Chapter 6

PAKISTAN'S FERTILIZER SECTOR: STRUCTURE, POLICIES, PERFORMANCE, AND IMPACTS

Mubarik Ali, Faryal Ahmed, Hira Channa, and Stephen Davies

Introduction

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

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

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

Few studies analyze the policy environment in the sector, which encompasses the whole value chain of processing, marketing, trade, and application to crops. One exception is a study by the Competition Commission of Pakistan (CCP), 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 most recent year of data included in the CCP (2010).

This chapter explores these issues in greater depth by reviewing the state of the fertilizer industry, identifying the main policy issues, and analyzing the costs and benefits associated with alternative policy interventions. The remainder of this chapter proceeds as follows. The second section provides a brief history of the industry. The third section describes fertilizer use and its effects on yield and soil. The fourth section reviews the performance of the fertilizer market and examines the effects of subsidies and imperfect competition. The fifth section develops an equilibrium displacement model and simulates the impacts of major government policy interventions. The final section concludes with recommendations aimed at improving the performance of Pakistan's fertilizer sector and its contribution to future agricultural productivity growth.

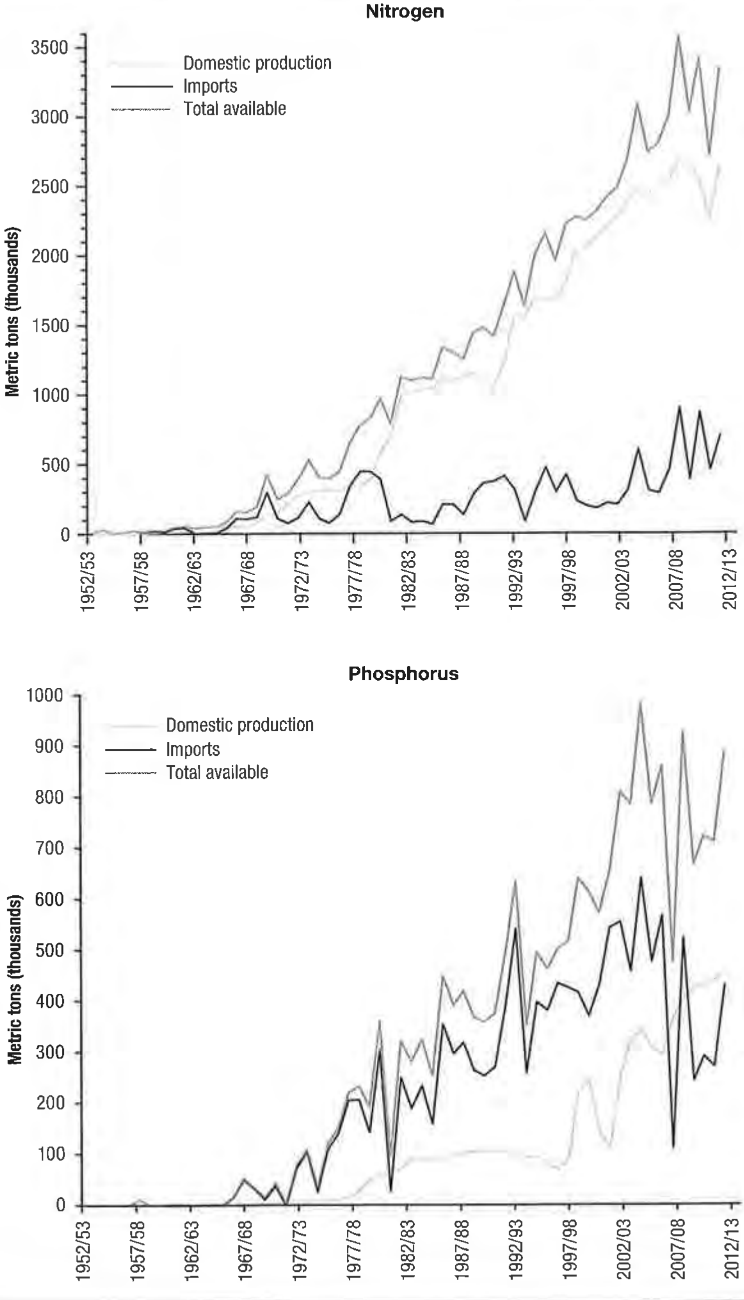
The Development of Pakistan's Fertilizer Industry

Fertilizer was introduced in Pakistan in the 1950s, primarily through imports (Figure 6.1). Nitrogenous chemical fertilizers were introduced through imports in 1952, followed by phosphorus in 1959 and potassium compounds in 1967 (NFDC 2014).[1] But Pakistan initially assumed that it possessed large reserves of natural gas—an input to the Haber-Bosch process used to form ammonia, a key ingredient in nitrogen fertilizers such as urea—which was interpreted to yield a comparative advantage for the domestic production of fertilizer. Beginning in the late 1950s and early 1960s, the government pursued an import-substitution industrialization policy and made strategic manufacturing investments to build a domestic fertilizer industry. These investments included both joint ventures with foreign companies, such as

---

[1] Fertilizer products are a combination of three primary fertilizer nutrients, which plants need in order to grow: nitrogen (N), phosphorus (P), and potassium (K). For example, urea is 46 percent nitrogen, while DAP contains 18 percent nitrogen and 46 percent phosphorus.

FIGURE 6.1 Domestic production, imports, and total available fertilizer, 1952/1953–2013/2014



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

Pak-American Fertilizers (now Agritech, which was established in 1958) and Pakarab Fertilizers (established in 1973), and the establishment of domestic fertilizer plants by independent companies, 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 a parastatal, the National Fertilizer Corporation (NFC).

By the late 1960s, Pakistan's emerging domestic fertilizer industry allowed the country to simultaneously increase the national supply of fertilizer and reduce the share of fertilizer imports, which had drawn down valuable foreign exchange reserves. Of course, large quantities of certain fertilizer products produced without natural gas (for example, di-ammonium phosphate and potassium compounds) still had to be imported, but domestic production capacity for both nitrogen and phosphate fertilizers nonetheless continued to increase (Figure 6.1). By this time, as farmers began adopting high-yielding modern wheat and rice varieties in Pakistan's irrigated areas, fertilizer use was gaining momentum. The size of this industry is significant in Pakistan, as the value of fertilizer sales (at domestic retail prices) was estimated at US$3.57 billion in 2013, up from just US$554 million in 1971. Approximately 70 percent of fertilizer consumed in Pakistan is produced domestically, with domestic production supplying 75 percent of urea, 54 percent of di-ammonium phosphate (DAP), and 29 percent of potash fertilizers consumed nationally. 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 nitrogen, the production growth rate (6.15 percent) has been greater than the consumption growth rate (5.54 percent), thereby keeping the import growth at 3.40 percent between 1971 and 2014. However, less dramatic trends were observed for phosphorus and potash (the fertilizer product with potassium as the active nutrient).

Initially, fertilizer was distributed through the agriculture extension wings of the provincial agriculture departments. There was no independent marketing system for agricultural inputs until the formation of the West Pakistan Agricultural Development Corporation (WPADC) in 1961 (Hussain 2011; Hassan and Pradhan 1998). However, WAPADC was abolished in 1972, and this responsibility was transferred to the provincial governments. Later, fertilizer marketing was the responsibility of National Fertilizer Marketing Limited (NFML), a parastatal established in 1976 that became responsible for distributing all domestic production from the NFC companies, as well

---

[2] Company dates of incorporation were retrieved from Agritech (2014), FFC (2014), and PFL (2014).

as all imports of fertilizer. After the privatization of all manufacturing units of NFC, NFML's role became restricted to the distribution of imported urea. Currently, domestically produced supply is marketed by private-sector processing companies through their registered dealers' networks.

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, which was formalized through successive fertilizer policies in 1989 and 2001. The later policy mainly protected the interests of fertilizer manufacturers by ensuring the supply of gas at subsidized rates, and relaxation of import duties on machinery used in fertilizer manufacturing, without addressing the interests of other stakeholders like farmers, traders, retailers, and government. Second, the Provincial Essential Commodity Act (PECA), promulgated in 1971 and amended in 1973, placed fertilizer production and marketing under the direct regulatory oversight 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 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 the provision of subsidies on fertilizer imports and distribution, the creation of a price environment that made the private sector unable to import urea, and the imposition of sales tax on farmers' fertilizer purchases.[3]

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 separate provincial Soil Fertility Research Institutes (SFRI) in 1971. Issues pertaining to economic policy—for example, those 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

---

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

recommendations for fertilizer use to farmers, although lately the private sector has started playing a role in this activity. 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 Limited, 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.

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. However, new challenges to Pakistan's agricultural sector also surfaced. First, no subsidies, or relatively smaller subsidies for nutrients other than nitrogen, led to a long-term pattern of unbalanced fertilizer use. Second, the regulators' strong control over the fertilizer industry, as set forth in PECA and later in the fertilizer policies, 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.

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 that are determined by the local supply and demand situation. The existence of a competitive market is, however, subject to government intervention, which is sometimes ad-hoc in nature and sometimes more structural. 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 the district to agree upon a price, even though deviations from this set price have become the norm. Despite the authority vested in regulators, they have almost never been able to smooth out the supply or keep prices at reasonable levels whenever shortages have occurred mainly due to mismanagement of imports controlled by NFML (Nadeem Tariq, Dawood Hercules Fertilizer Limited, personal communication, August 15, 2013).

Another issue related to fertilizer use efficiency has been the absence of research on traditional sources of nutrient such as animal and green manures. Little emphasis was given to developing standard operating procedures for composting, standards for nutrient content from these manures, and the monitoring of those standards. As a result, farmers stopped trusting these products' effectiveness, which varies dramatically compared to standard commercial fertilizer products. Testing and promotion of new products such as micronutrients, slow release fertilizers, and plant growth–promoting rhizobacteria—which not only can be cheaper and sustainable sources of soil nutrient but can also improve the efficiency of commercial fertilizers—was also ignored.

During the initial years of fertilizer introduction, provincial extension services played a major role in promoting fertilizer based on recommendations made by provincial SFRIs 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, the SFRIs had little success in disseminating new general or site-specific fertilizer recommendations—such as adoption of fertilizer placement methods and proper use of fertilizer on different soil types—based on their R&D activities. These limitations in the research and extension system have exacerbated trends toward unbalanced and unsustainable use, which caused serious resource degradation (Ali and Byerlee 2002).

In recent decades, Pakistan's fertilizer industry has undergone several changes aimed at addressing several of these issues. After the gradual privatization of NFC's manufacturing units over the period 1996–2005, NFML's role was restricted to the distribution of imported urea. The government is continuing its efforts to reduce the role of NFML, and even made an abortive attempt to transfer the responsibility for distribution and imports of urea to domestic manufacturers in 2013/2014. Nonetheless, subsidies remain central to the production and distribution of fertilizer, with the Ministry of Petroleum and Natural Resources deciding on the level of 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. This lower price of gas given to nitrogen producers, relative to its opportunity cost as seen by the prices to other consumers, provides the main mechanism for a nonbudgeted subsidy to fertilizer manufacturers. Hence, the government does not directly make expenditures on this subsidy.

Total domestic installed capacity of all types of fertilizer production in Pakistan is currently estimated at 10.0 million metric tons, 69 percent of which is for urea and 31 percent for DAP and potash fertilizers. In recent

TABLE 6.1 Operating capacity of selected fertilizer manufacturers by type of fertilizer (%), 2013/2014

Firm	Urea	DAP	NPK	NP	CAN	Phosphate	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
Pakarab	5.8	—	—	23.1	28.2	—	22.7
Agri Tech	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' calculations, based on MNFSR (2013).

Note: Operating capacity is calculated by dividing actual production (in tons) by the manufacturing plant's production capacity (in tons). The production can exceed the estimated operating capacity and thus be above 100. DAP = di-ammonium phosphate; NPK = nitrogen, phosphorus, and potassium; NP = nitrogen and phosphorus; CAN = calcium ammonium nitrate; — = a firm did not produce that type of fertilizer.

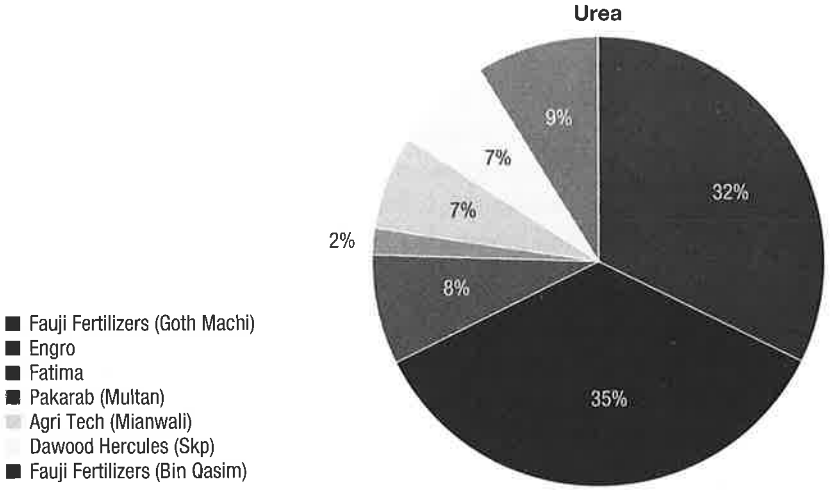
years, the industry has been operating below its full capacity, at approximately 75 percent in 2013/2014. During that year, urea production suffered the most, with operating capacity estimated at 78 percent, while DAP production ran at almost full capacity (Table 6.1). Had there been no underutilization of capacity, the production of urea would have been sufficient to meet domestic demand. However, DAP would remain short by about 50 percent even with full utilization of its installed capacity.

