Analyzing Energy Efficiency of Indian Fertilizer Industry: Evidence from Select Fertilizer Plants

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***Abstract*—Fertilizer industry is one of the most energy intensive industries in the country. Government of India has taken steps for a more efficient use of energy resources, with two main policies aimed specifically at achieving greater efficiency in energy use, viz., Perform-Achieve-Trade (PAT) scheme and New Pricing Scheme. The objective of this paper is to do a plant level analysis of the effect of these policies, along with other control variables, on the energy intensity of fertilizer industry. A fixed effects model is estimated for a sample period of 2006-07 to 2017-18. 28 out of 29 plants identified by the Bureau of Energy Efficiency for the implementation of the PAT scheme have been used in the study. Broadly the results show that PAT Cycle-I has helped to improve the energy intensity of the fertilizer plants. The other explanatory variables have the expected signs. The fertilizer industry has surpassed the energy saving target under PAT scheme, set by the Bureau of Energy Efficiency.**

***Index Terms*—Energy intensity, fertilizer plants, India, perform achieve and trade, new pricing scheme.**

I. Introduction

Energy is one of the primary inputs needed to achieve rapid growth of an economy. A developing country like India is highly dependent on energy as a resource in various sectors, especially the industrial sector. As per the World Bank data, the cumulative rate of growth of energy use in India for the period 2006-2014 was 3.52%. But if the dependence is on non-renewable energy like fossil fuels, then it has its own drawbacks. Fossil fuels are highly emission intensive and release greenhouse gases like carbon dioxide that damages the environment. In India the cumulative rate of growth of fossil fuel energy consumption as a percentage of total energy consumption was 1.08% for the period 2006-2014 [1]. Therefore, the objective should be to use energy resources efficiently without compromising the process of economic growth.

In India, the industrial sector is the highest consumer of energy. It accounted for 56% of the total energy consumption in the country in 2018-19 [2]. But what is more important is how efficiently energy was used by the industrial sector? There are different ways to measure efficiency in energy use. One of the ways is energy intensity. Energy intensity is a "single, simple, easy-to-compute, summary measure of the efficiency with which energy is utilized" [3]. In the Indian case, the Energy Statistics, Ministry of Statistics and Programme Implementation, Government of India defines energy intensity as the amount of energy consumed for generating one unit of Gross Domestic Product (at constant prices). It is one of the most frequently used policy indicators, the other being per capital energy consumption [2].

This paper considers energy intensity as a measure of efficiency in energy use in the industrial sector. In the past, in order to improve the energy intensity of the industrial sector, the Government of India has taken certain noteworthy steps that include penalties for non-compliance. Energy Conservation Bill was proposed in 1997 and the Energy Conservation Act was formed in October 2001 [4]. In order to implement various regulations of the Act, the Bureau of Energy Efficiency (BEE) was created in 2002. The objective of BEE was to reduce the energy intensity of the economy through various market-based instruments. The Perform-Achieve-Trade scheme targeted specifically for the energy intensive industries, introduced tradable energy saving certificates. Some other countries have also used various energy efficiency policies to save energy, like, Energy Efficiency Drive for European Union, Energy Performance of Buildings Directives, Energy Labeling Regulation, etc [5].

In the Indian case, one of the industries identified under the PAT scheme is the fertilizer industry. It is one of the most energy intensive industries of the country and also one of the most important as it is directly integrated with the agricultural sector. Energy is consumed in the form of natural gas, naphtha, fuel oil, low sulphur heavy stock and coal. India produces three types of fertilizers, viz., Straight Nitrogenous fertilizers which includes Urea, Straight Phosphatic fertilizers and Complex fertilizers. Out of these, energy consumption is the highest for urea, with the cost varying between 65% - 87% of production cost. Therefore, BEE has identified urea plants for the implementation of the PAT scheme.

The objective of this paper is to estimate the effect of two main policies on the energy intensity of the fertilizer plants, viz., the Perform-Achieve-Trade (PAT) scheme and the New Pricing Scheme-III (NPS-III) scheme. The paper uses plant level data to evaluate the effect of the two polices and other control variables on the energy intensity of fertilizer plants for a sample period of 2006-07 to 2017-18 (financial year)[1] and the time taken for the energy intensity of the fertilizer plants to become half of its current value to. It is a panel data regression with fixed effects model used in the analysis. The paper also estimates the energy saved by the fertilizer plants. Broadly, using an exponential model, the econometric results show that the half-life of the energy intensity will be reached in approximately 84 years.

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[1]The financial year in India is from April 1 to March 31.

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Regression results show that energy intensity is lower for the years the PAT scheme was implemented. But NPS-III does not have a statistically significant effect on energy intensity. Energy intensity is also found to be lower for the plants that use natural gas as feedstock, as compared to the firms that use other fuel. Finally, the paper finds that the fertilizer industry saves more energy than its assigned target of 0.478 million tonnes of oil equivalent (million toe). It achieves a total energy saving of 6.103 million toe, which is 5.625 million toe higher than the target energy saving.

