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Evaluation & Analysis of PAT Scheme: An initiative by Govt. of India

Abhash Kumar and Akshay Kumar

Abstract
The Perform Achieve Trade (PAT) is an innovative, market-based trading scheme announced by the Govt. of India in 2008 under its National Mission on Enhanced Energy Efficiency (NMEEE) in National Action Plan on Climate Change (NAPCC) for improving energy efficiency in industries. This scheme that covers energy conversion chain beginning from generation to the end use by industry and is considered as one of the most innovative actions undertaken by India towards Climate Change Mitigation. This paper analyses the PAT scheme using CMIE data. The analysis uses stochastic frontier analysis technique and calculates technical and efficiency and energy efficiency. The paper finds that there is potential of energy efficiency improvement in all the industries. It also tries to measure the impact in all industries under PAT cycle 1 specifically. It also finds that the larger firms are more energy efficient which might be due to economies of scale.

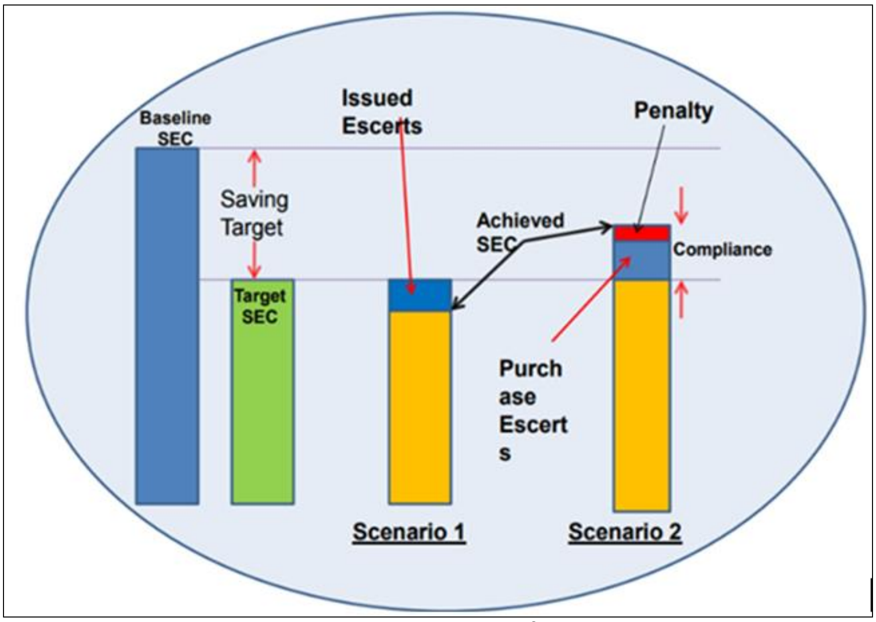
Keywords: Perform, achieve, trade, climate change, energy saving, ESCERTS, energy efficiency, stochastic frontier analysis, energy intensity, industry, emission, total factor productivity, aluminium, cement, chlor-alkali, fertiliser, iron and steel, paper & pulp, textile, thermal power plant, railways, refineries, electricity distribution companies, technical efficiency, firm-specific inefficiency, time variant inefficiency

1. Introduction

Considering the global energy discourse, there is an important emerging argument that energy efficiency should be treated as a resource as it gives the same outcome as any other energy resource and that too at a lower cost most of the time. At a time when growth stories are punctuated with increasing constraints of energy resource availability and emissions released to atmosphere from the usage of such resources, promotion of energy efficiency comes as a first choice. Given this fact, implementing a scheme that covers energy conversion chain beginning from generation to the end use by industry is the need of the hour.

The Perform Achieve Trade (PAT) is an innovative, market-based trading scheme announced by the Govt. of India in 2008 under its National Mission on Enhanced Energy Efficiency (NMEEE) in National Action Plan on Climate Change (NAPCC) for improving energy efficiency in industries by trading in energy efficiency certificates in energy-intensive sectors. Having said that, PAT cycles in 2008 were considered as one of the country’s most promising energy efficiency initiatives with very strong climate change mitigation co-benefits as well.