The production capacity and related market power in the fertilizer industry in Pakistan is concentrated in relatively few firms. The two big players, Fauji Fertilizer Company (FFC) (Gorth Machi) and Engro Corporation of Pakistan hold more than two-thirds of total installed production capacity of urea (Figure 6.2). The estimated Herfindahl-Hirschman Index of industry concentration for urea manufacturing in Pakistan was 3741 in 2013/2014, indicating that the industry was highly concentrated.[4] The CCP has come to a similar conclusion.

---

[4] The Herfindahl-Hirschman Index is calculated as the sum of the squared market share of each firm in the industry (Hannah and Kay 1977). This index approaches zero when a market consists of a large number of firms of relatively equal size, and it increases both as the number of firms in the market decreases and as the disparity in size between those firms increases. Because the index 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 6.2 Share in total urea production capacity, by firm, 2013/2014



Source: Authors' calculation, based on MNFSR (2013).

With respect to DAP, the situation is slightly different. The Fauji Fertilizer Bin Qasim Limited is the only domestic producer of DAP; it supplies about 54 percent of total DAP demand, while the remainder is imported by numerous smaller firms.[5] As such, there is likely greater competition in the market for DAP, and domestic DAP prices tend to be closely linked to the international price of DAP. But with this linkage comes greater exposure to international price volatility and currency risk.

There is some evidence of anticompetitive behavior in Pakistan's fertilizer industry, suggesting that firms benefiting from the government's largess described above have also invested heavily in securing and maintaining their market power. In 2012 the CCP fined FFC and the Dawood Hercules Chemical Limited for approximately PKR 6 billion for employing coalition tactics in an effort to manipulate the fertilizer market. Meanwhile, the returns on equity in Pakistan's fertilizer industry are well beyond those of international counterparts, suggesting the possibility of anticompetitive behavior that rewards investors. In Pakistan the return on equity (taken as an

---

[5] Fauji Fertilizer Bin Qasim Limited is a subsidiary of FFC, which is controlled by the Fauji Foundation.

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).

In sum, the development of Pakistan's fertilizer industry has been both a success story and a source of difficulty for farmers, industrialists, and policy makers 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 policy makers and investors to build a domestic fertilizer industry from the ground up. But difficulties in sustaining this success have emerged in the form of an emerging serious shortage of gas, unbalanced fertilizer use, poor management practices, poor allocation of public resources for R&D, and noncompetitive industrial practices. The sections that follow examine these elements.

Fertilizer Use, Efficiency, and Resource Degradation

To provide a better sense of how farmers actually use fertilizer in Pakistan, this section examines fertilizer application rates, impact on yields, and the unintended consequences of fertilizer use.

Data in this section are drawn from three sources. First, data on fertilizer use across agroecological zones and provinces, at an aggregated level, were obtained from the NFDC.[6] Second, data on yield response and soil nutrient content are drawn from SFRIs, collected from laboratories present at district levels in every province.[7] Third, household data on fertilizer use, yields, and related variables are drawn from the 942 agricultural households surveyed in Round 1.5 of the Pakistan Rural Household Panel Survey (RHPS), conducted in 2012, while information on household size and education for these households is extracted from Round 1 (IFPRI/IDS 2012; see Chapter 1 for details).

---

[6] All fertilizer traders in the country that are registered with the extension department are required to provide daily sales, price, and stock information to the Extension Wing of the provincial agriculture departments. The NFDC collects this information from the agriculture departments and from importers and companies directly to verify this 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 experimentation on farmers' fields every year for various crops and cultivars to evaluate optimum nutrient requirements and provide general and site-specific fertilizer recommendations.

TABLE 6.2 Fertilizer use by province and crop region, 1990/1991–2011/2012

Crop region	1990/91 (kg/ha)	1995/96 (kg/ha)	2000/01 (kg/ha)	2005/06 (kg/ha)	2010/11 (kg/ha)	2011/12 (kg/ha)	Annual growth rate (%)
Pakistan	**89.0**	**111.0**	**135.0**	**168.9**	**166.0**	**165.0**	3.0
Punjab	**90.7**	**114.9**	**107.4**	**150.7**	**158.7**	**157.4**	2.7
Barani	19.6	22.4	23.2	30.2	58.5	36.1	2.9
Mixed crop	70.0	103.1	94.1	134.2	136.5	137.2	3.3
Wheat/cotton	137.7	175.2	148.9	209.4	213.5	210.0	2.0
Wheat/rice	70.4	90.9	83.9	134.7	160.6	157.1	3.9
Wheat/gram/mung bean	67.9	66.7	80.4	107.2	112.2	115.4	2.6
Sindh	**88.0**	**134.7**	**154.9**	**208.8**	**246.5**	**296.5**	**6.0**
Mixed crops	136.3	123.0	151.3	179.1	154.6	325.8	4.2
Wheat/cotton	60.4	161.6	182.6	233.6	365.1	363.9	8.9
Wheat/rice	100.4	107.1	121.8	201.5	167.6	185.0	3.0
Khyber Pakhtunkhwa	**59.4**	**70.0**	**90.1**	**161.1**	**156.2**	**172.7**	**5.2**
Barani	16.8	20.1	24.9	129.4	110.9	69.2	7.0
Mixed crops	72.0	88.3	108.6	169.7	166.6	199.3	5.0
Balochistan	**28.7**	**31.9**	**65.0**	**299.5**	**148.2**	**215.2**	**10.1**
Wheat/cotton	31.6	22.4	40.8	1496.8	65.4	109.2	6.1
Horticultural crops	26.8	43.1	100.5	325.4	256.0	352.6	13.1

Source: Authors' calculations based on NFDC (2008, 2002, 1998). The data for 2010/11 and 2011/12 were collected from NFDC headquarters in Islamabad.

Notes: All districts in a province having a common major kharif crop, like 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 the kharif season. The district where no crop dominates in kharif is called a mixed-crop region. All districts where 85 percent of the area in a province depends on rain for irrigation are categorized as barani regions. In Balochistan, horticultural crops regions consist of districts where horticultural crops cultivation dominates. kg = kilograms; ha = hectares.

According to NFDC data, total fertilizer offtake increased over 14-fold between 1971 and 2014 in Pakistan. The three-year average of nitrogen (N) fertilizer use per ha increased from 21 kg during 1971–1974 to 133 kg during 2011–2014, while phosphate fertilizer use increased from 2 kg to 32 kg per ha in the corresponding periods. The highest increase in per-ha fertilizer use was recorded in 2009/2010, when the output-fertilizer price ratio jumped to a record level. The fertilizer application rate reached 180 kg/ha in 2013/2014. This rate is higher than that of India (141.3 kg/ha) but less than that in neighboring Indian Punjab (229 kg/ha).

In fact, fertilizer consumption in Pakistan's Punjab Province exhibited both the lowest level of nutrient use and the slowest growth rate between 1990/1991 and 2011/2012 (Table 6.2). The highest levels of nutrient use were found in Sindh, and the highest rate of growth was found in Balochistan.

Yield responses of major crops to different fertilizer nutrient levels were estimated using SFRI data collected from long-term controlled experiments conducted on farmers' fields. Experiments were conducted separately for nitrogen (N) and phosphorus (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 that the crop variety was changed to reflect the most common variety for that year. Other management practices such as seed rate, irrigation frequency during crop season, and so forth were kept at recommended levels. To estimate the yield response of nitrogen, separate regressions were run for irrigated wheat and rice based on data for two three-year intervals (2009/2010–2011/2012 and 1997/1998–1999/2000).

The results indicate that a positive relationship exists between yield and N levels, suggesting significant increases in yield with increased N levels. However, there is a limit on that relationship, as suggested by the quadratic form that best fits the data. It turns negative at higher levels of N (because the squared term for N in the equation is negative). The N level at which yield starts declining depends on the crop and its variety, environment, and management practice. In the response function in Figure 6.3, during the latest period, the yield starts declining at about 230 kg/ha in the case of wheat and 160 kg/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 that in irrigated areas.

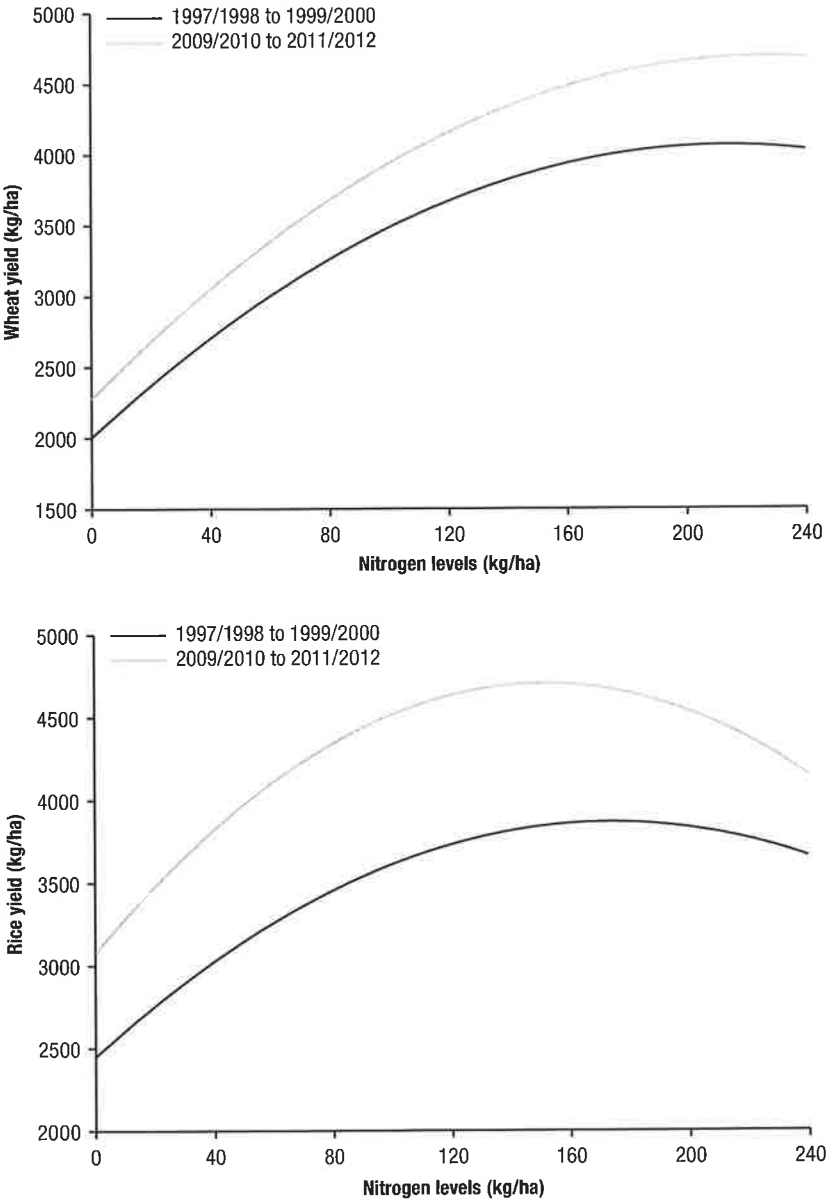
The results also indicate that the most recent period had the higher intercept for nitrogen in both rice and wheat in irrigated areas, thereby indicating that changes in variety may be a primary reason for the upward shift in the yield response curve (Figure 6.3).[8]

Cropwise optimal (profit-maximizing) values of fertilizer can be calculated using the response functions estimated by the SFRI under experimental conditions, based on fertilizer and commodity prices for 2011/2012. These values can be compared with the actual levels of per ha use for different crops from the 2012 RHPS Round 1.5 data. Profit is maximized at the level where the value of the marginal product of fertilizer is equal to the marginal cost of fertilizer.

---

[8] Similar trends were observed for nitrogen use in cotton and for phosphorus use 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 experiments.

FIGURE 6.3 Yield response of nitrogen fertilizer in wheat and rice, 1997/1998–1999/2000 and 2009/2010–2011/2012



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

Note: kg = kilograms; ha = hectares.

TABLE 6.3 Average fertilizer nutrient use by crop, 2012

Crop	N (kg/ha)	N (Optimal) (kg/ha)	Ratio N (Actual/Optimal) (%)	P (kg/ha)	P (Optimal) (kg/ha)	Ratio P (Actual/Optimal) (%)
Wheat	119.4	183.5	65	43.9	114.8	38
Rice	123.0	132.8	93	36.0	208.8	17
Cotton	123.1	209.0	59	37.3	107.2	35

Source: Authors' calculations, based on 2012 RHPS (IFPRI/IDS 2012) and SFRI (2013a).

Note: The optimal values are calculated by the authors using the nitrogen and phosphorus response equations estimated and provided by SFRI (2013a). N = nitrogen; P = phosphorus; kg = kilograms; ha = hectares.