In the literature a number of studies have been undertaken to assess the factors influencing energy intensity of various countries. The effect of energy consumption, GDP and FDI on CO_2 emissions in BRIC countries is estimated with a test for Granger Causality between these variables for the period 1980-2007 [6]. Indonesian manufacturing is studied to test if FDI diffuses energy saving technology into the host country [7]. The paper uses firm level panel data for 1993-2009. The effect of indigenous R&D on the energy intensity of Chinese industries is analysed by estimating a double log model to evaluate the effect of domestic research and development activities, and other control variables like technological progress, and FDI inflow on energy intensity ([8], [9]). Results show that R&D activities have a greater effect if they are in the developmental stage, than basic stage and if they have been undertaken by industries, rather than educational institutions. There have been similar effects of corporate R&D on energy intensity [10]. Fixed effects model is used to estimate the effect of various factors, like R&D, firm size, age of the firm, etc. influencing energy intensity of Indian industries [11].

This study is different from the other India based papers because none of the other papers have done a plant level analysis to estimate the effect of the PAT scheme and NPS-III on energy intensity of fertilizer industry. This study also uses various other classifications to compare energy intensity within the fertilizer sector, like feedstock used and ownership of plants. Also, none of the other studies on Indian fertilizer industry have estimated the time taken for energy intensity to become half of its present value.

The rest of the paper is organised as follows. Section II briefly explains the PAT and NPS-III schemes. Section III gives a background of select fertilizer firms that are together responsible for meeting approximately 52% of the total target under the PAT scheme. The variables used in the study and their data sources have been outlined in section IV. The econometric methodology followed in the paper has been explained in section V. Section VI presents the empirical results from the study and section VII summarizes and concludes the results of the study.

II. What Is the NPS-III Policy And the PAT Scheme?

Out of the three types of fertilizers used in India, urea, which is a straight nitrogenous fertilizer, is produced indigenously. For the other variants, either indigenous capacity is not fully developed or fertilizer is imported for direct application. Therefore, energy consumption is the highest for urea production. The New Pricing Scheme (NPS) was started in 2003 with the objective to use more efficient feedstock technology in the production process. Urea plants were given pre-set energy consumption norms. If the actual energy consumption of the plant was lower than the norm, the difference would be paid as per the basic rate of the weighted average of feedstock used [12]. The plants were grouped into six categories as per their year of incorporation and the feedstock used in the fertilizer plants (this is as per the Gokak Committee report). Four main types of feedstock are used in the production of urea, viz., natural gas, naphtha, fuel oil or low sulphur heavy stock fuel (FO/LSHS) and mixed feedstock (natural gas-based plants with consumption of naphtha or FO/LSHS more than 25% of total energy consumption). The six groups were: Pre-92 gas based plants (set up before 1992 and used natural gas as feedstock), Post-92 gas based plants (gas based plants set up after 1992), Pre-92 naphtha based plants (set up before 1992 and used naphtha as feedstock), Post-92 naphtha based plants (naphtha based plants set up after 1992), FO/LSHS based plants and Mixed feedstock based plants. The urea plants set up before 1992 were less energy efficient and required greater capital investment to improve technology. The plants set up after 1992 were more energy efficient. NPS was implemented in three stages on these six categories: NPS-I (April 2003 to March 2004), NPS-II (April 2004 to September 2006), NPS-III (October 2006 to March 2010. But it was extended up to March 2014 till a new scheme came into effect) and Modified NPS-III (April 2014 to march 2015).

The other government policy is the PAT scheme. The National Mission for Enhanced Energy Efficiency defines Perform-Achieve-Trade (PAT) scheme as a market based mechanism to enhance cost effectiveness of improvements in energy efficiency in energy-intensive large industries and facilities through certification of energy savings that could be traded [13]. PAT cycle-I runs from April 2012-March 2015. Under this scheme, the Ministry of Power and BEE identified eight most energy intensive industries, viz., Thermal Power Plants, Fertilizer, Cement, Pulp and Paper, Textiles, Chlor-Alkali, Iron and Steel and Aluminium. Within each industry, the most energy intensive plants were identified and called designated consumers. These were plants with annual energy consumption greater than the threshold level for the respective industry. The plants were given specific energy consumption targets to be achieved by the end of the implementation period of 2014-2015. If the plant met the assigned target, it would be given a tradable energy saving certificate. Otherwise, it would have to buy an energy saving certificate to undertake further production.

BEE has identified 29 plants as designated consumers from the fertilizer industry. The aim is to achieve energy saving target of 0.478 million toe under the first PAT cycle [13]. The minimum annual energy consumption by the designated consumers in this sector is 30000 toe. Of the total energy saving target for the eight industries, 7.15% of the target has to be met by the fertilizer industry. This target is then divided among the various designated consumers of the fertilizer industry.