The Aim of the Paper is to analyze the ways in which the scheme is unique particularly from the point of view of a developing country since it creates a market for energy efficiency through tradable certificates, called Energy Saving Certificate (ESCerts) by allowing them to be used for meeting energy reduction targets. These certificates can be issued by any of the 478 DCs who are able to exceed their respective notified target, the value of the certificate being the excess achievement, more than the target set. Any beneficiary firm can trade this certificate with any of the other entities (of the 478) that is unable to meet its target. Buying ESCerts has been allowed for the purpose of sufficient fulfillment of compliance requirement without any penal action.



***Source*:** National Productivity Council, Government of India

In its first cycle of three years (2012-2015), the scheme covers eight energy guzzling sectors— thermal power, aluminium, cement, fertilizer, iron and steel, pulp and paper, textiles and chlor-alkali. Together, these sectors account for 40 per cent of India's primary energy consumption. The target (as of 2012) is to save 6.68 million tonnes of oil equivalent in these eight sectors by 2015, the first cycle of the scheme. The target for each plant will vary, depending on its size, and will be set by BEE. Thermal power plants of India are the focus of the PAT scheme as they consume 50 per cent (3.21 million tonnes) of oil equivalent of the total 6.68 million tonnes (targeted saving). Hence, upon successful implementation of the first cycle of PAT, it is expected to help our country save energy to the tune of approximately 6.6 million tonnes of oil equivalent by the end of 2014-15.