For wheat, the optimal value of nitrogen is estimated to be 183.5 kg/ha, more than 50 percent higher than the average reported use of 119 kg/ha (Table 6.3). The difference indicates a potential of fertilizer use if all socioeconomic and institutional constraints at the farm levels are removed. However, the optimal value for wheat in barani conditions is much lower, around 108 kg/ha. This reflects the sensitivity of yield response of nutrients to timely and sufficient availability of water. For rice, the optimal value for nitrogen of 132.8 kg/ha is fairly close to the average of 123 kg/ha.

Using the RHPS Round 1.5 data, fertilizer use was analyzed under different soil and land types and by different farm categories. 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, but here the highest use was on the most fertile lands (Table 6.4). While this is contrary to the higher recommended fertilizer doses for less fertile lands, it may be because those farming on poor lands have greater cash and credit constraints.

Next, we explore the issue of fertilizer-use efficiency. Fertilizer-use efficiency (defined as fertilizer nutrient use divided by yield per hectare) has declined in Pakistan for both wheat and cotton, with more fertilizer per unit of produce being required over time (Figure 6.4). Possible explanations include increasing resource degradation, such as salinity, waterlogging, or lower levels of organic matter and other nutrient content in the soil, which we discuss further below. However in a few cases since the Green Revolution, technological changes such as the introduction of a new, more fertilizer-responsive variety or a change in soil and water management practices have helped to address this problem.[9]

---

[9] An example is the introduction of a new basmati rice variety in 1996, when increasing trends in fertilizer requirements were reversed. However, the new variety led to a one-time jump in nutrient-use efficiency in rice, indicating the importance of the continuous introduction of new varieties to maintain and add to fertilizer-use efficiency.

TABLE 6.4 Average fertilizer use for farm characteristics by fertilizer type and overall, 2012

Farm characteristics	N (kg/ha)	P (kg/ha)	K (kg/ha)	Overall (kg/ha)	Farmers using fertilizer (%)
Overall 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					
High fertility	127.44 (230)	39.42 (172)	1.14 (2)	168.00 (230)	93.12
Moderate fertility	121.66 (1069)	38.47 (788)	0.43 (7)	160.55 (1069)	91.92
Low fertility	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[a]

Source: Authors' estimates, based on 2012 RHPS (IFPRI/IDS 2012).

Note: The categories are based on the definitions used in the 2012 RHPS (IFPRI/IDS 2012). Numbers in parentheses represent numbers of plots in each category. kg = kilograms; ha = hectares.

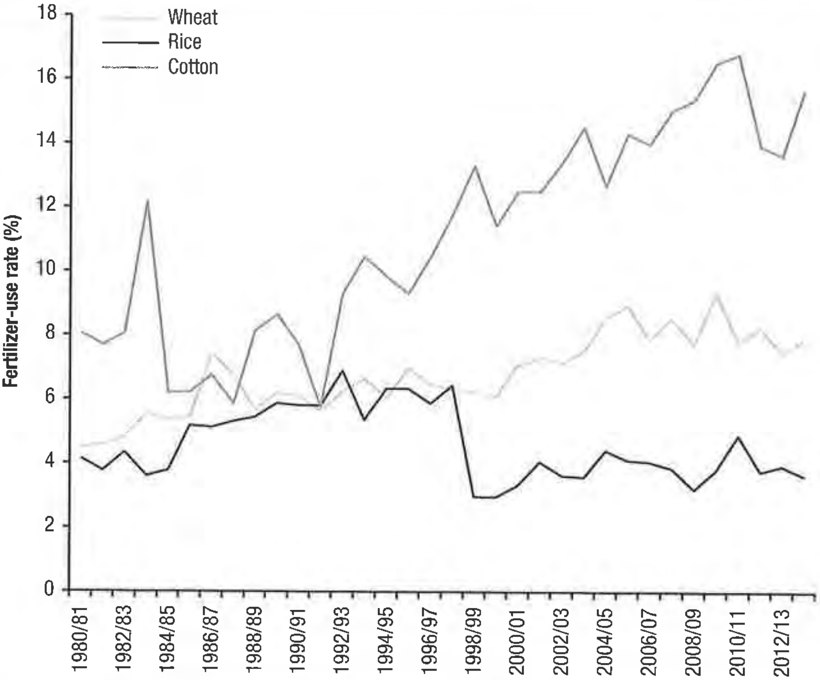
[a] This low number is because of a high number of missing values for this category.

As shown in Figure 6.4, the production of 100 kg of wheat in 1980/1981 required 4 kg of fertilizer nutrient, but by 2013/2014, the production of the same amount of wheat required 7.9 kg of fertilizer nutrient. Similar trends have been observed in cotton, although fertilizer-use efficiency in rice has remained largely unchanged over the time period.

As a result of declining marginal productivities of fertilizer and water, growth in total factor productivity (TFP) at the farm level initially slowed and later stagnated (Ali and Byerlee 2002; Ahmed and Gautam 2013). As such, Pakistan's TFP growth went from being one of the best in the world in the 1980s to being the lowest among comparable Asian nations such as Bangladesh, China, India, and Sri Lanka (Ahmed and Gautam 2013).

To determine the factors that affect fertilizer-use efficiency and estimate its optimal use under actual field conditions, we estimate a yield response

FIGURE 6.4 Fertilizer-use efficiency by crop, 1980/1981–2012/2013



Source: Authors' calculation based on NFDC (2014); MNFSR (2013); MNFAL (2007a, 2007b).
Note: Fertilizer-use rate = fertilizer use (kg/ha)/yield (kg/ha). kg = kilograms; ha = hectares.

function for wheat from the RHPS data (see Annex A for definitions, means, and standard deviations of the variables used in the regression). To do this, a semi-log estimation was conducted in which the log of yield per ha was regressed on quantities of various inputs and their squared terms, soil fertility and salinity variables, climate-related variables, and district dummies.[10]

The results indicate the following (Table 6.5). First and most obvious is the finding that yield is significantly responsive to nitrogen use, but it is also subject to decreasing marginal returns as captured in the squared term of nitrogen use. The estimates of elasticities at average levels of input use suggest that a 1 percent increase in the use of nitrogen results in a 0.2 percent increase in wheat yield.[11]

---

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

[11] The estimate is at average nitrogen use in our model, which is 115 kg/ha for wheat (including observations having no use).

TABLE 6.5 Yield response function of wheat

Variable	Log of yield (kg/ha) of wheat	Robust standard errors
Inputs		
Hired labor (hours)	0.000711***	(0.0002)
(Hired labor)^2	−1.23e-06***	(0.000)
Family labor (hours)	0.000162	(0.0002)
(Family labor)^2	−2.41e-07	(0.000)
Tractor usage (hours/ha)	0.0336***	(0.0126)
(Tractor usage)^2	−0.00172*	(0.0010)
Total sprays (number)	0.109***	(0.0294)
(Total sprays)^2	−0.0323***	(0.0074)
Nitrogen used (kg/ha)	0.00335***	(0.0011)
(Nitrogen used)^2	−1.74e-05***	(0.000)
Was phosphorous applied? (Yes = 1, No = 0)	−0.0396	(0.0718)
Total seed used (kg/ha)	0.000727	(0.0021)
(Total seed used)^2	1.28e-06	(0.000)
Groundwater irrigations (number)	0.00609	(0.0099)
(Groundwater irrigations)^2	−0.000428	(0.0009)
Canal water irrigations (number)	0.0344***	(0.0097)
(Canal water irrigations)^2	−0.00305***	(0.0011)
Resource quality		
Highly fertile soil (Yes = 1, No = 0)	0.237***	(0.0822)
Other factors		
Visit by extension agent (Yes = 1, No = 0)	−0.0308	(0.0314)
District fixed effects	Yes	
Constant	7.106***	(0.1270)
Observations	755	
R-squared	0.555	

Source: Authors' estimates, based on 2012 RHPS (IFPRI/IDS 2012).

Note: * = significant at 10%; ** = significant at 5%; *** = significant at 1%. Some insignificant results are not presented for the sake of brevity. kg = kilograms; ha = hectares.

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

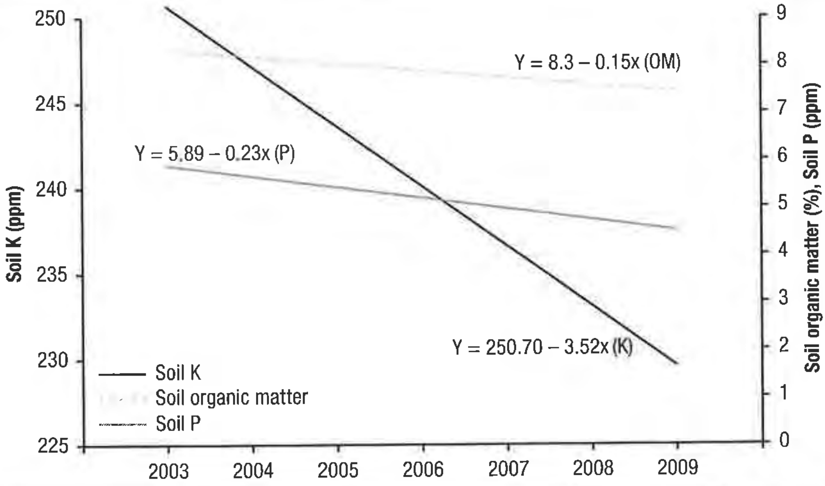
In addition to the fertilizer variable, all major inputs to wheat production were included, such as hired labor, tractor services, seed, and canal or tube well irrigation. They are generally significant with positive linear terms and declining squared terms, suggesting that there is a diminishing contribution of each input to increasing yield.

Using the elasticity estimated from our yield response function, the optimal (profit-maximizing) value of nitrogen for wheat under farmers' conditions is 125 kg/ha. This is lower than SFRI's recommended value of 183 kg/ha, which is based on experiments undertaken in controlled research environments. The actual level of nitrogen application in our sample (including zero observation) was 115 kg/ha, which is almost equal to the optimum level under the farmers' resource-quality and socioeconomic constraints.

But even at optimal use levels, there are unintended consequences of fertilizer use. The negative implications of the misuse of fertilizer on long-term sustainability of agricultural production have been pointed out by many researchers (Sankaram and Rao 2002; Bumb and Baanante 1996; Rashid et al. 2013). Failure to use fertilizer appropriately leads not only to inefficiencies at the farm level but also to wider resource degradation (Ali and Byerlee 2002; Ahmed and Gautam 2013). Both the overutilization 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 shown that an imbalance use of urea with phosphorus and potassium results in excessive soil mining, which causes yield stagnation (Concepcion 2007). In developed countries, application of fertilizer nutrients has also been shown to lead to environmental contamination of water supplies and soils (Gruhn, Goletti, and Yudelman 2000).

Fertilizer use produces the most efficient results under the following conditions: fertilizer-responsive varieties are used; a dissolvable form of fertilizer is placed near the root zone of the plant, in the right proportion and at the appropriate time; land is precisely prepared; and other inputs like 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, few farmers pay attention to them. The reasons for this are complex and range from exogenous constraints, such as the availability of surface irrigation or rainfall and proper technology, to more internal constraints, like the availability of credit to buy fertilizer in a timely manner, labor cost and availability, or the effort and drudgery associated with adhering precisely to recommended practices.

FIGURE 6.5 Soil nutrient levels, 2003–2009



Source: SFRI (2013b).

Note: Potassium (K) is measured against the left y-axis, while the phosphorous (P) and organic matter (OM) are measured against the right y-axis. The soil K and P are measured in parts per million (ppm), and the soil organic matter measures the percentage of organic matter in soil.

Furthermore, fertilizer policies and investments in Pakistan have tended to overlook the promotion of fertilizer-efficiency-enhancing practices. For example, fertilizer subsidies have been primarily allocated to the promotion of urea despite the fact that its use is quickly reaching an optimal level, while other nutrients—namely phosphorus and potassium—are both underutilized by farmers and overlooked by the subsidy policy. Meanwhile, extension agents have had limited success in educating farmers on practices that can improve fertilizer-use efficiency, such as timeliness of application, proper application methods, and appropriate combinations of different fertilizers. The technologies to apply fertilizer in the root zone of the crop are either not accessible to farmers, or farmers are not convinced about the efficacies of these technologies.

In Pakistan, the absence of farming practices that adjust nutrient applications to land resources has resulted in mining of several essential soil micronutrients, such as phosphorus, iron, zinc, and potassium. The underutilization of micronutrients and the reduction in the application of farm manure has decreased organic matter content to threateningly low levels (Figure 6.5).

Pricing Behavior and Government Interventions in the Fertilizer Market

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

Fertilizer prices—in real terms relative to output prices—have evolved in Pakistan as follows. The grain output prices (weighted average of wheat and rice) increased more than the price of nitrogen, meaning that one unit of nitrogen purchases more grain in 2014 than in 1976. Similar decreases in real urea fertilizer prices are observed in other Asian countries like India, Bangladesh, and Indonesia, but the decline is lowest in Pakistan (Rashid et al. 2013). However, the opposite is true for phosphorus (Figure 6.6). Thus, in terms of input-output prices, farmers did not lose over time, and their profitability did not shrink because of increased nitrogen prices. But the profitability of fertilizer use did fall with the decline in fertilizer-use efficiency in Pakistan, as Figure 6.4 shows.

