Determinants of Demand for Fertilizer: A Case for India

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ABSTRACT

In India agriculture contributes 14 percent to GDP and provides subsistence to two-thirds of the population. One of the top priorities of the Indian government is to provide food security to more than 1.25 billion people. Hence, increasing farm productivity is viewed as a primary goal for the government. Agricultural growth, with its forward and backward links to the industry and service sectors, is directly linked to India's economic growth. Using national time-series data, this study estimates a demand function for fertilizer using a simple linear regression model and explores the relationship between demand and various non-price factors. The results from the regression analysis found that non-price factors are more important than the price of fertilizer in determining fertilizer demand. This study recommends that to increase agricultural output, government subsidy policies need to be geared toward the use of balanced nutrients for improving soil conditions, at the same time, provide an incentive to fertilizer manufacturing firms to develop new environmentally-sustainable products for agriculture.

Keywords: productivity, fertilizer, India, demand, subsidy, agriculture
JEL Classification: D10, D24, D21, Q00, R00

INTRODUCTION

Agriculture contributes 14 percent to India's gross domestic product (GDP) and provides subsistence to two-thirds of the Indian population. One of the top priorities of the Indian government is to provide food security to its 1.25 billion plus population. Hence, increasing farm productivity is viewed as a primary goal of the government. The growth of agriculture with its forward and backward links to industry and service sectors, is directly linked to India's economic growth. However, with the rapid growth of population, urbanization, and infrastructural development the use of land for the production of food is diminishing. In the last few decades the use of technology combined with high-yielding variety (HYV) seeds, fertilizer, and irrigation took the center stage for raising agricultural productivity. Fertilizer consumption and production in India has been increasing over the last three decades and is currently the second largest consumer (behind China) and third largest producer (behind China and USA) of fertilizers in the world. The price of fertilizer, which is a capital intensive and high energy use product, in an unregulated market is beyond the reach of 83 percent of Indian farmers who are small or marginal. The government started its fertilizer price control and subsidy policy (i.e., maximum retail price [MRP] and retention price scheme [RPS] by paying subsidies to fertilizer manufacturers) in 1977/78. The government budget for subsidy payments has increased from INR 42.89 billion in 1990/91 to INR 612.64 billion in 2009/10 and to INR 1.07 trillion in 2014/15, which is 1.35 percent of GDP. Although the fertilizer subsidy has increased the use of fertilizers per hectare, the average intensity of fertilizer use is still lower than other developing nations.

During the last decade, Indian agriculture grew at 2.5–3.0 percent per year. The government set the growth target for agriculture at 4 percent for 2012–2016 (Gupta 2014). As a result, promoting rapid growth of agriculture is necessary to increase income for 18.7 million farmers (Census 2011). In India only 35 percent of cultivable land is under irrigation, hence, growth in agricultural productivity mostly depends on monsoon rainfall, improved technology, use of HYV seeds, and chemical fertilizers. Since there is a limited scope to increase cropped area, the biggest challenge for Indian agriculture is to increase food production through increased land productivity. The key to increasing land productivity is supplying plant nutrients via the use of chemical fertilizers in a sustainable manner. Over the last three decades India has experienced a reasonable growth in fertilizer consumption. The total consumption of fertilizers (nitrogen [N, urea], phosphorous [P], and potassium [K]) exceeded 28.2 million tons in 2011/12. Although India is the second largest consumer of fertilizers in the world (18% in 2012) the average intensity of fertilizer use in India (141 kilogram per hectare [kg/ha]) is lower than the average of most of the developing countries of the world. However, there is a significant variation in average intensity of fertilizer use among regions such as the western region with 40.7 kg/ha and the northern region (Punjab) with 224 kg/ha (Sharma and Thaker 2011).

Recent studies have found that soil fertility in India has declined due to poor adoption of fertilizer best management practices. The main reason for soil degradation is that the government fertilizer subsidy policy in the past encouraged farmers to use unbalanced proportion of urea compared to phosphorous and potassium. According to some studies the NPK consumption ratio deteriorated from 4.7:2.3:1 in 2010 to 8.2:3.2:1 in 2012 (Chander 2014). However, there is a large variation for the NPK ratio at the regional/state level in India. For example, the NPK ratio in 2013 for Punjab was 61.7:19.2:1; Harayana 61.4:18.7:1; Rajasthan