III. Background of Select Fertilizer Firms

The distribution of PAT targets to be met by individual plants is quite skewed. Almost 52% of the burden of reducing the energy intensity by end of the target year lies with three firms, viz., Brahmaputra Valley Fertilizers Corporation Ltd. (BVFCL), National Fertilizers Ltd. (NFL) and Indian Farmers Fertilizer Cooperative Limited (IFFCO). NFL and IFFCO also have the highest number of plants identified by BEE (5 plants each), followed by BVFCL with 2 plants. The success of the PAT scheme for the fertilizer industry will depend substantially on the ability of these firms to meet their targets.

The highest energy intensity target among the three firms is for BVFCL. It has two plants – BVFCL –Namrup III, which is a pre-92 gas-based plant and BVFCL –Namrup II, which is a mixed feedstock based plant. Both these plants have been singled out as outliers by BEE and assigned target reduction of approximately 12% each [14]. The energy intensity (toe/tonne of urea) is the highest for BVFCL as compared with the average energy intensity of NFL and IFFCO (Fig. 1).

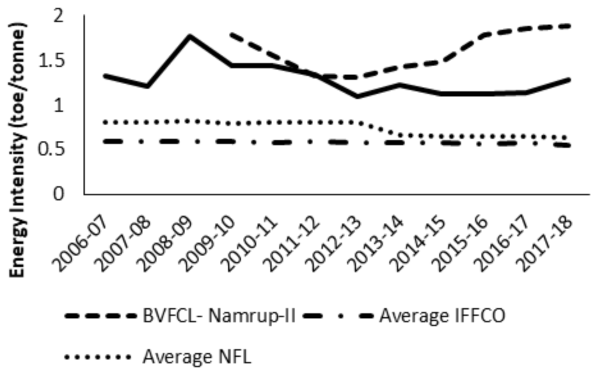

Fig. 1. Energy Intensity (toe/tonne of urea) for BVFCL.
Source: Indian Fertilizer Scenario (various years) & Own Calculations

Both the BVFCL plants have suffered from technological problems and have very low capacity utilisation. It is less than 60% for most years. These plants not only have high target reduction under PAT scheme, but also the highest pre-set energy consumption norms under NPS-III. The average pre-set energy consumption norms under NPS-III lies between 9.5 Gcal/MT of urea (average of FO/LSHS based plants) and 5.6 Gcal/MT of urea (average of post-92 gas-based plants) (this is equal to 0.949 toe/tonne and 0.559 toe/tonne[2] approximately). But for BVFCL-Namrum II and Namrup III it is at 12.6 Gcal/MT of urea and 12.7 Gcal/MT of urea respectively (which is equal to 1.26 toe/tonne and 1.27 toe/tonne respectively).

The five plants from IFFCO are IFFCO Phulpur-I, IFFCO Phulpur-II, IFFCO Aonla-I, IFFCO Aonla-II and IFFCO Kalol. As evident from Fig. 2, energy intensity is the highest for IFFCO Phulpur-I, which is a pre-92 naphtha based plant. The pre-set energy consumption norm was also the highest for this plant at 7.6 Gcal/MT of urea or 0.759 toe/tonne of urea. IFFCO Kalol, which is a mixed feedstock based plant and is the oldest among the five IFFCO plants (established in 1975), has the second highest energy intensity. But the energy intensity of this plant has been declining since 2008-09 as it has undertaken numerous modernization and modification measures [14].

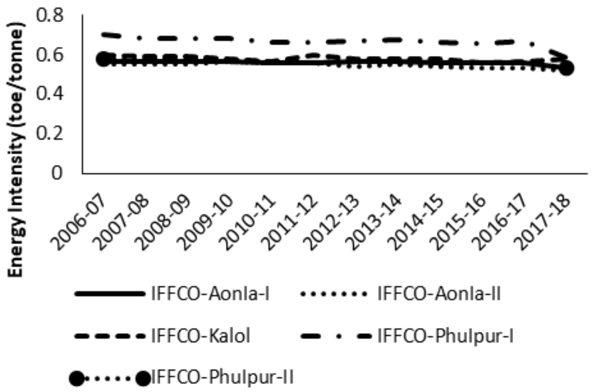

Fig. 2. Energy Intensity (toe/tonne of urea) for IFFCO.
Source: Indian Fertilizer Scenario (various years) & Own Calculations

The energy intensity of the remaining three IFFCO plants is almost similar. IFFCO Aonla-I and Aonla-II are pre-92 and post-92 gas based plants and have lower energy intensity mainly due to the feedstock used. Aonla-II plant has an additional advantage of being established after 1992. This was the period of maximum technological development in the production of urea. Plants established during this period were natural gas based and had much lower energy intensity due to the period of development. The pre-set energy consumption norm was also the lowest at 5.5 Gcal/MT of urea 0.549toe/tonne of urea. IFFCO Phulpur-II is a post-92 naphtha based plant, but has converted to natural gas. This has helped in achieving low energy intensity and a low pre-set energy consumption norm at 5.9 Gcal/MT of urea (0.589 toe/tonne). Therefore, all the five IFFCO plants are either natural gas based or have converted to the same and the reduction target under PAT is also close to 1% for these plants.