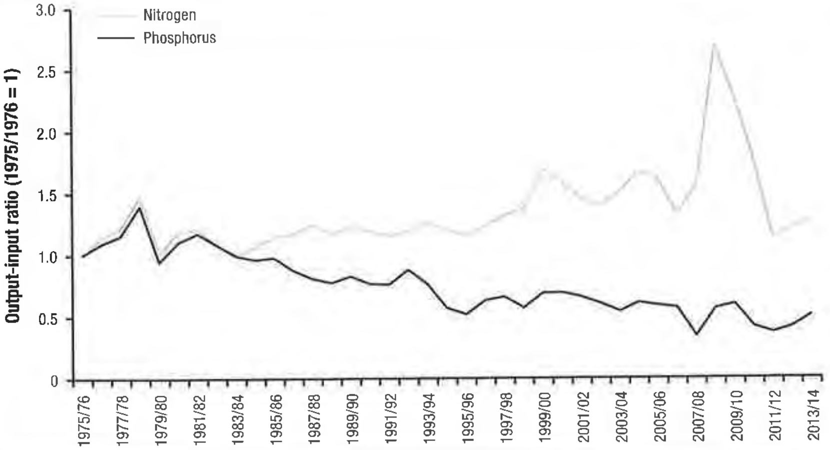
Against these prices, public subsidies on the production and distribution of fertilizer have also evolved. The most significant subsidy is the provision of natural gas to urea producers at prices that are lower than those charged to other industries and consumers. Approximately 16 percent of total gas consumed in the country is used by the fertilizer industry (HDIP 2013). The government subsidizes fertilizer manufacturing through a dual gas price policy, where one price exists for the fuelstock applicable to the general use of gas, and another 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.[12]

We estimate that the total value of the production subsidy on fertilizer in 2013/2014 was PKR 48 billion (Table 6.6). 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 20 billion in 2013/2014. It is

---

[12] The approval of new manufacturing plants from the Ministry of Industries and Production is linked to the availability of gas that could be supplied. Some firms complained about facing 35–50 days of gas shortage in a year. No schedule of gas supply was provided, which deterred companies from making operational plans. This shortage increased their fixed and operational costs (Nadeem Tariq, Dawood Hercules Fertilizer Limited, personal communication, August 15, 2013).

FIGURE 6.6 Change in output-input price ratio, 1975/1976–2013/2014



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

TABLE 6.6 Subsidies of fertilizer manufacturing through natural gas pricing, 2013/2014

Natural gas network/fertilizer firm	Price (PKR/MBTU) Fuelstock	 Feedstock	Gas consumption[a] (billions MBTU)	Subsidy[b] (millions PKR)
Sui Southern Gas Company Limited				
Fauji Fertilizer-Bin Qasim	488.23	123.41	12,325	4,497
Sui Northern Gas Pipelines Limited				
Pakarab	488.23	123.41	3,034	1,107
Dawood Hercules	488.23	123.41	1,446	527
Pak-American	488.23	123.41	3,367	1,228
Engro Chemicals ENVEN	488.23	73.17	3,729	1,548
Mari Gas Limited				
Engro Chemicals	488.23	123.41	2,8931	10,554
Fauji Fertilizer Company	488.23	123.41	55,044	20,081
Fatima Fertilizer	488.23	73.17	20,468	8,495
Total			**128,344**	**48,038**

Source: Authors' calculations, based on NFDC (2014). The figures for 2011–2014 are collected from NFDC in Islamabad.

Note: PKR = Pakistani rupees; MBTU = millions of British thermal units. Italicized text represents the source of natural gas for each firm.

[a] The consumption of gas to each firm was reported after adjusting for the difference in pressure of each field.

[b] Subsidy figures for fertilizer are calculated as import quantity multiplied by the difference between the international and domestic prices. The international price is taken as the cost, insurance, and freight price (with US$30 in freight charges) and is inclusive of general sales tax.

important to note that this subsidy would be much higher if we also took into account the subsidy on fuelstock gas, the price for which is also lower than the international price (EIA 2014). However, many other sectors enjoy this price; this is not specific to the fertilizer sector.

In addition to domestic production subsidies, the government subsidizes the importation and distribution of fertilizers. Underutilized capacity arose because of gas shortages in 2008, which forced Pakistan to import urea alongside regular imports of DAP. NFML intervenes when the difference in domestic and international prices becomes large and domestic supply falls short of demand. The intervention is made by importing higher-priced fertilizer and selling it at a lower domestic price. Normally, this intervention is limited to imported urea, but in 2007–2009, for the first time ever, the government intervened in the DAP market through a subsidy on imported DAP.[13] As discussed earlier, in an attempt to further reduce the role of NFML, the government allowed the private sector to import urea and sell it at the domestic price in 2014, while the NFML was to cover the price difference, including transportation and handling charges. However, this decision was not implemented, and the NFML's intervention in the market is costly for the government (Table 6.7).

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 it withdrew the exemption in 2011, along with exemptions for other agricultural inputs. We estimate the GST revenue (offtake multiplied by price and the tax rate) from urea and DAP at approximately PKR 50 billion in 2013/2014. It appears that the government attempted to even out its loss in revenue to production subsidies with GST collections, although it is unfair to farmers because, as discussed in the next section, little money from the production subsidy is passed on to farmers while they pay 100 percent of the GST.

In 2015, after a long legal battle with the industry, the government imposed a 20 percent Gas Infrastructure Development Cess on all gas consumers, other than domestic consumers. The Gas Infrastructure Development Cess has brought the fuelstock prices closer to international prices, while the difference between fuelstock and feedstock prices will continue.[14]

---

[13] The government announced a subsidy on DAP sales for 2014/2015, but it was not applied because of the lack of SOPs to implement this subsidy. However, during 2016, a subsidy of PKR 20 billion on P and K fertilizers was distributed.

[14] Feedstock gas is gas used for the manufacturing of chemical products such as fertilizers and pharmaceutical products, while the fuel gas price is for gas used for other purposes.

TABLE 6.7 Subsidies on fertilizer distribution, 2004/2005–2013/2014

Year	(1) Subsidy on imported urea (billions PKR)	(2) Imports of urea (thousands of tons)	(1)/(2) Subsidy per ton of imported urea (PKR/ton)
2004/2005	1.85	307	6,026
2005/2006	4.54	825	5,503
2006/2007	2.05	281	7,295
2007/2008	2.74	181	15,138
2008/2009	17.23	905	19,039
2009/2010	12.87	1,524	8,445
2010/2011	8.41	694	12,118
2011/2012	9.55	1,075	8,884
2012/2013	10.50	833	12,605
2013/2014	4.53	1,200	3,775

Source: Authors' calculations, based on NFDC (2014). The figures for 2011–2014 are collected from NFDC in Islamabad.

Note: PKR = Pakistani rupees. Subsidy figures for urea are calculated as import quantity multiplied by the difference between the international and domestic prices. The international price is taken as the cost, insurance, and freight price (with US$30 in freight charges) and is inclusive of general sales tax.

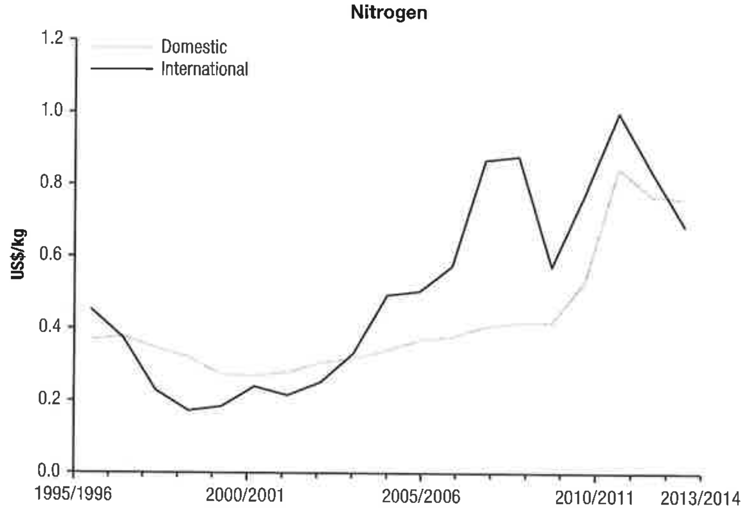
With all the subsidies and rent-seeking behavior found in Pakistan's fertilizer industry, we might wonder whether the industry is actually competitive in the wider international market for fertilizer. One way to evaluate the industry's competitiveness is to compare international and domestic prices, both with and without these subsidies. Although the government has also provided a distribution subsidy on imported urea, and such subsidies help to stabilize the domestic market, we assume that these leave the domestic prices unchanged. (Note that the distribution subsidy per ton varies significantly across years, depending on the difference between international and domestic prices.) Therefore, direct comparison of domestic prices without the production subsidy and international prices provides an indication of competitiveness in the domestic fertilizer sector.

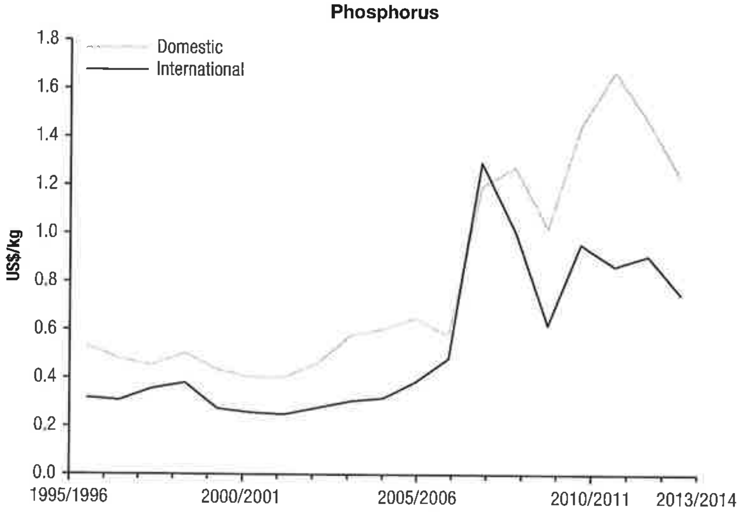
When viewing the domestic and international prices with the subsidy included, we find that until 2004, the domestic prices of nitrogen closely followed international trends, but despite the gas subsidy those prices remained higher than the FOB (free on board) international prices (Figure 6.7).[15] However, importing urea was not economical because the difference was negligible when shipment, loading/unloading, and in-country transportation costs were added. The domestic prices were kept higher than the FOB

---

[15] FOB refers to the prices at the port of shipment, when exporting.

FIGURE 6.7 International versus domestic fertilizer prices, 1995/1996–2013/2014


Nitrogen


Phosphorus

Source: Authors' estimates based on NFDC (2014).
Note: kg = kilograms.

price, perhaps to avoid smuggling. After 2004, until 2011, the domestic prices remained consistently lower than international market prices, and the difference was large enough to cover port and other handling charges, so, in principle, exports were possible. During that time, however, the government restricted fertilizer exports, but smuggling with Afghanistan would have been economical.[16] Thus, domestic manufacturing was competitive in the international market, albeit with the gas subsidy in place.[17]

The trend once again reversed during 2013/2014, when domestic prices became higher than the international prices, despite the gas subsidy on manufacturing, indicating that the sector had once again become uncompetitive with respect to the international market, despite the subsidy. However, domestic prices, for a variety of market structure and policy reasons, did not rise much, and thus the price of imported fertilizer (after covering freight, import value, and in-country distribution charges) remained higher than the domestic price. During 2015/2016, domestic prices exceeded international prices, and imported urea became economically viable, although the private sector did not pursue imports, mainly because of a lack of trust about the consistency of government policies related to import taxes/duties on urea.

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, summarized in Figure 6.8, indicates that the domestic unsubsidized price of urea was higher than the international price during 1996–2004, but lower than or equal to the international price after 2004. Our analysis suggests that the removal of the gas subsidy would have made urea producers even more uncompetitive in the international market prior to 2004 as the gap between the domestic and international prices increased. However, the domestic price from 2005 to 2011 was competitive relative to international prices, perhaps because of the presence of oligopolistic industry practices and noncompetitive imports, which led to pricing behavior that did not respond to international price changes.[18]

During 2011–2014, the trend reversed again, and domestic prices without subsidies became higher than international prices. This suggests that during those three years, the removal of the gas subsidy would have made urea

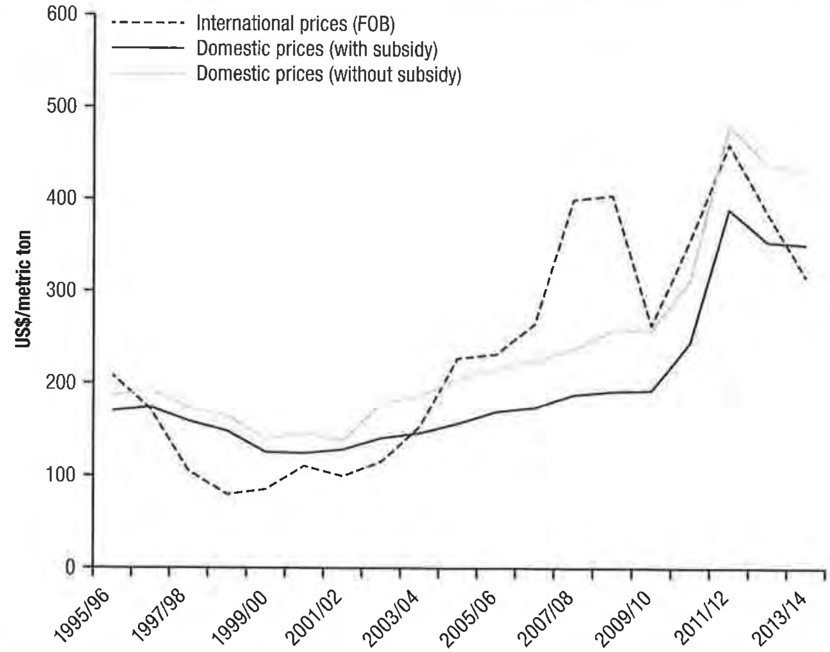
---

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

[17] This price mechanism permitted the absorption of shocks in international fertilizer prices during 2007 and 2008 without creating panic in Pakistan's domestic market.