44.9:16.5:1; and Uttar Pradesh 25.2:8.8:1 (Himanshu 2015). The current imbalance in the use of NPK ratio has created great problems for Indian agricultural growth leading to almost stagnant or declining soil productivity and farmers' income. According to Jaga and Patel (2012), balanced crop development needs 16 different plant food nutrients—each of which needs to be present in the soil in various proportions. These nutrients are grouped into primary nutrients (macro), secondary nutrients, and micronutrients. The primary nutrients are phosphorus and potassium. The secondary nutrients include calcium, magnesium, and sulphur, which are required at lesser amounts for all plants than primary nutrients. The micronutrients are boron, chlorine, copper, iron, magnesium, molybdenum, and zinc, which are used in small amounts but are necessary for all plant development (Sharma and Thaker 2011). The primary nutrients (NPK) are most frequently required for crop fertilization. As a result, since its independence, India's major focus of its fertilizer subsidy policy has been on these primary nutrients.

Because fertilizer production is highly capital- and energy-intensive, the government has set the policy to control the maximum retail price (MRP) of fertilizer, which has historically been implemented through various forms of subsidy. The government controls the MRP at a low level, which guarantees the producers a price that helps them to remain economically viable. The difference between the MRP and the actual cost of production is reimbursed as subsidy. Government policies generally control the pricing, distribution, and movement of fertilizers, which ultimately determine the growth of the industry (Patel 2014). Urea, ammonium sulphate, calcium ammonium nitrate, ammonium chloride, nitrogenous fertilizers, and single superphosphate (SSP) are domestically produced. Several complex fertilizers such as, DAP (diammonium phosphate) and several grades of nitrophosphates, are also produced in India. The common products are urea, DAP, SSP, and muriate of potash, however, DAP and urea are produced indigenously and the entire feedstock requirement for potassic fertilizers are imported (Patel 2014).

Over the last three decades, government subsidy kept the price of urea artificially low, which encouraged its overuse leading India to achieve self-sufficiency in food production. This, however, created an imbalance in the nutrient composition of the soil. Reduced subsidies on P and K (causing higher prices) discouraged farmers to use these fertilizers, compared to urea, which eventually deteriorated the overall soil nutrient balance and productivity. The subsidy policy has also created an enormous budget provision for the disbursement of the fertilizer subsidy. For example, in 1990/91 the total amount for government fertilizer subsidy which was INR 4.389 billion (USD 686 million), increased to INR 13.244 billion in 2000/01, and further increased to INR 100 billion in 2011/12. It is estimated that the subsidy will increase to INR 1.07 trillion (USD 1.88 billion) in 2014/15. In 2010 the government replaced the old fertilizer policy with the nutrient-based subsidy (NBS) with the aim of eliminating the problem of soil degradation and improve the production of food grains and soil conditions. Although fertilizer subsidy policies have played a significant role in farmers' consumption of fertilizer and raised the yield per acre, research exploring factors that influence the demand for fertilizer is very limited. The current study attempts to fill this void by estimating a demand function for fertilizer and identifying the main factors that influence the demand using data exclusively from the deregulation era (1991–2012).

BACKGROUND

The consumption of fertilizers has been increasing steadily in the post-reform era after 1990/91 when consumption increased from 12.54 million tons to 25.80 million tons in 2012. Increased use of fertilizer made India the second largest producer of wheat, rice, cotton, sugarcane, and groundnuts (Salunkhe and Deshmush 2014). However, the intensity of fertilizer use varies across states and regions. For example, the intensity of fertilizer use in Rajastan is 48 kg/ha while the intensity for Punjab is 237 kg/ha (Jaga and Patel 2012). There are several price and non-price factors that influence the demand for fertilizer including government pricing policies for agricultural commodities. Most of the studies analyzing the demand for fertilizer used pre-reform data (Raju 1989; Kundu and Vashist 1991; Sharma 1993; Subramaniyan and Nirmala 1991; Schumacher and Sathaye 1999). Fertilizer policies such as decontrolling DAP/complex fertilizer and SSP in 1992, which abolished the subsidy; the New Policy Scheme (Stage I [2003–2004], Stage II [2004–2005], and Stage III [2006–2010]); and NBS had significant impact on fertilizer demand in the post-reform era. Under the NBS, the government sets a uniform subsidy per nutrient (NPK and S) for all decontrolled fertilizers and producers have the freedom to set the MRP. For example, producers may offer a discount to their dealers for products not covered by the subsidy; the government then decides the profit margins for distribution channel members (Pathak, Dubey, and Pandey 2014). From June 2013 the government decided to set reasonable MRPs (for NPK and S) prohibiting all manufacturers from charging prices higher than the MRP (Gupta 2014). Rice is the most subsidized crop, followed by wheat, sugarcane, and cotton. These four crops account for two-thirds of total fertilizer subsidy.