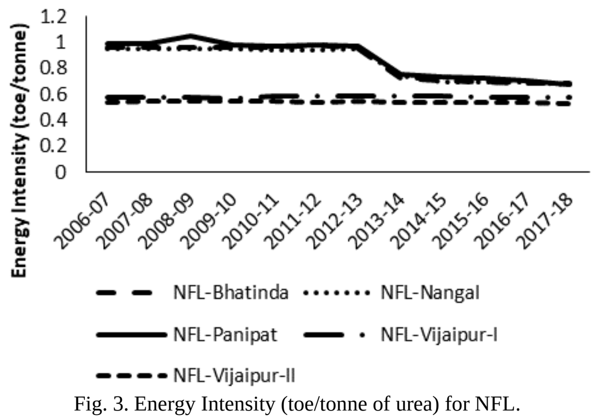

Fig. 3. Energy Intensity (toe/tonne of urea) for NFL.
Source: Indian Fertilizer Scenario (various years) & Own Calculations

NFL has five plants identified by BEE, viz., NFL-Panipat, NFL-Bhatinda, NFL-Nangal, NFL-Vijaipur-I and NFL-Vijaipur-II. The capacity utilisation for all the plants is more than 100%. The first three plants are FO/LSHS based plants, Vijaipur-I plant is pre-92 gas based plant and Vijaipur-II is post-92 gas based plant. As per PAT, the target reduction from the baseline year is 2.7% and 1% respectively for the two Vijaipurgas based plant. For the three FO/LSHS based plants, the target reduction is 22%, 24% and 25%

[2]Using conversion factor 1Gcal = 0.099933123 toe.

Ministry of Power, Government of India, “Normalization Document and Monitoring & Verification Guidelines Fertilizer Sector”, 2015, New Delhi gives the figures in Gcal/tonne. It is converted to toe/tonne to make it compatible with the data used in the paper.

respectively [14]. The pre-set energy consumption norms under NPS-III is also high for these plants at 9.7 Gcal/MT of urea, 10.2 Gcal/MT of urea and 9.5 Gcal/MT of urea respectively (which converts to 0.969 toe/tonne, 1.02 toe/tonne and 0.949 toe/tonne respectively). As seen from Fig. 3 below, the energy intensity of the gas-based plants, viz., NFL-Vijaipur-I and NFL-Vijaipur-II, is much lower than the FO/LSHS based plants. As per the PAT document on the fertilizer sector, the three FO/LSHS based plants are in the process of converting to natural gas, which will improve energy efficiency. There has been a sharp decline in the energy intensity post 2011-2012 for these three plants.

IV. Description of Variables and Data Sources

The paper uses plant level to estimate the effect of the two policies, PAT and NPS-III, and various control variables on the energy intensity of fertilizer plants and fertilizer firms. Energy intensity, defined as the amount of energy used per unit of output produced, is one of the most frequently used policy indicators both at national and international levels [2]. Therefore, this paper also uses it as an indicator of how efficiently energy is being utilised by the fertilizer industry and takes it as the dependent variable. A number of studies on India have defined energy intensity in monetary units ([11], [15], [16]). But this paper defines energy intensity in physical units as defined by BEE [13] as follows:

EI = (Energy consumed (toe))/(Production (tonnes))

Energy consumed is defined as energy consumption achieved during the year by the urea plants, measured as tonnes of oil equivalent (toe). Production is defined as the urea output measured in tonnes. Energy Intensity (toe per tonne of output produced) is the dependent variable in the fixed effects model.

The paper uses the following regressors to capture the effect of PAT, NPS-III and other control variables:

PATyear is a year dummy that takes value 1 for the compliance years of the PAT scheme, i.e., 2012-13 to 2014-15 and takes value 0 for the other years i.e., 2004-05 to 2011-12 and 2015-16 to 2017-18.

New Pricing Scheme dummy (*NPS-III*) - Government of India started the New Pricing Scheme for urea in April 2003 to provide subsidies to urea manufacturers based on feedstock used and the age of the plant. The plants were assigned pre-set energy consumption norms. In this paper, since the sample period starts from 2006-07, *NPS-III* is defined to take value 1 for the years 2007-08 to 2014-15 and 0 otherwise.

Per unit subsidy –Government of India pays subsidy to the producers of urea (in Rs crores). The variable is defined as subsidy paid per unit output produced. A rise in per unit subsidy paid will improve the energy intensity of the plants because it will give more funds to the producers to invest in improving the efficiency of production.