[18] Our analysis shows that Pakistan is not competitive in the international market, while the CCP study concludes the reverse. The CCP's conclusion is based on eight quarters in 2008 and 2009, when international prices were high, while our conclusion is based on the period 1995–2012 (CCP 2010). In our study, the normalized prices, after adding back the subsidy on domestic prices, are lower than the international price during 2007, 2008, and 2009 as well, but over the longer run they have been higher, especially recently.

FIGURE 6.8 International versus domestic urea prices, with and without subsidy, 1995/1996–2013/2014

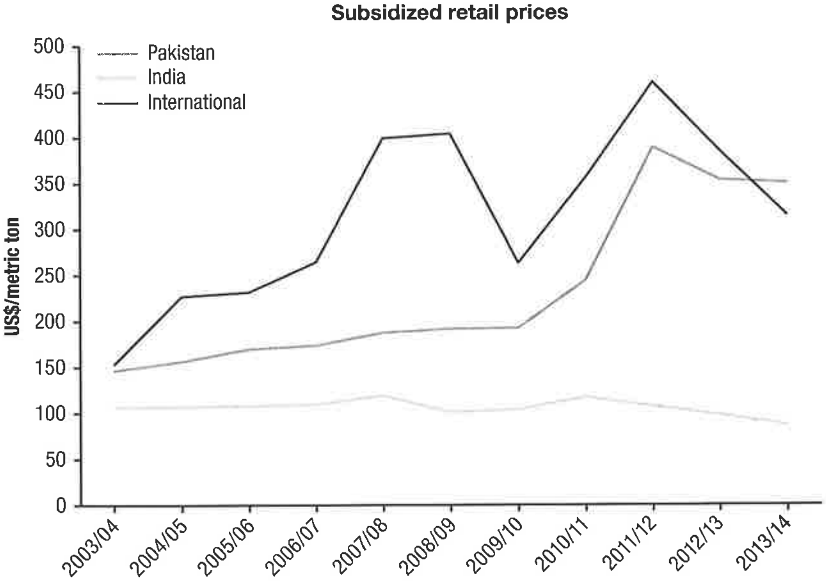


Source: Authors' estimates, based on NFDC (2014) and HDIP (2013).
Note: FOB = freight on board.

producers uncompetitive in the international market, as was the case prior to 2004. Overall, during the past 20 years, the fertilizer manufacturing sector without subsidies was competitive with the international market for only 6 years.

A comparison of fertilizer prices between India and Pakistan, keeping the subsidies intact in both countries, shows that Indian prices are far lower than Pakistani prices, suggesting a higher subsidy at the retail level in India (Figure 6.9). Indian prices after removing the subsidy in both countries, however, became basically equivalent to international market prices but slightly higher than those in Pakistan. Because nitrogen prices in Pakistan were either lower than or equal to international prices during 2004–2011, India during this period could have imported nitrogen fertilizer from Pakistan, rather than from the international market, and enjoyed the proximity advantage with Pakistan. However, Pakistan would never allow that as long as it

FIGURE 6.9 India, Pakistan, and international urea prices, 2003/2004–2013/2014



Source: Authors' estimates, based on NFDC (2014); DoP (2012); and HDIP (2013).
Note: India and Pakistan prices are subsidized retail prices.

has a shortage of domestically produced urea, because of gas shortages, which Pakistan has a chance to overcome in the long term because of its proximity to the gas-abundant region of Iran and Central Asia.

Impact of Policy Interventions

This section uses an equilibrium displacement model (EDM) to estimate the impact of exogenous policy shocks on the market for urea, DAP, and selected major crops, including cotton, rice, wheat, and other crops (sugarcane, maize, and all vegetables and fruits). It examines various policy alternatives, singly and in different combinations. These policy alternatives include (1) removing the production subsidy on natural gas, (2) increasing the supply of natural gas, (3) removing the sales tax on fertilizer, and (4) increasing investment on R&D. The analysis allows us to see changes in prices and quantities, identify winners and losers from each intervention, and thereby give policy makers information to help them make more informed decisions on fertilizer; we also give quantitative estimates of various costs and benefits.

The model uses parameters derived from demand and supply equations for the input markets (urea and DAP) and output markets (cotton, rice, wheat, and other crops).[19] (See Annex B for details.) For each crop, we assume that output supply is a function of the respective endogenously determined output price, the prices of its substitute outputs (or complements), and fertilizer prices. In addition, technology is included as an exogenous trend variable in all output supply equations. Crop demand is a function of the crop's own price, the price of its substitutes (or complements), and the income of the consumer (which is an exogenous variable).

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 exogenous quantity of natural gas supplied. The DAP supply equation, similarly, is a function of its own factory price, the price and quantity of natural gas (but with smaller coefficients compared to the urea equation to reflect its reduced role in DAP production), and the price and quantity of phosphorous, which are also exogenous variables.

The marketing margins linking producer and retailer prices, both in input and output markets, are assumed to be fixed at zero, that is, changes in producers' and retailers' prices occur in the same proportions. As such, the model allows us to see the impact of changing the GST, which acts as a wedge between producer and consumer prices in both input and output markets. Improvement in input or output market efficiencies can also be potentially studied by changing this wedge.

Both input and output markets are cleared by equating domestic demand plus exports to domestic supply plus imports so that international trade balances any deficit or surplus in the domestic markets. International trade in the input and output markets is, for exports, a positive function of the domestic price of the relevant commodity and, for imports, a negative function of this price. The distinction between world price and domestic price is established by the fixed import duty/tariff/transportation cost, which is exogenously determined.[20]

These input and output markets are first reduced by substituting the demand equation in the market-clearing equation. Each equation in this

---

[19] The model does not differentiate between basmati and other rice varieties because different elasticities for each variety are not available.

[20] This again in effect implies that the world price has the same proportional change as domestic prices, unless we conduct a simulation changing the wedge between these prices.

linear system is then totally differentiated and manipulated so that all variables are converted into proportional changes that are functions of the choice of elasticities. (The development of this approach is given in Annexes C and D.) The equations are then used to estimate the impact of exogenous shocks on the variables of interest.

Large numbers of own-price and cross-price elasticities are needed to fully specify the relations in the model and are taken from various sources shown in Annex E.[21]

The model assumes that the elasticities for the variables used in these estimations are constant. The model also assumes no limitations on inputs such as total cropland, irrigation water, or in the case of this chapter's simulations, the quantity of natural gas.

We simulate the results in each scenario with two import elasticities of α_k at 1 and 5 to judge how ease of imports will affect the outcomes. The results of these simulations in terms of actual and percentage changes with respect to the baseline scenario of 2013/2014 are presented in Table 6.8, when α_k is equal to 1, and in Annex F, when α_k is equal to 5.

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 fuelstock by 297 percent. The first important impact of this policy is a rise in the factory cost of urea, which shifts the supply curve back because of a higher input cost. This increases the factory price of fertilizer and reduces its domestic supply. However, a higher domestic price creates incentives for importers, so imports increase, with the amount depending upon the import elasticity (which reflects the ease of importing). In the low-elasticity scenario (with an import elasticity of 1), the equilibrium factory price of urea increases by over 10 percent, while with a high import elasticity scenario of 5, it increases by only 4 percent. The price of DAP fertilizer also increases in both scenarios, but to a lesser extent, because one unit of DAP requires less than one-half of the amount of ammonia, which is produced from natural gas, than is used in urea production. Farm gate 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 farm gate prices lower demand (except in the high import elasticity scenario,

---

[21] When certain elasticities are not available but are important, we simulate different levels of these elasticities to understand the sensitivity of our results to particular choices of elasticities.

TABLE 6.8 Simulated changes from 2013/2014 baseline value using EDM for various policy interventions with low import elasticity (α = 1)

	Change from 2013/2014 baseline value				
Variables	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Fertilizer market					
Domestic supply of urea (1,000s MT)	–696 (–14.1)	–574 (–11.6)	120 (2.4)	–576 (–11.7)	280 (5.7)
Domestic supply of DAP (1,000s MT)	–49 (–7.1)	–45 (–6.5)	13 (1.9)	–36 (–5.2)	25 (3.6)
Import supply of urea (1,000s MT)	118 (10.2)	154 (13.3)	35 (3.1)	153 (13.3)	–47 (–4.1)
Import supply of DAP (1,000s MT)	42 (4.5)	55 (5.9)	45 (4.8)	87 (9.3)	–21 (–2.3)
Demand of urea (1,000s MT)	–578 (–9.5)	–420 (–6.9)	155 (2.6)	–423 (–6.9)	233 (3.8)
Demand of DAP (1,000s MT)	–8 (–0.5)	10 (0.6)	58 (3.6)	50 (3.1)	4 (0.2)
Farmer price of urea (PKR/MT)	3729 (10.2)	4860 (13.3)	–5099 (–14)	–1369 (–3.8)	–1498 (–4.1)
Farmer price of DAP (PKR/MT)	3260 (4.5)	4309 (5.9)	–8882 (–12.2)	–5622 (–7.7)	–1653 (–2.3)
Factory price of urea[a] (PKR/MT)	3188 (10.2)	4154 (13.3)	951 (3.1)	4139 (13.3)	–1281 (–4.1)
Factory price of DAP[a] (PKR/MT)	2786 (4.5)	3683 (5.9)	2986 (4.8)	5773 (9.3)	–1412 (–2.3)
Import cost for fertilizer (billion PKR)	15 (15.2)	20 (20.2)	7 (8.7)	21 (24.5)	–6 (–6.3)
Output market					
Overall pressure on output prices (PKR/MT)	0 (–0.1)	0 (–0.4)	0 (–0.1)	0 (0)	0 (0)
Overall trade surplus (billion PKR)	–1 (–0.5)	6 (4.6)	1 (0.8)	0 (0.3)	0 (0.2)
Total crop production gain (billion PKR)	–7 (–0.3)	52 (2.2)	11 (0.5)	4 (0.2)	3 (0.1)
Fertilizer expense for farmers (billion PKR)	4 (1.2)	20 (5.9)	–37 (–10.8)	–29 (–8.5)	–3 (–1)
Production revenue (billion PKR)	–7 (–0.3)	52 (2)	11 (0.4)	4 (0.2)	3 (0.1)
Overall farmer benefit (billion PKR)	–11 (–0.5)	32 (1.4)	48 (2.1)	33 (1.5)	6 (0.3)
Gas expense (billion PKR)	38 (242.4)	40 (251.9)	0 (2.4)	40 (252)	1 (5.6)
Subsidy and others					
Fertilizer revenue (billion PKR)	–8 (–4.8)	0 (–0.1)	9 (5.8)	1 (0.8)	2 (1.3)
Overall manufacturer benefit (billion PKR)	–46 (–32.3)	–40 (–28.2)	9 (6.2)	–38 (–27.1)	1 (0.9)
Production subsidy (urea) (billion PKR)	–47 (–100)	–47 (–100)	1 (2.4)	–47 (–100)	3 (5.6)

(continued)

	Change from 2013/2014 baseline value				
Variables	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Retail subsidy (DAP) (billion PKR)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Distribution subsidy (billion PKR)	2 (16)	3 (21)	0 (3)	1 (13.3)	−1 (−6.1)
Tax revenue from fertilizer (billion PKR)	1 (1.2)	3 (5.9)	−50 (−100)	−50 (−100)	0 (−1)
All subsidies (billion PKR)	−45 (23.6)	−44 (24.6)	1 (102.5)	−46 (10.9)	2 (103.2)
Investment on R&D (billion PKR)	0 (0)	12 (0)	0 (0)	0 (0)	0 (0)
Total change in govt. revenue (billion PKR)	46 (0)	35 (0)	−51 (0)	−3 (0)	−2 (0)
Consumer crop demand (billion PKR)	−7 (−0.3)	46 (1.9)	10 (0.4)	4 (0.2)	3 (0.1)
Eventual social benefit (billion PKR)	−18 (0)	74 (0)	16 (0)	−5 (0)	8 (0)

Source: Authors' estimates.