Historically, fertilizer consumption in India has always exceeded domestic production in both N and P fertilizers leading to India's dependency on imports. During the last two decades, imports have increased by 500 percent (i.e., imports increased from 2.75 million tons in 1991 to 13 million tons in 2010). The demand for fertilizer is a derived demand which is determined by the final demand for agricultural products, hence, the price of agricultural products also influence the demand for fertilizer. Due to the complex fertilizer subsidy policy, a farmer's demand for fertilizer is less likely to be influenced by its price. It is hypothesized in this study that non-price factors would have more impact on demand than the price of fertilizer. Venkatesan and Arulraj (2014) and Jaga and Patel (2012) used a simple linear regression model and estimated the demand for fertilizer using time-series data. Sharma and Thaker (2011) used time series data to examine the major determinants of fertilizer demand and found that non-price factors are more important than the price of fertilizer affecting farmers' demand. Some of the explanatory variables used in past studies are price of fertilizer, price of wheat and rice, cropping intensity, availability of institutional credit, etc. Jaga and Patel (2012) found that among non-price factors, irrigation is one of the most important factors that influence demand for fertilizer. The authors also found that increased cropped area under HYVs increases fertilizer use. Their study suggested that in order to increase fertilizer consumption the government should increase investment in irrigation, agricultural research and development, extension services, and infrastructure. Sharma and Thaker (2011) found that HYVs and irrigation are more important factors influencing demand for fertilizer than price and recommended that the government policy should be geared toward availability of fertilizer at an affordable price.

THE MODEL

Following Venkatesan and Arulraj (2014), Jaga and Patel (2012), and Sharma and Thaker (2011) the empirical analysis in this study uses a simple linear regression equation for fertilizer demand estimation. Unlike the abovementioned studies, this study uses log transformation of the dependent variable while explanatory variables are at level. The equation is as follows:

$$\log(Y) = \beta_1 + \beta_2 P_{fert} + \beta_3 P_{RW} + \beta_4 GIA + \beta_5 HYV + \beta_6 PRO + \beta_7 INSCR + \beta_8 SUB + \varepsilon \quad (1)$$

where:

Y	=	total fertilizer consumption (demand) per year (N+P+K)
P_{fert}	=	weighted average price of fertilizer (N+P+K)
PRW	=	weighted average price of rice and wheat
GIA	=	percent of gross irrigated area to gross cropped area
HYV	=	gross area cultivated under HYV
PRO	=	total production of fertilizer
INSCR	=	availability of short-term institutional credit to farmers per hectare of gross cropped area
SUB	=	amount of fertilizer subsidy distributed by the government (per year)

It is hypothesized that the coefficient of the price of fertilizer would be negatively related to demand and all other explanatory variables would be positively related to the dependent variable. Based on past studies, it is also expected that the price variable may not be one of the most important parameters for farmers' decision on buying fertilizer. This is because there are significant changes in government subsidy policies in the post-reform era (period under study), hence, some other non-price factors might have stronger influence on the demand for fertilizer.

The Dataset

The macro-level time-series data covering 22 years (1991–2012) used for the regression analysis were collected from various published reports by the government of India (GOI) and the Ministry of Agriculture and Ministry of Chemicals and Fertilizers.[1] The descriptive statistics for the variables used in the regression analysis are reported in Table 1.

RESULTS

Initially, several non-price explanatory variables such as cropping intensity and national average rainfall were included in the regression equation but were dropped later due to unexpected signs and/or because they were statistically insignificant. Several functional forms (e.g., Cobb-Douglas) were tested but the linear form with log transformation on the dependent variable fits the data best. Variables that are included in the final model are reported in Table 2. The coefficients on GIA, FERPRO, FERSUB, and INSCR are highly significant and have expected signs. Similar results were obtained by Narayanan (2015) and Sharma and Thaker (2011). For example, higher percent of gross irrigated area, higher production of fertilizer, higher subsidy, and higher institutional credit would increase demand for fertilizer.

Unlike studies by Jaga and Patel (2012) and Sharma and Thaker (2011), this study found that the coefficient of the price of rice and wheat

1 These sources include Annual Report 2013-14 of the Department of Agriculture and Cooperation, Ministry of Agriculture; Indian Fertilizer Scenario 2013 of the Department of Fertilizer, Ministry of Chemicals and Fertilizers; Annual Review of Fertilizer Production and Consumption: Highlights 2013-14 of the Fertilizer Association of India; and Agricultural Statistics 2013.

