51)	20(24.07)	-6(-6.34)	-6(-6.5)
		Output Market				
Overall pressure on output prices	PKR/ton	**-**	(-0.04)	(-0.09)	(-0.03)	(-0.01)
Overall trade surplus	Billion PKR	**129**	0(0.27)	1(0.74)	0(0.21)	0(0.07)
Total crop production gain	Billion PKR	**2591**	4(0.16)	11(0.44)	3(0.13)	1(0.04)
Fertilizer expense for farmers	Billion PKR	**341**	-29(-8.5)	-59(-17.29)	-3(-1)	6(1.85)
Production revenue	Billion PKR	**2591**	4(0.15)	11(0.41)	3(0.12)	1(0.04)
Overall farmer benefit	Billion PKR	**2250**	33(1.46)	70(3.09)	6(0.29)	-5(-0.23)
Gas expense	Billion PKR	**16**	40(252)	36(225.7)	1(5.57)	1(7.61)
Fertilizer revenue	Billion PKR	**158**	1(0.81)	-20(-12.55)	2(1.32)	9(5.62)
Overall manufacturer benefit	Billion PKR	**142**	-38(-27.12)	-55(-39.04)	1(0.85)	8(5.4)
Production subsidy (urea)	Billion PKR	**47**	-47(-100)	-47(-100)	3(5.57)	4(7.61)
Retail subsidy (DAP)	Billion PKR	**-**	0(0)	0(0)	0(0)	0(0)
Distribution subsidy	Billion PKR	**11**	1(13.25)	1(23.43)	-1(-6.12)	-1(-7.94)
Tax revenue from fertilizer sales	Billion PKR	**50**	-50(-100)	-50(-100)	0(-1)	1(1.85)
All subsidies	Billion PKR	**58**	-46(10.85)	-46(11.83)	2(103.2)	3(104.45)
Investment in R&D	Billion PKR	**-**	0	0	0	0
Total change in government revenue	Billion PKR	**-**	-3	-4	-2	-2
Consumer crop demand	Billion PKR	**2433**	4(0.15)	10(0.4)	3(0.11)	1(0.04)
Eventual social benefit [3]	Billion PKR	**-**	**-5**	**20**	**8**	**2**

Table F.2 Continued

Variables	Units	Base values	Scenario 5		Scenario 6	
			α=1	α=5	α=1	α=5
		Fertilizer market				
Domestic supply of urea	Tons	**4932000**	-686326(-13.92)	-952230(-19.31)	-573790(-11.63)	-913313(-18.52)
Domestic supply of DAP	Tons	**694000**	-27133(-3.91)	-50506(-7.28)	-45405(-6.54)	-56384(-8.12)
Imports supply of urea	Tons	**1155000**	120686(10.45)	214239(18.55)	153629(13.3)	271201(23.48)
Imports supply of DAP	Tons	**933000**	116632(12.5)	190390(20.41)	55222(5.92)	91613(9.82)
Demand of urea	Tons	**6087000**	-565640(-9.29)	-737991(-12.12)	-420160(-6.9)	-642111(-10.55)
Demand of DAP	Tons	**1627000**	89499(5.5)	139884(8.6)	9817(0.6)	35229(2.17)
Farmer price of urea (inclusive GST)	PKR/ton	**36540**	3818(10.45)	1356(3.71)	4860(13.3)	1716(4.7)
Farmer price of DAP (inclusive GST)	PKR/ton	**72800**	-12739(-17.5)	-18869(-25.92)	4309(5.92)	1430(1.96)
Factory price of urea (exclusive GST)	PKR/ton	**31231**	3263(10.45)	1159(3.71)	4154(13.3)	1467(4.7)
Factory price of DAP (exclusive GST)	PKR/ton	**62222**	7778(12.5)	2539(4.08)	3683(5.92)	1222(1.96)
Import cost for fertilizer	Billion PKR	**98**	24(25.62)	23(24.56)	20(20.18)	20(20.36)
		Output market				
Overall pressure on output prices	PKR/ton	**-**	(0.03)	(-0.03)	(-0.44)	(-0.49)
Overall trade surplus	Billion PKR	**129**	0(-0.2)	0(0.21)	6(4.58)	6(5.01)
Total crop production gain	Billion PKR	**2591**	-3(-0.12)	3(0.13)	52(2.15)	58(2.41)
Fertilizer expense for farmers	Billion PKR	**341**	-15(-4.38)	-43(-12.58)	20(5.85)	-9(-2.69)
Production revenue	Billion PKR	**2591**	-3(-0.11)	3(0.12)	52(2.01)	58(2.25)
Overall farmer benefit	Billion PKR	**2250**	12(0.54)	46(2.04)	32(1.43)	67(3)
Gas expense	Billion PKR	**16**	38(243.83)	35(222.84)	40(251.87)	36(225.64)
Fertilizer revenue	Billion PKR	**158**	-3(-2.07)	-21(-13.51)	0(-0.13)	-20(-12.86)
Overall manufacturer benefit	Billion PKR	**142**	-42(-29.41)	-56(-39.78)	-40(-28.15)	-56(-39.38)
Production subsidy (urea)	Billion PKR	**47**	-47(-100)	-47(-100)	-47(-100)	-47(-100)
Retail subsidy (DAP)	Billion PKR	**-**	13(0)	12(0)	0(0)	0(0)
Distribution subsidy	Billion PKR	**11**	2(16.37)	2(20.8)	3(21.03)	3(26.45)
Tax revenue from fertilizer sales	Billion PKR	**50**	-17(-34.63)	-20(-40.53)	3(5.85)	-1(-2.69)
All subsidies	Billion PKR	**58**	-32(46.41)	-32(45.59)	-44(24.58)	-44(25.68)
Investment in R&D	Billion PKR	**-**	0	0	12	12
Total change in government revenue	Billion PKR	**-**	14	12	35	30
Consumer crop demand	Billion PKR	**2433**	-3(-0.11)	3(0.12)	46(1.9)	52(2.13)
Eventual social benefit [3]	Billion PKR	**-**	**-18**	**4**	**74**	**94**

Source: Authors' results.

Notes: DAP = diammonium phosphate; GST = general sales tax; PKR = Pakistani rupees; R&D =research and development. Parentheses represent percentage changes.

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