Note: Figures in parentheses are percentage changes with respect to the baseline value of 2013/2014. DAP = di-ammonium phosphate; MT = metric tons; GST = general sales tax; α = trade elasticity of fertilizer; PKR = Pakistani rupees. The results for higher trade elasticity ($\alpha = 5$) are presented in Annex F. The overall social benefit does not incorporate trade loss/profit. We assumed this is already reflected in the loss/gain in crop production. In scenario 1, we remove the subsidy on natural gas; in scenario 2, we increase investment in crop research and development while removing natural gas subsidy; in scenario 3, we remove the GST; in scenario 4, we remove gas subsidy and GST simultaneously; and in scenario 5, we remove the shortage of gas.

[a] Exclusive of GST.

where imports increase more than the decrease in domestic supply, thereby offsetting some of the price rise from higher natural gas prices).

The changes in the fertilizer market trigger effects in the crop markets, which produce impacts on government, farmers, and manufacturers. The lower demand for fertilizer reduces crop output, depending on the output supply elasticity with respect to fertilizer price.[22] This leads to higher output prices. The farmers lose from the lower crop production but benefit from higher output prices and lower production cost as fertilizer demand declines. In the low import elasticity scenario, farmers' overall loss is about PKR 11 billion, or 0.5 percent of the original value of farm production. However, this loss is mitigated and turned into a profit of PKR 15 billion if imports are made flexible enough, as occurs in the simulation with high import elasticity. Although crop output still decreases and output prices increase, both are

---

[22] The crop supply elasticities with respect to fertilizer prices used are from Haile, Kalkuhl, and von Braun (2014). This is an international study that reports low crop supply elasticities for Pakistan compared to older studies. One reason for high elasticities in earlier studies may be the low use of fertilizer when these elasticities were estimated. In addition, using the higher elasticities from the earlier literature blows up effects of policy interventions on crop production to what seems to be too high a level.

moderated by higher imports of fertilizers, and the farmer's losses from lower output declines from PKR 7 billion to PKR 3 billion. On the other hand, expenses on fertilizer drop by PKR 19 billion relative to the low import elasticity because of the reduction in fertilizer prices and decrease in fertilizer demand. Thus, the moderating effect of a higher import elasticity and facilitation of imports of fertilizer can be used to lower the impact on farmers from removing gas subsidies.

The government is the biggest net beneficiary, as gas subsidies decline by PKR 46 billion.[23] There is a small change in GST and distribution subsidies, so the net gain to the government is around PKR 42 billion in the high import elasticity scenario and PKR 46 billion in the low import elasticity scenario.

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

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

With the increase in output prices, consumers' demand for agricultural commodities decreases by PKR 7 billion, although the reduction is only PKR 2 billion if fertilizer imports are more liberally imported. The society as a whole loses by about PKR 5 billion in this scenario.[24]

In this simulation, we assumed that the elasticity of fertilizer supply with respect to the price of natural gas as 0.1 and 0.025 for urea and DAP,

---

[23] Because the subsidy arises from an administered price of gas, the government would likely have to charge a cess, or tax, to actually recover these funds. Thus, this value should best be seen as an opportunity cost.

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

respectively. As this elasticity may be argued to be low, we also simulated impacts with increased elasticities of 0.4 percent and 0.1, respectively. This further increases the manufacturers' loss, from PKR 46 billion and 58 billion in the scenarios of low and high import elasticity to PKR 70 billion and 116 billion, respectively, mainly because of the greater decline in revenues from fertilizer sales.

Policy Scenario 2: Increasing Investment in Crop Research and Development While Removing the Natural Gas Subsidy

There is little investment in agricultural R&D in Pakistan. This has reduced the flow of innovations to farmers, and, as a result, productivity-led growth has lagged behind compared to other developing countries such as China, India, Brazil, and Turkey (Ahmed and Gautam 2013). In Scenario 1, we created a "fiscal space" for the government to increase R&D investment by eliminating the production subsidy. Here, we assume that 25 percent of this savings, about PKR 12 billion, goes to R&D in the crop sector, implying a 150 percent increase in the R&D budget for agriculture of PKR 8 billion in 2011/2012 (ASTI-PARC 2012). We assume that this brings about a modest increase in crop productivity of 3 percent across the board, thereby shifting the supply curves outward.[25]

The shift in the crop supply curves induced by the R&D expenditures will create growth in the fertilizer sector, while the opposite occurred in Scenario 1. Another important difference is that unlike the earlier scenario, there is a significant time lag between the investment on R&D and returns through enhanced productivity.[26]

For the first year that the new technologies generated from R&D expenses produce a 3 percent increase in crop productivity, the shift in supply curves will increase crop production and lower the crop's prices. More fertilizer is

---

[25] This productivity increase might come from a variety of sources, such as improved high-yielding varieties; development and promotion of appropriate input application techniques; improvement in the timely delivery of inputs such as fertilizer, credit, water, and information; development of new crop management models that improve productivity and also reduce postharvest losses; and so forth. We assume that the technological innovations are neutral with regard to fertilizer-use efficiency, so a general 3 percent shift in the overall supply curve occurs, rather than an increase in the fertilizer coefficient in the production function.

[26] 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 2 of Table 6.8. We assumed a gradual decline in the 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, and we ran the model for five years. We then discounted these benefit streams at a 15 percent rate.

required to produce the larger crop production, which will shift the fertilizer demand curve upward. The greater fertilizer demand increases both the farm and factory prices, and it induces more fertilizer manufacturing and imports. If domestic manufacturers cannot expand production capacity, importers will fill the gap (especially under the high import elasticity scenario). Although the import bill for fertilizer increases, the expanded crop supply reduces output prices and generates a higher trade surplus, which compensates for the higher import bill of fertilizer. We also generated results for four subsequent years, with 0.5 percent less productivity enhancement in each year until the value of the technology gets completely exhausted or the technology becomes completely obsolete.

The discounted benefits of the R&D investment to the farmers are PKR 59 billion in the case of a low import elasticity, and PKR 54 billion under the high import scenario. Despite assuming a modest gain of 3 percent in crop productivity after increasing the R&D investment, the gains to farmers as well as to the society are the highest of all scenarios. Despite having a similar cost (approximately PKR 12 billion), the benefits derived from this policy are more than double those from providing a subsidy on phosphate fertilizer.

Another advantage of this scenario is that, except for the manufacturers, all stakeholders including government benefit from this intervention. In fact manufacturers also benefit, through the increased fertilizer price as well as the expansion in production of fertilizer, and their losses decrease by 15 percent compared to the case when only the subsidy on gas is removed. The government benefits from the savings from eliminating subsidies, as well as increased GST from enhanced fertilizer demand. Consumers benefit from reduced output prices because of the expansion of crop production. International competitiveness increases and leads to an improvement in the trade surplus. Additional production creates new jobs and businesses in the agricultural sector.

The 25 percent investment in R&D is capable of reducing all negative impacts of removing gas subsidies, when both policy scenarios are combined together. The combined interventions reduce the urea demand by only 7 percent compared to 10 percent (in case of low import elasticity) when only gas subsidies are removed. Crop production gains become highly positive, at PKR 52 billion, instead of the decline of PKR 7 billion when the policy of a removal of the gas subsidy alone is applied. Although government savings decline by PKR 12 billion, farmers gain substantially, by PKR 32 billion, when both policies are combined, as opposed to the loss of 11 billion when the gas subsidy alone was removed. Similarly, international crop trade becomes positive with the combined policy.

Table 6.9 shows the beneficiaries of all interventions discussed above. For instance, investment in enhancing agricultural productivity, while removing the subsidy on feedstock gas, the energy source for urea manufacturing, will have positive outcomes for consumers from higher crop production, increase farmers' benefits, raise government revenues, and benefit society overall.

Policy Scenario 3: Removal of the General Sales Tax

The removal of the 17 percent GST on prices of urea and DAP will immediately reduce fertilizers' cost to farmers, while, at the same time, raising the price for manufacturers as the tax wedge is removed. With this intervention, different reactions occur in all markets, and the final outcome again depends upon the import elasticity of fertilizer.[27] In our model, the eventual decline in urea and DAP prices at the farm gate was around 14 percent and 12 percent, respectively. These lower prices also increase 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. The higher prices increase the domestic supply of urea and DAP by about 2 percent.[28] The reduction of prices at the farm gate can get close to the full value of the GST (17 percent) if import elasticity is higher. However, a higher import elasticity will reduce the impact on factory prices, and thus domestic supply further declines as imports are encouraged.

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

---

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

[28] The model assumes that any additional input, including gas, will be freely available to produce equilibrium quantities of fertilizer (as well as crops). One may, however, obtain a small increase in fertilizer supply, as in this scenario, through enhanced efficiency even if additional gas is not available.

Policy Scenario 4: Removal of the Gas Subsidy and GST Simultaneously

Some policy makers would like to see the fertilizer sector without any tax, but also without production subsidies, so we analyze the impact of this scenario in this fourth simulation. The result is a shift of the supply curve of fertilizer upward due to a decrease in the subsidy, as well as a shift of the demand curve upward because of the removal of GST. The net results thus depend on the particular supply and demand elasticities. The removal of the GST reduces the price to farmers by 17 percent, but the cost of natural gas nearly triples, and that input is about 40 percent of the total cost for urea manufacturers. Thus, the effect of the removal of the gas subsidy is much greater than the tax reduction. In summary, under the assumed elasticities in our model, the total availability of urea decreases despite rising demand from the lower prices seen by farmers. However, in the case of DAP, the demand (increases) and farmer price (decreases) move in opposite directions. The factory prices and fertilizer supply both increase, although the response is relatively low.

The factory prices of urea and DAP increase by 13 percent and 9 percent, but their farm gate prices decrease by 4 percent and 7 percent, respectively, as 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. The import cost of fertilizer rises in the low import elasticity scenario by 24 percent to PKR 21 billion. The import cost is reduced slightly (by PKR 1 billion) by increasing the import elasticity of fertilizer. This reduction occurs because the price of fertilizer falls by a greater percentage as imports come more easily into the country, and therefore more urea fertilizer can be obtained for about the same total cost.

This change in policy leaves the government with little change in revenue, despite its loss of PKR 50 billion from the GST, because it saves PKR 47 billion from the removal of the gas subsidy.

The 7 percent decrease in the demand for urea lowers crop production and creates upward pressure on prices, which costs the economy PKR 4 billion, without much change in the trade deficit. Farmers gain PKR 33 billion from this scenario from increased output prices and lower fertilizer prices. The farmers' benefit from the policy, however, can be improved to PKR 70 billion with the 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 is captured by importers. The social cost of this reshuffling would be PKR 5 billion, which is turned into a social profit of PKR 20 billion when the higher import elasticity is assumed.

Policy Scenario 5: Removing the Shortage of Gas

The fertilizer industry, as of 2013/2014, was operating at around 72 percent of its installed capacity. One of the key factors affecting the future and viability of the industry will be the availability of natural gas to the sector.[29]

In this scenario, we assume that surplus gas is available, and we thus increase the amount of natural gas supplied to the fertilizer industry by 28 percent while keeping all other exogenous effects constant.[30]

The policy scenario causes a shift in the supply curve outward and decreases the prices of urea and DAP by 4 percent and 2 percent, respectively, both at the farm and factory levels, while increasing the equilibrium quantities of domestic supply by about 6 percent and 4 percent. As domestic prices decrease, imports become less competitive and are reduced by 4 percent and 2 percent, respectively (the decrease in fertilizer prices and imports is higher under the high import elasticity scenario, implying a greater increase in domestic supply as well as demand). The domestic demand of urea and DAP 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 crop prices. Given the baseline values in 2013/2014, the value of domestic production of all crops increases by about PKR 3 billion, while the trade surplus for these crops increases insignificantly.

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

Although the removal of the gas shortage benefits all stakeholders, except the government, the extent of benefits is relatively small. Moreover, removal of the gas shortage relies on the exploitation of a scarce economic resource in the country. It is estimated that, with the existing rate of use, the most extensive recoverable gas reserves available to the fertilizer sector, from the Mari

---

[29] This analysis does not take into account the rapid depletion of the supply of natural gas in Pakistan and the cost to other sectors if gas is allocated from them to the fertilizer sector.

[30] The model, however, only reflects use of gas that is needed by a firm to reach equilibrium demand.

TABLE 6.9 Benefits for stakeholders of policy interventions with low import elasticity ($\alpha = 1$)

Intervention	Consumers	Farmers	Manufacturers	Government	Society
Removing subsidy on feedstock gas				▨	
Investing in R&D and removing gas subsidy	▨	▨		▨	▨
Removing GST	▨	▨	▨		▨
Removing both gas subsidy and GST	▨	▨			
Removing gas shortage	▨	▨	▨		▨

Source: Authors.

Note: Shaded box indicates that stakeholder benefits. α = trade elasticity of fertilizer; R&D = research and development; GST = general sales tax.

field, will be exhausted in 16 years.[31] This depletion rate suggests that the government should start planning now for a gradual shift from domestic supply to imports, which is inevitable anyway, rather than promoting the speedy exploitation of a scarce resource, waiting until it is completely exhausted, and then passing through a stressful transition toward imports.

Table 6.9 shows beneficiaries of all five interventions discussed above. For instance, investment in R&D while removing the subsidy on feedstock gas will have positive outcomes for consumers from higher crop production and will increase farmers' benefits, raise government revenues, and benefit society overall.