Table 1. Descriptive statistics for the variables analyzed in the study (1991–2012)

Variables	Mean	Min	Max	SD
Consumption of fertilizer (million tons) (CONS)	18.03	12.15	28.12	4.92
Gross irrigated area as a percent of gross cropped area (GIA)	41.04	34.03	45.52	3.43
Weighted average price of rice and wheat (PRIRW) (INR/1,000 kg)	250.68	210.00	1,168.00	276.95
Flow of institutional credit (INSCR) (INR trillion)	1.345	0.0728	5.110	1.562
Fertilizer production (million tons)	13.40	9.04	16.38	2.50
Fertilizer imports (million tons)	4.79	1.67	13.00	3.44
Fertilizer subsidy (trillion INR)	24,277	4,389	99,495	27,046
Fertilizer price (INR/1,000 kg)	6,561	1,660	12,381	2,778
Gross area cultivated under HYV (million ha) (HYV)	159.82	48.50	364.840	119.712
Crop Intensity (CROPI) (percent)	134.24	128.67	142.120	3.53

Note: Approximate exchange rate for Indian currency (INR) USD 1 = INR 60; USD 1,600 = INR 100,000; USD 160,000 = INR 1 trillion

Table 2. Regression results, dependent variable = Log (fertilizer consumption)

Description of Variables	Coefficient	*t*–statistic
Constant	1.3030	4.689*
Percent of gross irrigated area (GIA)	0.0253	2.450*
Average price of rice and wheat (INR/1,000 kg) (PRIRW)	–0.0003	–1.239
Gross area cultivated under HYV (HYV)	–0.0002	–0.794
Total production of fertilizer (FERPRO)	0.0387	2.704*
Fertilizer subsidy (trillion INR) (FERSUB)	0.0001	2.406*
Flow of institutional credit (INSCR)	0.0001	2.815*
Price of fertilizer (INR/1,000 kg) (FERPRI)	0.0004	0.385
R-squared	0.9840	n/a
F-statistics	123.03	n/a
D-W Statistics	2.25	n/a

Note: *significant at $p<.05$; n/a = not applicable

(PRIRW) and fertilizer price (FERPRI) were insignificant. The author would like to argue that the insignificant coefficient of the price variable might be due to the fact that subsidy policies in the post-reform era impacted more on farmers' consumption decisions than the price of fertilizer. This assertion is strengthened by the fact that the coefficient of the subsidy variable (FERSUB) is positive and significant. Further, it is observed from the raw data that the gap between domestic production and consumption of fertilizer is largely met by imports.[2] The price of such imports are set by a handful of countries in the world market and the government makes adjustments to its subsidy policy to counterbalance the import price fluctuations. This is because the domestic production of P and K fertilizers is independent of the imported price of the feedstock. In order to check the rationality for such assertion, a separate regression equation was estimated using Equation 2 where production of fertilizer is regressed on subsidy, imports, and price of fertilizer. The results (Table 3) show that the coefficients for both fertilizer subsidy and fertilizer imports have no significant influence on the production of fertilizer, intuitively implying that domestic production of P and K fertilizer appears to be independent of the imported price of feedstock, as one reviewer pointed out. However, we need to remember that the fertilizer production data includes all (N+P+K) fertilizers.

$$FERPRO + \beta_1 + \beta_2 FERIMP + \beta_3 FERSUB + \beta_4 FERPRI + \varepsilon \quad (2)$$

As a result, it is expected that the demand for fertilizer is mostly dependent on the domestic production, import, and subsidy policies. This happened when government changed its subsidy policy from cost-push approach to import parity policy during the reform era after 1991. In an effort to examine this hypothesis further, the study estimated another regression equation presented below:

$$\log(CONS) = \beta_1 + \beta_2 FERPRO + \beta_3 FERIMP + \beta_4 FERSUB + \beta_5 FERPRI + \varepsilon \quad (3)$$

Except for the coefficient of fertilizer price (FERPRI), all three independent variables have the expected sign and are highly significant (Table 4). The results from this regression confirm that the fertilizer price is not a major determinant of farmers' demand for fertilizer. Since the government subsidy policy is mainly geared toward farmers' affordability, this encouraged more use of fertilizer on the one hand, while creating an environment for fertilizer manufacturing firms to increase production, on the other. Further, an attempt is made in this study to investigate whether the government subsidy payments are dependent on fertilizer imports and domestic price of fertilizer. The regression equation estimated is as follows:

$$FERSUB = \beta_1 + \beta_2 FERIMP + \beta_3 FERPRI + \varepsilon \quad (4)$$

The coefficients of fertilizer import (FERIMP) and fertilizer price (FERPRI) are positive and highly significant (Table 5). This implies that an increase in volume of imports and price of fertilizer would increase government subsidy payments. The results are consistent with the primary goal of government subsidy policy. For example, the main purpose of fertilizer subsidy is to reimburse the fertilizer manufacturers

2 Sharma and Thaker (2009) mentioned that 97.4 percent of world export of potash is controlled by Canada, Belarus, Russia, Germany, Israel, and Jordan while 88.4 percent of world export of monoammonium phosphate and DAP are controlled by the same countries.