Per unit capacity utilisation - Capacity of a plant is the total output that can be produced by the plant, using all the available resources. If the plants produce beyond its capacity, then the average cost of production will start rising. Traditionally, capacity utilisation has been defined as the ratio of the current output produced (in tonnes) to maximum potential output of a firm [17]. Greater capacity utilisation will help in better utilisation of all resources, including energy, and will help to reduce the per unit energy used.

Plants using natural gas as feedstock (*Gas-based plants*) – This is a dummy variable that takes value 1 if the plants use natural gas as feedstock and 0 otherwise. The plants that use natural gas as feedstock are more energy efficient than the plants using other fuel like naphtha, FS/LSHS. In various notifications issued by the Government of India (Indian Fertilizer Scenario, Government of India, various years), the plants not using gas have been asked to convert to natural gas within a stipulated time period. Failure to convert to natural gas would lead to reduction in the subsidies paid to these plants (Indian Fertilizer Scenario, Government of India, various years). On an average the gas-based plants are expected to use less energy per unit of output produced than the non-gas based plants.

Plants that belong to the firms BVFCL, IFFCO and NFL (*BIN firms*) – This is a dummy variable that takes value 1 if the plant belongs to one of the BIN firms, and 0 otherwise. These plants are more energy intensive than the other plants. Out of the total target under the PAT scheme, approximately 52% has to be met by the plants from the BIN firms. On an average, plants from the BIN firms use more energy per unit of output produced.

Ownership of the firm (*Ownership*) - This is a dummy variable that takes value 1 if the firm is a government enterprise (this includes firms belonging to Central government, State government, Co-operative sector) and 0 if the firm is a private enterprise. This is to see if organisation type has any relationship with energy intensity.

All variables, except the dummy variables, are in logarithms. The plant level data on energy consumption (Gcal/MT), production (‘000 MT), capacity (‘000 MT) and subsidy (Rs. Crores) has been taken from Indian Fertilizer Scenario (various years). Data on energy consumption has been converted to tonnes of oil equivalent per tonne of output produced (toe/tonne) to make it comparable with the PAT target published by BEE. Production and Capacity in thousand tonne has been converted to tonnes. The Ministry of Power, Government of India’s Perform-Achieve-Trade document published in July 2012 is used to identify the names of fertilizer plants identified by BEE.

V. Econometric Methodology and Model Specification

The paper uses an exponential model to estimate the growth rate of energy intensity overtime and the effect of other independent variables on energy intensity. The exponential model to estimate the growth rate of energy intensity is estimated as

$$EI(t) = (EI_0)(b)^{\text{time}} \qquad (1)$$

where EI_0 is the initial value of energy intensity

Taking natural logarithms on both sides, the model becomes

$$\ln(EI) = \ln(EI_0) + \text{time} * \ln(b)$$

$$\ln(EI) = \alpha+\beta{*}\text{time where } \alpha = \ln(EI_0) \text{ and } \beta = \ln(b)$$

This is also called the semi-log or growth model. The coefficient of time, β, is the instantaneous rate of growth or the annual rate of growth of energy intensity.

Let time t^* be the time taken for energy intensity to become half of its initial value EI_0, i.e., the time it takes for Let t^* be the time taken for energy intensity to become half of its initial value EI_0, i.e., the time it takes for energy intensity to become half. Mathematically this can be written as

$$EI(t^*) = (EI_0)(b)^{t^*} \quad (2)$$

Since it is half of the initial value,

$$EI(t^*) = (EI_0)^*(1/2) \quad (3)$$

Equating equations (2) and (3) will give

$$(EI_0)(b)^{t^*} = (EI_0)^*(1/2)$$

$$b^{t^*} = (1/2)$$

Taking logarithms on both sides

$$t^* \ln(b) = \ln 1 - \ln 2$$

$$t^* = -(\ln 2 / lnb)$$

Next, the paper estimates the effect of various independent variables on energy intensity. A fixed effects model is estimated to control for time invariant effects that differ across firms but remain constant overtime, to take care of any omitted variable bias and time variant effects. The sample period is from 2006-07 to 2017-18. The fixed effects regression is:

$$\ln(EI_{it}) = \alpha_i + \lambda_t + \beta_0 + \beta_1(PAT\text{year}) + \beta_2(NPS\text{-}III) + \beta_3\ln(\text{Per unit subsidy})_{it} + \beta_4\ln(\text{Capacity utilization})_{it} + \beta_5(\text{Gas-based plants}) + \beta_6(\text{BIN firms}) + \beta_7(\text{Ownership}) + \mathcal{E}_{it}$$

where i represents fertilizer plants and t represents year. α_i and λ_t are time invariant plant and year fixed effects respectively. $\ln(X_{it})$ is the log of the independent variables that influence energy intensity.

The paper also calculates the actual energy savings by the fertilizer industry, based on the energy intensity at the end of the target period of PAT scheme, in the following way:

Energy consumption for target year (toe) =
(*EI* in target year)*(Production in baseline year)

where *(EI in target year)* is the specific energy consumption (toe per tonne) for the target year 2014-15 given by BEE for each designated consumer. *(Production in baseline year)* in tonnes is the output produced in the baseline year. The baseline year is the average of three years 2007-2010. The data has been taken from the document PAT, Ministry of Power, Government of India, 2012 [13].