Conclusions

Historically, Pakistan has offered a favorable setting for growth in fertilizer uptake and increased agricultural production. Beginning in the mid-1960s, 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. On the supply side, Pakistan's perceived abundance of natural gas aided in the rapid construction of a domestic fertilizer industry. That

---

[31] According to data from the Ministry of Petroleum and Natural Resources, the balance of the recoverable reserve of gas from the Mari field as of December 31, 2014, was 3,382 billion cubic feet, and the utilization rate during 2014 was 211 billion cubic feet. This means the field's gas reserves will last for no more than 16 years. This is also recognized by IRG (2011) in its report on page 17.

perception has proved to be false, as evidenced by the serious shortage of gas in the country.

The general policy emphasis on building domestic production capacity and promoting urea use among farmers also occurred at the expense of a more efficient and 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 anticompetitive behavior is emerging (CCP 2010). Despite policies to encourage the industry and the 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 US$3.57 billion in 2013/2014, has been operating at approximately 75 percent of capacity in recent years, despite subsidies on both production and distribution. These two sources together total about PKR 53 billion in subsidies, 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 control the pricing, quality, promotion, manufacturing, importation, and distribution of fertilizer in Pakistan. The elaborate marketing rules provided sweeping and discretionary powers to farm-level controllers, who represent the extension wings of provincial agriculture departments. The controllers' powers included stopping or limiting sales, sealing stocks, and fixing prices. Such powers, along with the control of the gas supply and prices at the macro level, limited entry into fertilizer processing and marketing, inducing an oligopolistic cartel (CCP 2010 and our analysis).

Our analysis found that various factors positively influence fertilizer applications. These factors include the use of fertilizer-responsive crop varieties and the availability of irrigation water. Moreover, fertilizer use was not closely related to soil or land types, indicating farmers' laxity to adjust use according to their own resource base and holding size. Our survey found that smaller farms applied higher doses of fertilizer on a per-hectare basis.

The NFDC brings various stakeholders together for issue resolution and policy formulation. However, not enough attention appears to be given to policies that promote a balanced use of fertilizer and environmentally friendly products and efficient application methods. The provincial soil fertility research institutes do a good job of 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 the needs of the specific site. However, plot-level data collected in RHPS Round 1.5 suggest that this had almost no impact, as we found that farmers did not adjust fertilizer use enough to be consistent with the SFRI recommendations such as using urea and phosphate fertilizers in a 2:1 ratio or applying more fertilizer on poor and saline soils. A more-rigorous campaign to educate farmers to adjust fertilizer use according to the natural resource endowment needs to be initiated by the provincial agriculture departments.

An EDM was developed to examine the fertilizer market and four related major agricultural product markets. The markets cleared via trade linkages to international markets and by equating supply and demand. Using the specified model, we simulated the effects of various government policies in the fertilizer and output markets, including trade, and looked at the gains to government, consumers, farmers, and manufacturers. Our results suggest that removing the gas subsidy results in a potential gain in government revenues, if a tax is used to raise the gas price (see footnote 23) but losses to manufacturers, consumers, and farmers occur. Removing the gas subsidy on urea manufacturers' key input, and the GST charged on farmers' purchases of fertilizer, simultaneously reduces farmers' expenses and increases manufacturers' expenses, but the government's potential gain is nullified. Increasing gas supply results in small benefits to consumers, manufacturers, and farmers, but government expenditure also increases because of the increased gas subsidy. Removing the GST alone results in benefits similar to those observed in increasing the gas supply, but the government loses much more revenue. Our model suggests that removing the gas subsidy and investing in agriculture R&D will result in the highest social benefit, where all major stakeholders benefit at least to some degree and the return to the society is highest. An additional advantage of R&D investment compared to other scenarios would be the highest increase in agricultural productivity and the generation of trade surplus, which will create new jobs, stimulate overall economic development, and help alleviate poverty in rural areas (Schneider and Gugerty 2011). As growth in the industrial sector is closely linked with agricultural sector growth, this will induce overall economic development in the country.

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. Our recommendations follow.

With respect to fertilizer manufacturing, policy should move away from encouraging expansion based on subsidies to promote a competitive use and modernization of existing capacity, thereby improving efficiency and preparing the industry for an era with fewer subsidies and more international competition, both in gas and fertilizer prices. Our findings also suggest that the production subsidy on gas should be removed, because doing so will not harm farmers or consumers to a great extent and the high profit in the industry will enable these firms to absorb these shocks.

However, the sector should be closely protected with antitrust laws, and approaches should be considered to distribute gas in ways that are closer to market outcomes, such as diverting more gas to efficient firms. A broad fertilizer policy should be considered to address issues of all stakeholders. A Fertilizer Board, consisting of a group of relevant stakeholders, could help monitor the performance of the sector, including pricing, import strategies, and other provisions of the policy.

Incentives for the industry need to be redesigned to reflect several dimensions in the outlook for world and domestic fertilizer and natural gas markets. We compared domestic fertilizer prices without subsidies to international fertilizer prices and found the former generally higher than the latter, suggesting that the fertilizer industry does not have much of an opportunity to sell its product in international markets. Also, a key issue is the outlook for natural gas, because domestic supplies may disappear within a decade or so. The questions are how Pakistan should prepare itself for the scenario of running its fertilizer plants with imported gas and whether importing fertilizer directly makes more sense. Given the limited reserves of natural gas, it seems unlikely that Pakistan will become an exporter, even though the CCP analysis makes some suggestions along these lines (CCP 2010). However, fertilizer trade with India may become a possibility if both countries remove subsidies on fertilizer.

With respect to fertilizer marketing, the policy focus needs to change from controlling fertilizer markets, the existing norm, to freeing the market to improve efficiency. First, laws need to be rationalized, and regulators should be allowed to operate only within some clear parameters of market failure. Second, antitrust laws need to be enforced at district levels as well, and standards for animal manure, micronutrients, plant growth–promoting rhizobacteria, and so on should be developed and strictly enforced. Farmers need to be educated about these standards so they can create demand for these products.

With respect to 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. To foster this, knowledge-based agriculture should be promoted, where farmers become aware of and trained for the use of various technological options to improve fertilizer efficiency. This support will require assessments of the capacity of agricultural extension and soil fertility labs to provide more-advanced consulting to farmers. For example, can computer-based models be developed to synchronize fertilizer use with resource quality, in order to meet plot-specific needs? These models could identify efficient fertilizer application methods such as placement, fertigation, or machinery that would 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 manure, and micronutrients, as well as more efficient crop varieties, especially for barani areas.

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

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

References

Agritech. 2014. "Our Company." http://www.pafl.com.pk/our-company. Accessed July 25, 2014.

Ahmed, A. S., and M. Gautam. 2013. *Increasing Agricultural Productivity*. Pakistan Policy Note 6. Washington, DC: World Bank.

Ali, M. 1990. "The Price Response of Major Crops in Pakistan: An Application of the Simultaneous Equation Model." *The Pakistan Development Review* 29 (3/4): 305–325.

Ali, M., and D. Byerlee. 2002. "Productivity Growth and Resource Degradation in Pakistan's Punjab. A Decomposition Analysis." *Economic Development and Cultural Change* 50 (4): 839–863.

ASTI-PARC (Agricultural Science and Technology Indicators and Pakistan Agricultural Research Council). 2012. *Country Note July 2012*. Islamabad and Washington, DC.

Bumb, B., and C. Baanaate. 1996. *The Role of Fertilizer in Sustaining Food Security and Protecting the Environment in 2020*. 2020 Vision Discussion Paper 17. Washington, DC: International Food Policy Research Institute.

Byerlee, D., and A. Siddiq. 1994. "Has the Green Revolution Been Sustained? The Quantitative Impact of the Seed-Fertilizer Revolution in Pakistan Revisited." *World Development* 22 (9): 1345–1361.

CCP (Competition Commission of Pakistan). 2010. *Competition Assessment Study of the Fertilizer Sector in Pakistan*. Islamabad: Competition Commission of Pakistan, World Bank.

Concepcion, R. N. 2007. *Sustainable Fertilization Management of Croplands: The Philippines Scenario*. Bangkok: Food and Agriculture Organization. http://www.fao.org/docrep/010/ag120e/AG120E16.htm.

Conway, G. R., and J. N. Pretty. 1991. *Unwelcome Harvest: Agriculture and Pollution*. London: Earthscan Publications.

Din, M. S., and H. S. Jafry. 2007. *Pakistan Fertilizer Sector Review*. Karachi: IGI Securities.

DoF (Department of Fertilizer). 2012. *Indian Fertilizer Scenario 2012*. New Delhi: Department of Fertilizer, Ministry of Chemicals and Fertilizers, Government of India.

EIA (Energy Information Administration). 2014. "Natural Gas." http://www.eia.gov/dnav/ng/hist/rngwhhdd.htm. Accessed September 25, 2014.

FAO (Food and Agriculture Organization of the United Nations). 2014. "Food Balance/Food Balance Sheets." http://faostat3.fao.org/faostat-gateway/go/to/browse/FB/FBS/E. Accessed July 25, 2014.

FFC (Fauji Fertilizer Company Limited). 2014. "About Us." http://www.ffc.com.pk/company-profile.aspx. Accessed July 25, 2014.

Gruhn P., F. Goletti, and M. Yudelman. 2000. *Integrated Nutrient Management, Soil Fertility, and Sustainable Agriculture: Current Issues and Future Challenges*. Food, Agriculture, and the Environment Discussion Paper 32. Washington, DC: International Food Policy Research Institute.

Haile, M. G., M. Kalkuhl, and J. von Braun. 2014. "Inter- and Intra-Seasonal Crop Acreage Response to International Food Prices and Implications of Volatility." *Agricultural Economics* 45 (6): 693–710.

Hannah, L., and J. A. Kay. 1977. *Concentration in Modern Industry: Theory, Measurement and the UK Experience.* London: Macmillan.

Hassan Ul, M., and P. Pradhan. 1998. *Coordinated Services for Irrigated Agriculture in Pakistan.* Proceedings of the IWMI National Workshop, Lahore, October 29–30.

HDIP (Hydrocarbon Development Institute of Pakistan). 2013. *Pakistan Energy Yearbook 2012.* Islamabad: Hydrocarbon Development Institute of Pakistan, Ministry of Petroleum and Natural Resources, Government of Pakistan.

Hudson, D., and D. Ethridge. 2009. *The Pakistani Cotton Industry: Impacts of Policy Changes.* Lubbock: Texas Tech University.

Hussain, A. 2011. *Seed Industry in Pakistan.* Paper presented at World Bank Roundtable Discussion on Agriculture and Water, Islamabad, March 10–11.

IFPRI/IDS (International Food Policy Research Institute/Innovative Development Strategies). 2012. *Pakistan Rural Household Panel Survey.* Rounds 1 and 1.5 dataset. Washington, DC: IFPRI; Islamabad: IDS.

IRG (International Resource Group). 2011. *Pakistan Integrated Energy Model (Pak-IEM).* Final Report, Volume II, Policy Analyses Report, ADB TA-4982 PAK. Prepared for Asian Development Bank and Ministry of Planning and Development, Government of Pakistan.

Kaneda, H. 1969. "Economic Implications of the 'Green Revolution' and the Strategy of Agricultural Development in West Pakistan." *The Pakistan Development Review* 2: 111–143.

Khan, S. A. 2014. "DAP Sales Plunge on Subsidy Issue." *Dawn*, July 12.

MNFAL (Ministry of Food, Agriculture and Livestock). 2007a. *Agricultural Statistics of Pakistan,* vol. 4 *1981–1990.* Islamabad: Ministry of Food, Agriculture and Livestock, Government of Pakistan.

———. 2007b. *Agricultural Statistics of Pakistan,* vol. 5 *1991–2000.* Islamabad: Ministry of Food, Agriculture and Livestock, Government of Pakistan.

———. 2007c. *Agricultural Statistics of Pakistan,* vol. 3 *1971–1980.* Islamabad: Ministry of Food, Agriculture and Livestock, Government of Pakistan.

MNFSR (Ministry of National Food Security and Research). 2013. *Agricultural Statistics of Pakistan 2011–2012.* Islamabad: Ministry of National Food Security and Research, Government of Pakistan.

Nazli, H., S. H. Haider, and A. Tariq. 2012. *Supply and Demand for Cereals in Pakistan, 2010–2030.* IFPRI Discussion Paper 01222. Washington, DC: International Food Policy Research Institute.

NFDC (National Fertilizer Development Centre). 1998. *Pakistan Fertilizer Related Statistics.* Islamabad: National Fertilizer Development Centre, Planning Commission, Government of Pakistan.

———. 2002. *Pakistan Fertilizer Related Statistics.* Islamabad: National Fertilizer Development Centre, Planning Commission, Government of Pakistan.

———. 2008. *Pakistan Fertilizer Related Statistics.* Islamabad: National Fertilizer Development Centre, Planning Commission, Government of Pakistan.

———. 2014. "Statistics." www.nfdc.gov.pk/stat.html. Accessed June 20, 2014.

NRC (National Research Council). 1989. *Alternative Agriculture.* Washington, DC: National Academy Press.

PFL (Pakarab Fetilizers Limited). 2014. "Company Overview." http://www.fatima-group.com/pakarabfertilizers/companyoverview.php. Accessed July 25, 2014.