Table 3. Regression results, dependent variable = fertilizer production

Description of Variables	Coefficient	*t*-statistic
Constant	7.786	6.111*
Fertilizer import (million tons) (FERIMP)	–0.218	–0.821
Fertilizer subsidy (trillion INR) (FERSUB)	–0.000	–0.484
Fertilizer price (INR/1,000 kg) (FERPRI)	0.001	3.935*
R-squared	0.6469	n/a
F-statistic	10.99	n/a
D-W Statistics	1.28	n/a

Note: *significant at p<.05; n/a = not applicable

Table 4. Regression results, dependent variable = Log (fertilizer consumption)

Description of Variables	Coefficient	*t*-statistic
Constant	1.881	33.534*
Fertilizer production (million tons) (FERPRO)	0.582	9.843*
Fertilizer import (million tons) (FERIMP)	0.019	2.909*
Fertilizer subsidy (trillion INR) (FERSUB)	0.000	2.295*
Price of fertilizer (INR/1,000 kg) (FERPRI)	0.000	0.850
R-squared	0.9763	n/a
F-statistics	217.79	n/a
D-W Statistics	1.62	n/a

Note: *significant at p<.05; n/a = not applicable

Table 5. Regression results, dependent variable = subsidy

Description of Variables	Coefficient	*t*-statistic
Constant	–21571.46	–3.517*
Fertilizer import (million tons) (FERIMP)	4835.36	3.985*
Fertilizer price (INR/1,000 kg) (FERPRI)	3.45	2.300*
R-squared	0.8773	n/a
F-statistics	67.94	n/a
D-W Statistics	1.78	n/a

Note: *significant at .05 level; n/a = not applicable toward the high cost of imported feedstock and help the farmers by making fertilizers affordable.

SUMMARY AND CONCLUSION

With the rising demand for fertilizers, it is imperative for the Indian government to construct subsidy policies that encourage a sustainable and environment-friendly agricultural growth. This study made an attempt to estimate a demand function for fertilizers and explore the impact of various non-price factors on demand. Unlike past studies, this study used data entirely from the post-reform era (after 1991) and captured the impact of recent government subsidy policies and other non-price factors on the rising demand for fertilizer. Regression results from Equation 1 found that non-price factors have a strong and positive effect on farmers' demand for fertilizer. Contrary to conventional wisdom, this study found that the price of fertilizer is not a major determinant of the demand for fertilizer. The results from the second regression equation suggest that the production of fertilizer is independent of the import price of P and K feedstocks. The results from the third regression equation found that the consumption of fertilizer is strongly and positively related to domestic production, imports, and subsidy. It is evident from the fourth regression equation that the government subsidy payments are strongly and positively related to the volume of imports and price of fertilizers. This implies that an increase in the import of feedstock and an increase in the domestic price of fertilizer would prompt the government to raise subsidy payments on fertilizers. These findings are consistent with the historical trend in the data. No other studies in the past have attempted to uncover this fundamental relationship among subsidy payment, import of feedstock, and the price of fertilizer which is the core of various current government subsidy policies.

LIMITATIONS

The results from this study will provide some valuable insights to policy makers. For example, higher use of fertilizer is dependent more on non-price factors such as subsidy, domestic agricultural production, gross irrigated area, and availability of institutional credit and less on the price of fertilizer. In order to increase agricultural production, government subsidy policies should be geared more toward the use of balanced nutrients and improved soil conditions while providing incentives to fertilizer manufacturers to develop new environmentally-sustainable products for agriculture.

One of the major limitations of this study is the availability of consistent and reliable data sources for conducting a time-series study. There are some discrepancies in some of the data series collected from multiple sources, which might be the cause for the insignificant price coefficients for two regression equations. One other problem found in this study is non-availability of reliable information/data on fertilizer price for the current study period. The primary data on the maximum retail price for complex fertilizers over a period of 22–25 years are not directly available to the author, hence, this study relied upon a few secondary sources.

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