The implementation period for PAT Cycle-I ended in 2014-15. The actual energy consumption in the year 2015-16, just after the PAT Cycle-I ended, is calculated as:

Energy consumption in 2015-16 (toe) =
(*EI* in 2015-16 (toe/tonne))*(Production in 2015-16 (tonne))
Therefore, energy saving by the fertilizer industry is
Energy Saving (toe) =
(Energy consumption in 2015-16)- (Energy consumption for target year)

VI. Empirical Results

Table I summarizes the number of observations, mean value, standard deviation and maximum and minimum values of the dependent and independent variables used in the study. The maximum and minimum values of each variable will indicate whether there are extreme values or not in the data and the standard deviation indicates dispersion around the mean value. Comparing the number of observations across variables will indicate the number of missing observations in the data.

TABLE I: Summary Statistics for Fertilizer Plants

Variables	Obs	Mean	Std. Dev.	Min	Max
Energy Intensity	324	0.681	0.243	0	1.890435
PAT year	324	0.250	0.434	0	1
NPS-III	324	0.667	0.472	0	1
Per unit subsidy	312	0.001	0.001	0.0001	0.006
Capacity utilisation	324	1.060	0.220	0.242	1.446
Gas based plants	324	0.444	0.498	0	1
BIN firms	324	0.444	0.498	0	1
Ownership	324	0.556	0.498	0	1

A. Results from Regression Models

The cumulative rate of decline of energy intensity for the period 2006-2015 is 1.78% [1]. In Table II below the paper estimates a growth model to calculate the time taken by the fertilizer industry to reduce energy intensity to half of its present value.

Model 1 is the semi-log model or the growth model used to calculate the growth rate of the dependent variable. Results show that overtime energy intensity of the fertilizer plants has been decreasing at 0.829% per year [3]. The compound rate of decline of energy intensity is 0.825% approximately.

TABLE II: Effect of Time on the Energy Intensity of Fertilizer Plants-Growth Model

Variables	Model 1
Time	-0.00829*** (0.00256)
Constant	-0.360*** (0.0168)
Observations	321
Number of id	27
R-squared	0.175
Firm fixed effects	Yes
Year fixed effects	Yes

, and ***: Null hypothesis rejected at 10%, 5% & 1%; levels of significance respectively.*
Robust Standard Errors in parenthesis.
ln(EI) is the dependent variable in all the specifications. EI is the ratio of energy consumed (toe) to total production (metric tonne).

The results obtained from Model 1 above show that

[3] Exponential model: $EI = (EI_0)(b^{time})$ Taking natural logs, the model becomes $ln(EI)=ln(EI_0)+time*ln(b)$ or $ln(EI)=\alpha+\beta time$ where $ln(EI_0)=\alpha$ and $ln(b)=\beta$. This is the semilog or growth model.
$[d(EI)/EI]/dt = \beta$ i.e. relative change in Y over absolute change in t.
$[(d(EI)/EI)*100]/dt = \beta*100$ is the instantaneous rate of growth.

b=0.991744[4], i.e., 0<b<1, which implies that it is a case of exponential decay. The half-time of energy intensity, i.e., the time it takes for energy intensity of fertilizer plants to become half, is 83.61[5] years approximately.

Table III below estimates the effect of the PAT scheme and NPS-III and other independent variables on the energy intensity of fertilizer plants.

The coefficient of *PAT year* is negative and statistically significant in all the models 2 to 6. In the years the PAT scheme was implemented, energy intensity of the fertilizer industry was lower as compared to the other years. The result is statistically significant at 5% level of significance. But the coefficient of the dummy variable *NPS-III* is positive and statistically insignificant in models 2 and 3. This implies that there was no significant difference in the energy intensity of fertilizer plants before and after Government of India started Stage-III of New Pricing Scheme for Urea. Therefore, *NPS-III* is not included in the other three regression models.

TABLE III: EFFECT OF PAT AND NPS-III ON THE ENERGY INTENSITY OF FERTILIZER PLANTS

Variables	Model 2	Model 3	Model 4	Model 5	Model 6
PAT year	-0.0782*** (0.0258)	-0.0246** (0.00948)	-0.0678** (0.0326)	-0.0167** (0.00780)	-0.0167** (0.00780)
NPS-III	0.0194 (0.0118)	-0.00903 (0.00699)			
ln(Per unit subsidy)		0.0246 (0.0169)	0.0161 (0.0167)	-0.018*** (0.00646)	-0.018*** (0.00646)
ln(Capacity utilisation)			-0.237*** (0.0756)	-0.269*** (0.0414)	-0.269*** (0.0414)
Gas based plants				-0.073*** (0.0275)	-0.244*** (0.0180)
BIN firms				0.604*** (0.0481)	0.433*** (0.0517)
(Gas based plants)(BIN firms)*					0.222*** (0.0490)
Ownership				0.0693*** (0.0145)	
Constant	-0.386*** (0.00946)	-0.207 (0.133)	-0.276** (0.131)	-0.631*** (0.0495)	-0.391*** (0.0387)
Observations	321	309	309	309	309
R-squared	0.200	0.194	0.326	0.951	0.951
No. of id	27	26	26		
Plant fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes

, and ***: Null hypothesis rejected at 10%, 5% & 1%; levels of significance respectively.*

Robust Standard Errors in parenthesis.

ln(EI) is the dependent variable in all the specifications. EI is the ratio of energy consumed (toe) to total production (metric tonne).

ln*(Per unit subsidy)* is included in models 3 to 6. There are links between energy subsidy and energy intensity [18]. Though the subsidy paid to the fertilizer industry is not related directly to energy consumption, indirectly the NPS in its various stages of implementation, has given pre-set energy consumption norms to urea plants and has tried to rationalize the subsidy burden of the government. Results from Table III shows a negative and statistically significant relationship in models 5 and 6. A 1% rise in per unit subsidy causes energy intensity to fall by 0.018%. More subsidy gives more resources to the plants to invest in energy saving technology.

Capacity utilisation is the ratio of actual production to installed capacity of the fertilizer plant and is included in models 4, 5 and 6. The coefficient is negative and statistically significant at 1% level of significance. A 1% rise in *ln(Capacity utilization)* causes energy intensity to fall by 0.27% approximately because if actual production is closer to the installed capacity, that will mean better utilisation of all the available inputs, including energy. Further analysis of data shows that on an average, plants that use natural gas as their feedstock are fully utilising their production capacity, as compared to the plants that use other fuel as feedstock.

Model 5 estimates the effect of three dummy variables, viz., *Gas based plants*, *BIN firms* and *Ownership*. Natural gas is preferred to be used as feedstock and fuel in the fertilizer industry, because it is the most energy efficient as compared to other fuels like naphtha. It is the cleanest form of energy causing least damage to the environment [19]. Most of the urea plants have already been converted to natural gas. Currently, out of 30 urea plants in the country, 27 urea plants use natural gas as feedstock and fuel [20]. However, the conversion to natural gas has occurred in stages. In 2003, The Department of Fertilizers, Government of India appointed a committee under the chairmanship of Shri A.V. Gokak to suggest energy consumption norms for the urea units. The committee grouped urea units into six categories, based on the feedstock used. The dummy variable *Gas based plants* in models 5 and 6, takes value 1 for the urea plants set up before and after1992 that used natural gas as feedstock. The remaining plants were naphtha, fuel oil or mixed feedstock based plants. Results from Models 5 and 6 show that *Gas based plants* are less energy intensive than plants that use other fuel as feedstock. Although now most of the fertilizer plants have been converted to natural gas, except for three plants [20] but the energy intensity of plants that were natural gas based since 1992, was lower during the years PAT scheme was implemented, than the other plants that were converted later. The average energy intensity for the gas-based plants is 0.608 toe/tonne during the years 2012-13 to 2014-15, while for the non-gas based plants that were converted later, the average energy intensity was 0.732toe/tonne. Even after the implementation period of PAT Cycle-I finished in 2014-15, average energy intensity of the gas-based plants of 1992 continued to be lower than the other plants (0.603 toe/tonne and 0.726 toe/tonne respectively). This implies that the plants that used natural gas from the year 1992, are more energy efficient that the plants that were converted later.

Dummy variable *BIN firms* tests if the average energy intensity is different for plants belonging to the firms BVFCL, IFFCO and NFL. Fertilizer industry has identified 29 plants as designated consumers. Out of these, 28 plants manufacture urea and only one plant, viz., The Fertilisers and Chemicals Travancore Limited (FACT Udyogmandal) manufactures ammonia. Under the PAT scheme, the total energy intensity target to be met by the fertilizer industry's

[4] $ln(EI)=\alpha+time*ln(b)$

Using the property $ln_e b=constant$, then $e^{constant}=b$. This gives $b=0.991744$

[5] $t^* = -(ln2 / lnb)$

$t^* = -(0.693147 / -0.00829) = 83.609$

urea producing plants is 12.483 toe/tonne of urea produced[6]. Out of this, approximately 52% has to be met by the plants from the BIN firms. These plants are more energy intensive than the other plants. Regression results also show that the coefficient of *BIN firms* is positive and statistically significant. On an average, plants from the *BIN firms* have higher energy intensity than the other plants.

An interaction variable, *(Gas based plants * BIN firms)* is included in Model 6 to estimate the average energy intensity of plants using natural gas as feedstock and belonging to the BIN firms. The coefficient is positive and statistically significant. The BIN firms that use natural gas as feedstock are more energy intensive than all the other plants in the fertilizer industry.