PPI (Pakistan Press International). 2012. "Gas Shortage: Fertiliser Manufacturers Claim Losses of Nearly Rs5b." *The Express Tribune,* November 21.

Quddus, M. A., M. W. Siddiqi, and M. M. Riaz. 2008. "The Demand for Nitrogen, Phosphorus and Potash Fertilizer Nutrients in Pakistan." *Pakistan Economic and Social Review* 46 (2): 101–116.

Rashid, S., P. A. Dorosh, M. Malek, and S. Lemma. 2013. "Modern Input Promotion in Sub-Saharan Africa: Insights from Asian Green Revolution." *Agricultural Economics* 44: 705–721.

Sankaram, A., and P. Rao. 2002. "Perspectives of Soil Fertility Management with a Focus on Fertilizer Use for Crop Productivity." *Current Science* 82 (7): 797–807.

Schneider, K., and M. K. Gugerty. 2011 "Agricultural Productivity and Poverty Reduction: Linkages and Pathways." *The Evans School Review* 1 (1): 56–74.

SFRI (Soil Fertility Research Institute). 2013a. *Fertilizer Response Curve Studies.* Lahore: Soil Fertility Research Institute, Punjab Agriculture Department, Government of Pakistan.

———. 2013b. *Nutrient Depletion over Time.* Lahore: Soil Fertility Research Institute, Punjab Agriculture Department, Government of Pakistan.

Zuberi, H. A. 1989. "Production Function, Institutional Credit and Agricultural Development in Pakistan." *The Pakistan Development Review* 28 (1): 43–55.

Annex A: Definitions and Summary Statistics

TABLE A6.1 Definitions of variables used in the regression

Variable name	Variable definition
Dependent variable	
Yield of wheat (kg/ha)	Natural log of kilograms of wheat produced per hectare
Input variables	
Nitrogen used (kg/ha)	Total kilograms of nitrogen consumed per ha
Tractor usage (hours/ha)	Total number of hours for which tractors were used per ha
Family labor (hours)	Number of hours per ha for which family labor was used
Hired labor (hours)	Number of hours per ha for which hired labor was used
Number of pesticide sprays	Total number of pesticide sprayings on the plot
Total seed used (kg/ha)	Total kilograms of seed or seedlings used per ha
Groundwater irrigations (no)	Number of groundwater irrigations applied on the plot
Canal water irrigations (no)	Number of canal water irrigations applied on the 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)	
Visit by extension agent	Extension agent visited the household = 1 and 0 otherwise
Seed was registered after 2005	The farmer used the seed registered after 2005 = 1 and 0 otherwise
Loss experienced during harvesting	Household experienced loss in production during harvesting of crop = 1 and 0 otherwise
Loss due to natural disaster	Household experienced loss in production due to floods, drought, frost, and so forth = 1 and 0 otherwise
Loss due to pests	Household experienced loss in production due to pests = 1 and 0 otherwise
Plot experienced salinity	Presence of salinity on plot as reported by respondent = 1 and 0 otherwise
Highly fertile soil	High quality of soil as reported by the respondent = 1 and 0 otherwise
Manure application	Whether manure was applied during the rabi 2011/2012 season = 1 and 0 otherwise

Note: kg = kilogram; ha = hectare. Each of the values was standardized by the cultivated land size in hectares.

TABLE A6.2 Summary statistics of the variables used in the regression

Variables	Mean	SD
Agricultural output		
Yield of wheat (kg/ha)	2,760.30	1,061.80
Inputs		
Canal water irrigations (no)	2.73	4.12
Groundwater irrigations (no)	4.66	5.41
Hired labor (hours/ha)	97.37	154.10
Family labor (hours/ha)	130.40	139.70
Number of pesticide sprays	1.02	1.10
Nitrogen used (kg/ha)	114.70	57.60
Age of the household head (years)	47.17	12.67
Average education of household (years)	6.43	8.47
Tractor usage (hours/ha)	8.01	4.39
Total seed used (kg/ha)	141.20	40.95
Extension, loss, seeds, and soil health (proportion answering yes)		
Was phosphorous applied?	0.83	0.38
Manure application	0.26	0.44
Plot experienced salinity	0.05	0.22
Highly fertile soil	0.96	0.20
Loss experienced during harvesting	0.06	0.24
Loss due to pests	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 after 2005	0.61	0.50

Source: Authors' estimates, based on IFPRI/IDS (2012).

Note: SD = standard deviation. These statistics are for 755 observations that are used to estimate our yield response function.

Annex B: Initial Equations for the EDM Model

Crop market

$$Q_i^s = f(P_i^f, P_j^f, P_k, T_i)$$

$$Q_i^d = h(P_i, P_j, C_i)$$

where Q is the quantity of *i*th output ($i = 1, 2, 3, 4$, with each number representing a different crop: cotton, rice, wheat, and other crops[32]); P_i is *i*th domestic commodity price at the equilibrium where supply and demand curves cross each other; P_j is the price of all other commodities, where $j \neq i$; P_k is the domestic price of fertilizer k (k = u and p fertilizer, that is, urea and 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.

$$Q_i^d = Q_i^s + I_i$$

$$I_i = l(P_i)$$

$$P_i = P_i^f(1 + t_i)$$

$$P_i^f = P_i^w(1 + z_i)$$

where I_i is quantity 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/transportation cost, which establishes the difference between the world price and domestic price.

Urea market

$$Q_k^s = m(Q_g, P_g, P_k^f, Q_{po}, P_{po})$$

$$Q_k^d = r(P_k, Q_i^s)$$

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; the superscripts and subscripts *s*, *d*, *g*, *po* are for supply, demand, world , natural gas, and phosphate, respectively.

$$Q_k^d = Q_k^s + I_k$$

$$I_k = v(P_k)$$

---

[32] We do not differentiate between basmati and other rice varieties, mainly because of data constraints.

$$P_k = P_k^f(1 + t_k)$$

$$P_k^f = P_k^w(1 + z_k)$$

where Q_k^d, Q_k^s is 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/transportation cost and represents the difference between the domestic and world price.

Annex C: Transformation of Equations

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

$$Q_i^s = f(P_i^f, P_j^f, P_u, P_p, T_i)$$

In its linear form, the above equation becomes

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

Where Q_1^s, the domestic production of wheat, is a function of P_1^f, the factory price of wheat—and shifters include P_2^f, P_3^f, and P_4^f, which are factory prices of rice, cotton, and other crops, respectively; P_u is the price of urea; and P_p is the price of DAP; while T is a technology adoption shifter.

Total differentiation of equation (a) yields

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

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

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

This yields

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

where the operator E is the proportional change in a given variable, and the various symbols denote elasticities, which are presented in Annex E.

The derivation of the tax equation is

$$P_1^f(1 + t_1) = P_1$$

$$dP_1 = P_1^f d(1 + t_1) + (1 + t_1)dP_1^f$$

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

$$dP_1/P_1 = (P_1^f dt_1/P_1) + ((1 + t_1)dP_1^f) / P_1$$

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

$$dP_1/P_1 = (P_1 dt_1/(1 + t_1)P_1 + \left((1 + t_1)dP_1^f\right) / P_1^f(1 + t_1)$$

Assuming initial tax rate = 0, $dt_1 = t_1$ and $\frac{t_1}{1+t_1} = t_1$

$$EP_U = t_u + EP_u^f$$

Annex D: Final Equations for the EDM Model

The input and output markets are first reduced by substituting the demand equation in the market-clearing equation (where demand is equal to supply and imports). 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 explained in Annex E. These transformed equations are entered in the General Algebraic Model 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:

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

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

$$EI_i = \beta_i \, EP_i$$

$$EP_i^f = EP_i^w + z_i$$

$$EP_i = EP_i^f + t_i$$

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

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

$$EI_k = \alpha_k \, EP_k$$

$$EP_k^f = EP_k^w + z_k$$

$$EP_k = EP_k^f + t_k$$

Annex E: Values of Elasticities Used in the EDM Model

Demand elasticity			Supply elasticity		
Descriptor	Symbol	Elasticity	Descriptor	Symbol	Elasticity
Crop market					
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_3	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*		

Demand elasticity			Supply elasticity		
Descriptor	**Symbol**	**Elasticity**	**Descriptor**	**Symbol**	**Elasticity**
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			
Fertilizer market					
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

Demand elasticity			Supply elasticity		
Descriptor	Symbol	Elasticity	Descriptor	Symbol	Elasticity
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 et al. 2012; and authors' own judgment assumptions.

Note: Elasticities were drawn from previous literature whenever possible. According to our research, elasticities on fertilizer manufacturing are not available, and our estimates are based on feedback from industry professionals. DAP = di-ammonium phosphate.

Annex F: Simulated Changes from 2013/2014 Base Value Using EDM for Various Policy Interventions with High Import Elasticity ($\alpha = 5$)

	Change from 2013/2014 baseline value				
Variables	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Fertilizer market					
Domestic supply of urea (1,000s MT)	−956(−19.4)	−913(−18.5)	43(0.9)	−913(−18.5)	385(7.8)
Domestic supply of DAP (1,000s MT)	−58(−8.3)	−56(−8.1)	4(0.6)	−53(−7.7)	30(4.2)
Import supply of urea (1,000s MT)	208(18)	271(23.5)	62(5.4)	270(23.4)	−84(−7.2)
Import supply of DAP (1,000s MT)	69(7.4)	92(9.8)	73(7.8)	142(15.3)	−35(−3.8)
Demand of urea (1,000s MT)	−748(−12.3)	−642(−10.6)	105(1.7)	−643(−10.6)	301(5)
Demand of DAP (1,000s MT)	11(0.7)	35(2.2)	77(4.8)	89(5.5)	−6(−0.4)
Farmer price of urea (PKR/MT)	1317(3.6)	1716(4.7)	−5816(−15.9)	−4499(−12.3)	−529(−1.5)
Farmer price of DAP (PKR/MT)	1082(1.5)	1430(2)	−11238(−15.4)	−10156(−14)	−546(−0.8)
Factory price of urea[a] (PKR/MT)	1125(3.6)	1467(4.7)	339(1.1)	1464(4.7)	−452(−1.5)
Factory price of DAP[a] (PKR/MT)	925(1.5)	1222(2)	973(1.6)	1898(3.1)	−466(−0.8)
Import cost for fertilizer (B PKR)	15(15.5)	20(20.4)	7(8.3)	20(24.1)	−6(−6.5)
Output market					
Overall pressure on output prices (PKR/MT)	−0.03(0)	(−0.5)	(−0.1)	(−0.1)	(0)
Overall trade surplus (B PKR)	0(−0.2)	6(5)	1(0.9)	1(0.7)	0(0.1)

Variables	Change from 2013/2014 baseline value				
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Total crop production gain (B PKR)	−3(−0.1)	58(2.4)	13(0.5)	11(0.4)	1(0)
Fertilizer expense for farmers (B PKR)	−18(−5.2)	−9(−2.7)	−46(−13.4)	−59(−17.3)	6(1.9)
Production revenue (B PKR)	−3(−0.1)	58(2.3)	13(0.5)	11(0.4)	1(0)
Overall farmer benefit (B PKR)	15(0.7)	67(3)	59(2.6)	70(3.1)	−5(−0.2)
Gas expense (B PKR)	35(222.3)	36(225.6)	0(0.9)	36(225.7)	1(7.6)
Subsidy and others					
Fertilizer revenue (B PKR)	−23(−14.4)	−20(−12.9)	3(2)	−20(−12.6)	9(5.6)
Overall manufacturer benefit (B PKR)	−58(−40.7)	−56(−39.4)	3(2.1)	−55(−39)	8(5.4)
Production subsidy (urea) (B PKR)	−47(−100)	−47(−100)	0(0.9)	−47(−100)	4(7.6)
Retail subsidy (DAP) (B PKR)	0(0)	0(0)	0(0)	0(0)	0(0)
Distribution subsidy (B PKR)	2(20.2)	3(26.5)	0(5.4)	1(23.4)	−1(−7.9)
Tax revenue from fertilizer (B PKR)	−3(−5.2)	−1(−2.7)	−50(−100)	−50(−100)	1(1.9)
All subsidies (B PKR)	−44(24.4)	−44(25.7)	1(101.3)	−46(11.8)	3(104.5)
Investment on R&D (B PKR)	0(0)	12(0)	0(0)	0(0)	0(0)
Total change in govt. revenue (B PKR)	42(0)	30(0)	−50(0)	−4(0)	−2(0)
Consumer crop demand (B PKR)	−2(−0.1)	52(2.1)	12(0.5)	10(0.4)	1(0)
Eventual social benefit (B PKR)	−3(0)	94(0)	24(0)	20(0)	2(0)

Source: Authors' estimates.

Note: Figures in parentheses are percentage changes with respect to the baseline value of 2013/2014. B = billion; DAP = di-ammonium phosphate; MT = metric tons; GST = general sales tax; α = trade elasticity of fertilizer. The overall social benefit does not incorporate trade loss/profit. We assumed this is already reflected in the loss/gain in crop production.

In scenario 1, we remove the subsidy on natural gas; in scenario 2, we increase investment in crop research and development while removing natural gas subsidy; in scenario 3, we remove the GST; in scenario 4, we remove gas subsidy and GST simultaneously; and in scenario 5, we remove the shortage of gas.

[a] Exclusive of GST.