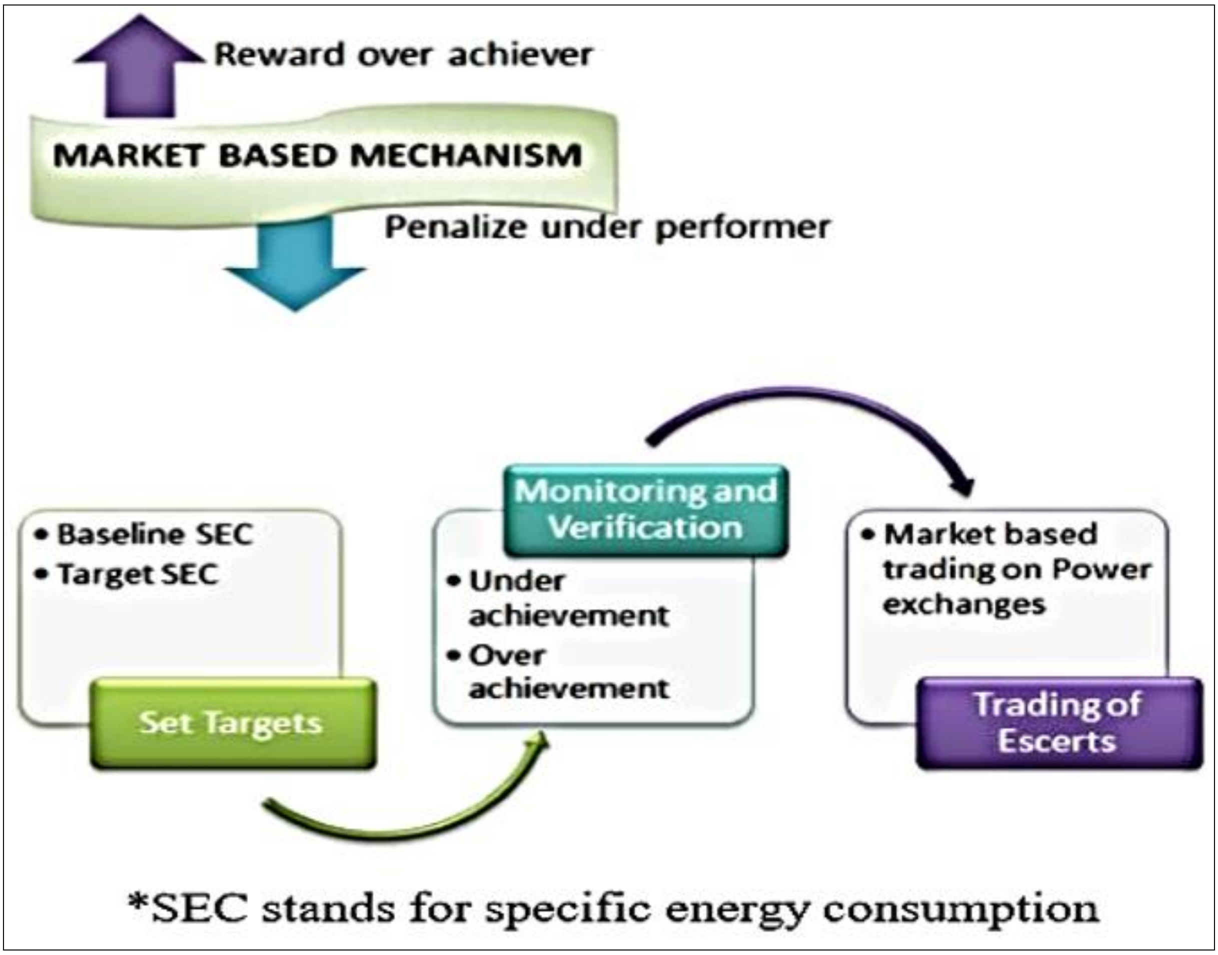


Fig 1: Step-wise approach to setting up of targets, monitoring and trading of escerts

Thus, we seek to analyze the ways in which the PAT scheme has the makings of becoming a benchmark for design and implementation of schemes, policies and measures (for the 8 industries) while highlighting its innovative approach of introducing market-based instruments within a regulatory framework in-order to encourage compliance. Successful implementation of the scheme could serve as a model for addressing upcoming challenges in a transparent and economically efficient manner.

2. Literature Review

The growing requirement of energy, constrained access to the resources, questions pertaining to energy security, environmental concerns and increasing competitiveness in global markets has driven the urgency to layout strategies to attain higher efficiency in energy utilisation.