Finally, dummy variable *Ownership* is included in Model 5. Results show that plants owned by the government and cooperatives are more energy intensive than the plants from the private sector. The result is not surprising because all the BIN firms are either state owned or owned by cooperatives.

B. Energy Saving by Fertilizer Plants under PAT Cycle-I

The fertilizer sector was given an energy saving target of 0.478 million toe to be achieved by the end of the implementation period. But the fertilizer industry achieves a total energy saving of 6.103 million toe, which is 5.625 million toe higher than the target energy saving.

In this section the fertilizer plants have been divided into three categories, with two groups under each category. The paper compares which group withing each category has saved more energy than the other group. The three categories are: on the basis of the PAT targets of plants (whether PAT target of the plants is greater than or lower than the average target for the industry), on the basis of feedstock used (plant uses natural gas or not as feedstock) and on the basis of ownership (whether plants are government owned or private owned). The energy saving is heterogeneous between categories, as shown in Fig. 4 below.

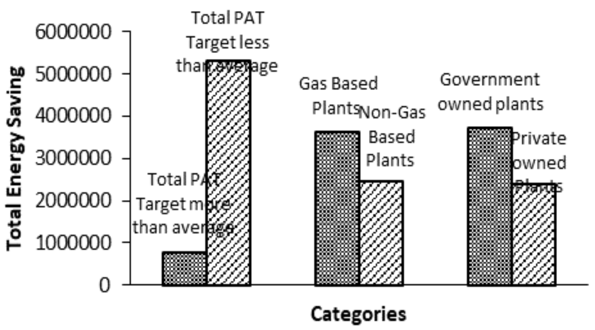

Fig. 4. Total Energy Saving (million toe) by Fertilizer Plants as per various categories
Source: Own analysis

The average energy intensity target to be met by fertilizer plants is 0.444toe/tonne (own analysis using data [13]). The first group with eight plants, viz., GNVFC-Bharuch, NFL-Nangal, NFL-Panipat, NFL-Bhatinda, MFL-Madras, SFC-Kota, BVFCL-Namrup II and BVFCL-Namrup III, have target energy intensities greater than the average energy intensity, i.e., these plants need to save relatively less energy as compared to the industry average. Except for BVFCL-Namrup III, none of the other seven plants use natural gas as feedstock. The second group with 19 plants has energy intensity lower than the average energy intensity, i.e., under the PAT scheme these plants have to save more energy as compared to the industry average. Out of total energy saving of 6.103 million toe, 0.775 million toe has been saved by the first group and 5.328 million toe has been saved by the second group.

Between gas-based plants and non-gas-based plants, the gas-based plants save 3.641 million toe worth of energy and the non-gas based plants save 2.462million toe worth of energy. Gas based firms save 1.178 million toe more energy than non-gas based firms.

The plants that are owned by the government or cooperatives save 3.71 million toe worth of energy, while the plants owned by the private sector save 2.393 million toe worth of energy. The government owned plants save 1.318 million toe worth of energy more than the privately owned plants.

VII. Conclusion

The fertilizer sector is an important industry because it helps in the growth of the agricultural sector. Urea is the fertilizer produced indigenously. Production of urea is also the most energy intensive. Therefore, out of 29 designated consumers in the fertilizer sector, 28 are urea plants. Both the NPS-III and PAT Cycle-I are government policies meant to improve the energy efficiency of the fertilizer sector. The objective of this paper is to estimate the effect of these two policies, and other control variables, on the energy intensity of fertilizer plants. The sample period is from 2006-07 to 2017-18. It covers the period before PAT Cycle-I was implemented and after PAT Cycle-I ended. The paper also estimates the energy savings by the fertilizer plants.

Sample data shows that the energy intensity of the fertilizer industry has been declining since 2010-11. Over the 27 years in the sample, the compound rate of growth of energy consumption is 0.17% and production is 0.45%, leading to a fall in energy intensity. The growth model confirms exponential decay and energy intensity will become half of its present value is approximately 84 years. Regression results from the fixed effects model shows that on an average energy intensity is lower in the years PAT scheme was implemented. But NPS-III did not have a similar effect. A rise in per unit subsidy and capacity utilisation helps in reducing energy intensity. The plants that use natural gas as feedstock have lower energy intensity than the other plants. Also, plants that are owned by BVFCL, IFFCO and NFL are more energy intensive than the plants from other firms. Overall, the fertilizer industry saves more energy at the end of the implementation period than their target as per PAT Cycle-I.

There are other variables that can also affect the energy intensity, like research and development expenditure, imports, size of the firm, etc. However, plant level data is not available for these variables. For future research if such data becomes available, then a better evaluation of energy intensity will be possible.

[6]This excludes FACT Udyogmandal because it manufactures ammonia and all other plants taken in this paper are urea producing plants.

Conflict of Interest

The author declares no conflict of interest.

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