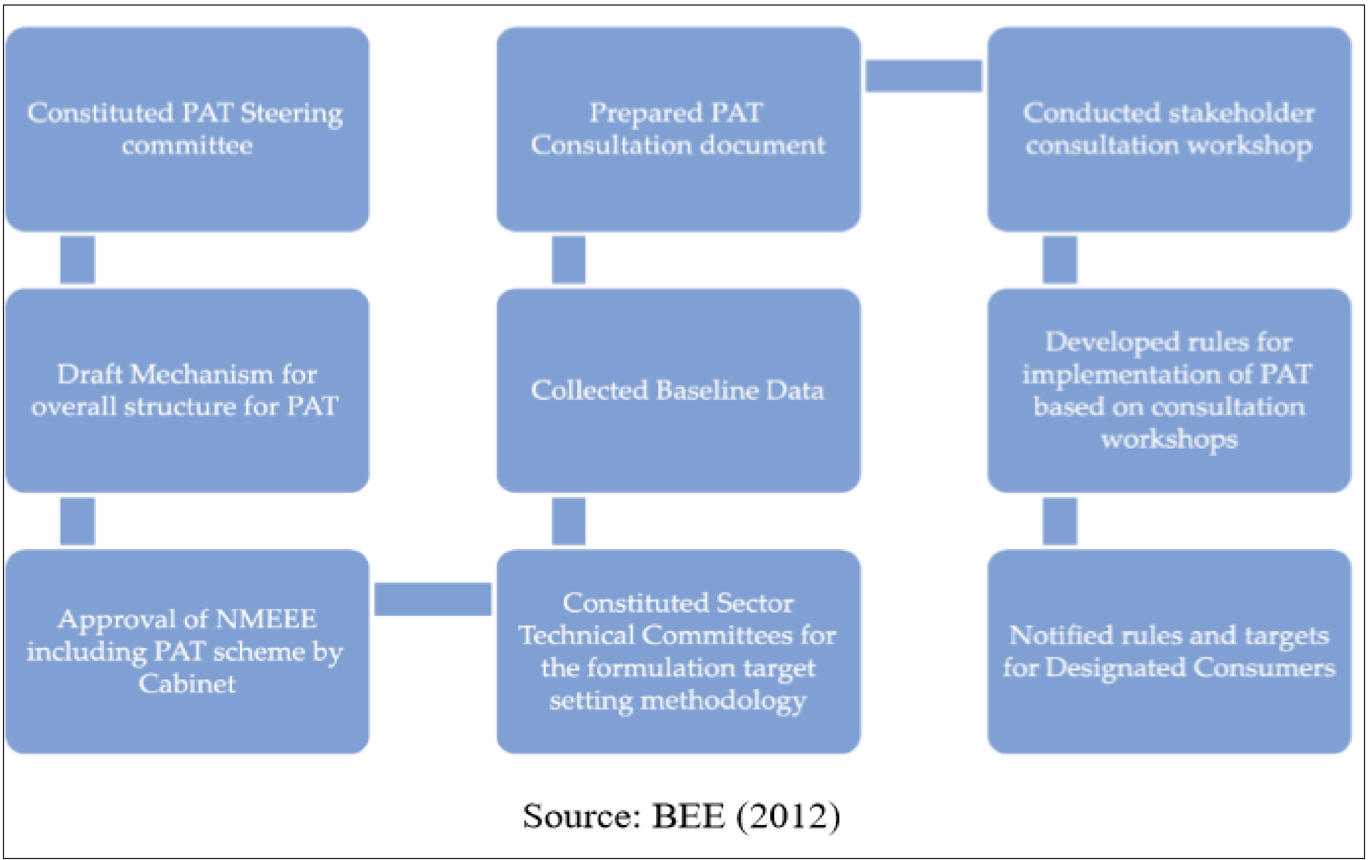


Fig 2: Step wise implementation followed for pat scheme

Kaushik Ranjan (2016) [5] stressed on various aspects of the PAT scheme covering its Evolution, Importance (for a developing country like India) and Mechanism. PAT scheme is a market based instrument that mimics a cap and trade mechanism and is intended to enhance cost-effectiveness of improvement in energy efficiency in energy intensive large industries. He emphasizes that the programme would facilitate in scaling up energy efficiency in targeted industries while allowing for increased production and energy consumption to cater to the needs of the much needed growth. The scheme has the potential to pave the way for creating a more holistic market for emission trading in India and holds lot of promises in linking with the international carbon offsets market through adjustments and harmonization in monitoring, reporting and verification (MRV). In the light of this, the paper also provides a review of the operation and institutional Mechanism of the scheme and explores the potential in its linking with other international carbon offsetting schemes.

Potdar, Unnikrishnan and Singh (2016) [11] assess various energy management systems in India. They advocate for inclusion of more designated consumers present under Energy Consumption Act 2001 to make the scheme robust. They argue for a scheme like Top 1000 Energy Consuming Enterprises program by China to target more entities and give them favorable allowances and economic incentives to motivate energy consumption. Proper implementation of schemes like PAT can help India achieve its dream of becoming 'low carbon economy'.

Ravneet Kaur (2015) [1] in her paper while addressing the critical challenge: "Climate Change" faced by the humanity today, focusses on the National Mission for Enhanced Energy Efficiency (NMEEE) as an innovative initiative taken by Government of India to address climate change and to provide legal consent for the implementation of energy efficiency measures through the institutional mechanism of Bureau of Energy Efficiency (BEE), highlighting one of the major components of NMEEE -PAT. The paper uses both Primary, as well as Secondary sources to analyze the contribution of PEDA (Punjab Energy Development Agency) in PAT scheme by undertaking a study on industries situated in District Ropar. Primary data is collected by using telephonic interview method and general discussion. It includes the officials of PEDA who are involved in PAT scheme and the Energy Managers of industries chosen as Designated Consumers. Secondary data is collected through annual reports and documents provided by PEDA. The main contribution of the paper is towards the beneficial impacts of the PAT mechanism for the planners and the agencies who conduct workshops for State Designated Agencies and Designated Consumers.

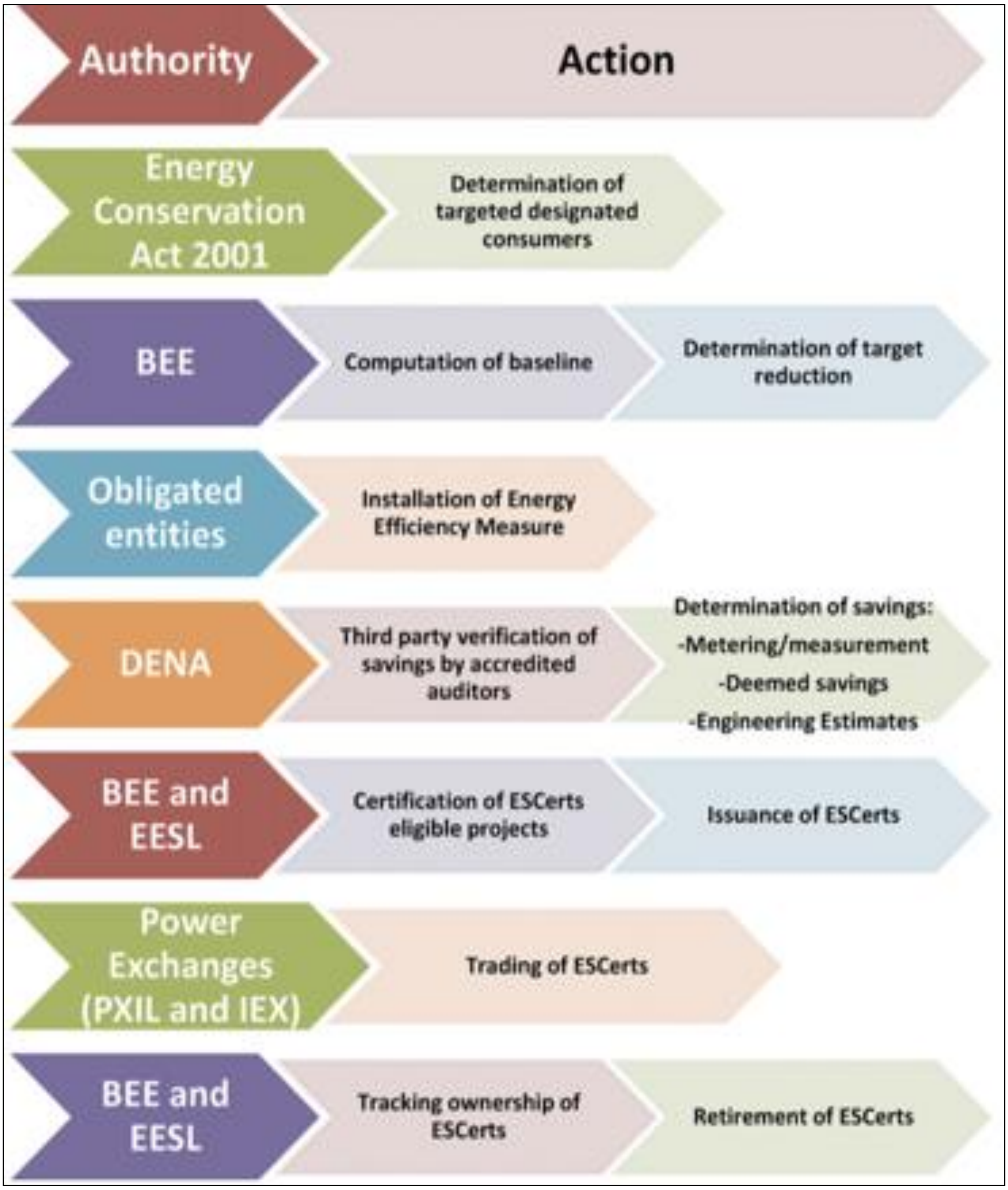


Fig 3: Procedure for Issuance of ESCerts

Marlene Arens, Ernst Worrell, Joachim Schleich (2012) analyzes the development of the SEC of the main processes in the German iron and steel industry between 1991 and 2007. They find improvements in energy efficiency due to technological progress, diffusion of best available technologies and improved energy management. In their system boundary of the quantitative analysis, four step approach in analysis have been used. The main route is suing blast furnaces and basic oxygen furnace (BF/BOF) to produce steel from iron ore. The paper finds that energy efficiency of the processes did not improve significantly, and also identified potential to increase the recovery of BOF growth. They have shown that Energy Efficiency would improve continuously over time due to diffusion of new technologies (e.g. strip casting, top gas recycling blast furnace, smelting reduction, heat recovery from EAF, Heat recovery from slag) and improved process management. Such an analysis may be expected to provide valuable insights into the effect of capacity utilization on energy intensity in the iron and steel sector.

Bhattacharya and Kapoor (2011) [7] have discussed Energy Saving Instruments as an instrument for reducing the energy intensity of the high energy intensive Indian industries under the light of Energy Conservation Act, 2001 and PAT scheme (under NMEEE) and suggests a way forward for ESCerts market in India. The success of ESCerts depend upon many factors like baseline determination, pricing of ESCerts, energy saving audits.

Anoop Singh and Bharat Sharma (2018) [4] have stressed on continuous challenge to balance the tripod of environment, development and resource utilization and energy efficiency offers a strong case to be pursued for to attain this balance. They attempt to provide a Data Envelopment Analysis (DEA) based alternate approach for target setting. This paper shows the Energy consumption across the industrial sectors varies depending on technological aspects governing output mix and input mix. Further adoption of captive power generation, internal waste heat recovery and co-generation of electricity and steam also differentiate energy consumption pattern across similar plants. Energy efficiency has been extensively researched and examined and categorized the employed analytical techniques in four different types. First, econometric methods used to assess the demand outcome of energy based on prices or energy taxes. Second, simulation and optimization models based on top-down and bottom-up approach to study the interplay of technology and energy consumption. Third, the industry and process specific microeconomic analyses based on simulation, optimization and statistical techniques. Fourth is the decomposition methods. The monitoring of the scheme and correctness of data of the firm remains a limitation of this study. The firm-level data does not give the information about the pattern and behavior of the plants.

The paper by Garnaik, Thapliyal and Mathur (2011) [9] assesses PAT mechanism in Pulp and Paper industry focusing on each of its designated consumers. They find that the energy consumption targets require the understanding of various factors that affect and control energy consumption. They also warn implementers of the chances of significant errors at the time of reporting due to manual reporting by some units not monitored through automation or upgraded technology. They also found that the method of averaging the energy consumption has been quite useful to measure the savings potential. With proper learning of the mechanism along with efficient energy techniques, India can meet its energy demands effectively.

In their paper, Sahoo *et al*. (2017) [10] aim to bring out some veiled weaknesses of the PAT scheme as applied to the thermal power sector in India. In this study, they have limited their scope to the coal-based thermal power plants only and their analysis is based on data available for 71 power plants out of 97 plants representing 86.5% of generation capacity, obligated under the PAT scheme. DEA, which is extensively used for efficiency analysis, was applied to undertake the study. The study brings home two major points with respect to rationalizing the target setting methodology of PAT policy for the thermal power sector in India. First, the study shows that, if the heat rate reduction potential is fully realized, then 4.7 million ESCs are expected to be earned by the coal based thermal power plants, against a demand of 0.95 million ESCs. However, considering the fact that complete realization of potential is highly optimistic, the study suggests that 40-50% realization of potential may create a favourable condition for ESC market formation. Second, the study shows that there exists substantial inefficiency in energy use and managerial practice. The analysis, however, does not depict a complete picture of the ESC market, because there are seven more energy-intensive sectors, which are envisaged to supplement the certificate market with about half of the numbers of certificates.

Thapliyal (2016) [3] have presented the challenges and achievements of PAT scheme in Indian Pulp and Paper Sector and scope for energy improvement in PAT Phase- 2. They have proposed technological improvement in several areas such as raw material handling, paper machinery, chemical recovery, power generation, solid waste management for combatting pollution and achieving the targets of energy and environmental compliance. They are optimistic about the industry being progressive and meeting all assigned targets for PAT cycle 2 as well as the demand forecasted for the near future.

3. Data and Methodology

3.1 Data

The study is based on the data derived from various sources:

- **Prowess by CMIE:** Firm level datasets for the various industries under PAT Scheme.
- **BEE (Bureau of Energy Efficiency)**, Ministry of Power, Govt. of India: PAT scheme and energy use limit settings.
- **Energy statistics 2018, Ministry of Statistics & Planning, Government of India**

Table 1: Number of sample firms under PAT Cycles I and II

Sector	PAT Cycle I	PAT Cycle II	Total
Aluminium	1	0	1
Cement	26	5	31
Chlor-Alkali	13	0	13
Fertilizer	8	2	10
Iron and Steel	21	2	23
Paper & Pulp	8	5	13
Thermal Power Plant	0	0	0
Textile	27	3	30
Electricity Distribution Companies	-	0	0
Refineries	-	5	5
Railways	-	0	0
Total	104	22	126

3.1.1 Choice of Variables

Energy efficiency can be estimated using a stochastic frontier function, wherein the frontier or benchmark of cost-minimizing energy demand is estimated. Previous studies on energy productivity have usually used energy intensity, i.e. the ratio of total energy use to an output measure as an approximation to energy efficiency, which, however, appears to be inadequate as suggested in studies by Lundgren and Filippini. Energy intensity or productivity is often used to set targets as a proxy for energy efficiency. Moreover, the energy efficiency target under PAT Scheme also refers to an increase in annual energy productivity. The definition of energy intensity is the ratio of energy consumption to output at the industry or firm level and energy productivity is the inverse of energy intensity. Filippini and Hunt (2011) [12] show – based on country-level data - that it is not clear if energy intensity is actually a good proxy for energy efficiency. Lundgren *et al*. (2016) [13] also show the same ambiguous relationship based on data for the Swedish manufacturing sector. The authors compare the energy efficiency scores derived from a SFA with calculated energy intensities using a simple correlation analysis. The relationship is expected to be perfectly negatively correlated, if both are perfectly comparable. The authors however found negative correlations in most sectors, but with a relatively low magnitude. Thus, they cannot confirm that energy intensity is a clear-cut proxy for energy

efficiency.
However, energy efficiency, as we estimate it here, is defined as the difference between the actual and predicted energy use. The estimated energy demand function gives the minimum amount of energy that is necessary to produce a given level of output, given the technology, input prices, and other factors. As a measure of output, we use annual sales of a firm deflated by industry specific WPI. Raw material expenditure deflated by industry specific WPI is also included. We also include average energy price in our energy demand frontier function. The energy price is calculated as a weighted average of price of individual energy source where quantity consumed of each energy source (coal, electricity or gas) is used as weights. As a measure of capital, the net fixed assets (NFA) deflated by WPI for plant and machinery is used due to limited availability of data on capacity for each sample unit for every year. Based on Total Factor Productivity (TFP) studies, the use of NFA is justified as the services rendered by capital assets are proportional to their prices and NFA also account for the loss of efficiency due to depreciation and wear and tear of assets over time. Because the data regarding compensation of labour is available in Prowess, it is possible to use a proxy variable which captures the heterogeneity of employees across firms. Total Compensation to Employees which is a sum total of wages and salaries, profit sharing and social security costs is used as a proxy variable for labour input. It is deflated by annual CPI for Industrial Workers.

3.2 Methodology
With the implementation of PAT Cycles, the eight energy sectors of first cycle-thermal power, aluminium, cement, fertilizer, iron and steel, pulp and paper, textiles and chlor-alkali have tried to achieve energy conservation through energy efficiency techniques. To analyse this change in trends, if any, DID regression techniques may be estimated to differentiate the energy consumption patterns in pre-implementation and post implementation periods.

Our regression function comes to be:

$$E_{it} = \alpha_i + \beta_i X_{it} + \gamma_i + \delta_t + \varepsilon_{it}$$

Where,
E_{it} is the total energy consumed by entity i in period t
X_{it} is the set of covariates determining the energy consumption for entity i in period t
γ_i is an unobserved industry-specific effect

δ_t is an unobserved time-dummy for PAT Scheme 1.

Here, we expect δ_t to be statistically significant to capture the effects of policy implementation and if the coefficients vary for different industries during the PAT Cycle, it indicates differences in the behavior of the Designated Consumers over the Cycle years.

3.2.1 Model Selection
Out of two primary methods to measure technical or efficiency change, DEA (Data Envelopment Analysis) is a non-parametric method of efficiency measure where no assumptions are made about the probability distributions of the variables being assessed. However, in case of parametric methods of measuring efficiency like SFA, the assumptions of the underlying distribution of a variable, enable us to make predictions about how, in repeated samples of equal size, this particular statistic will behave and how it is distributed.
The advantage of SFA (Stochastic Frontier Analysis) is that it takes inefficiency explicitly into modelling and represented by some random error (say u_i). In this method econometric theory is used to estimate pre-specified functional form and inefficiency is modelled as an additional stochastic term. This was a natural choice to our paper.

3.2.2 Stochastic Frontier Analysis
The stochastic frontier model was originally developed by Aigner, Lovell and Schmidt (1977). The canonical formulation of the model is given by the following equation:
$y = \beta'x + v - u$, where
y is the observed outcome (goal attainment),
$\beta'x + v$ is the optimal frontier goal (e.g., maximal production output or minimum cost) pursued by the individual,
$\beta'x$ is the deterministic part of the frontier and $v \sim N[0,\sigma_v^2]$ is the stochastic part. The two parts together constitute the "stochastic frontier".
The amount by which the observed individual fails to reach the optimum (the frontier) is u, where $u = |U|$ and $U \sim N[0,\sigma_u^2]$. Here, u captures the inefficiency. This is the half normal model which represents the basic form of the stochastic frontier model.
The complete error term can also be written as ε with $\varepsilon_{it} = v_{it} + u_{it}$

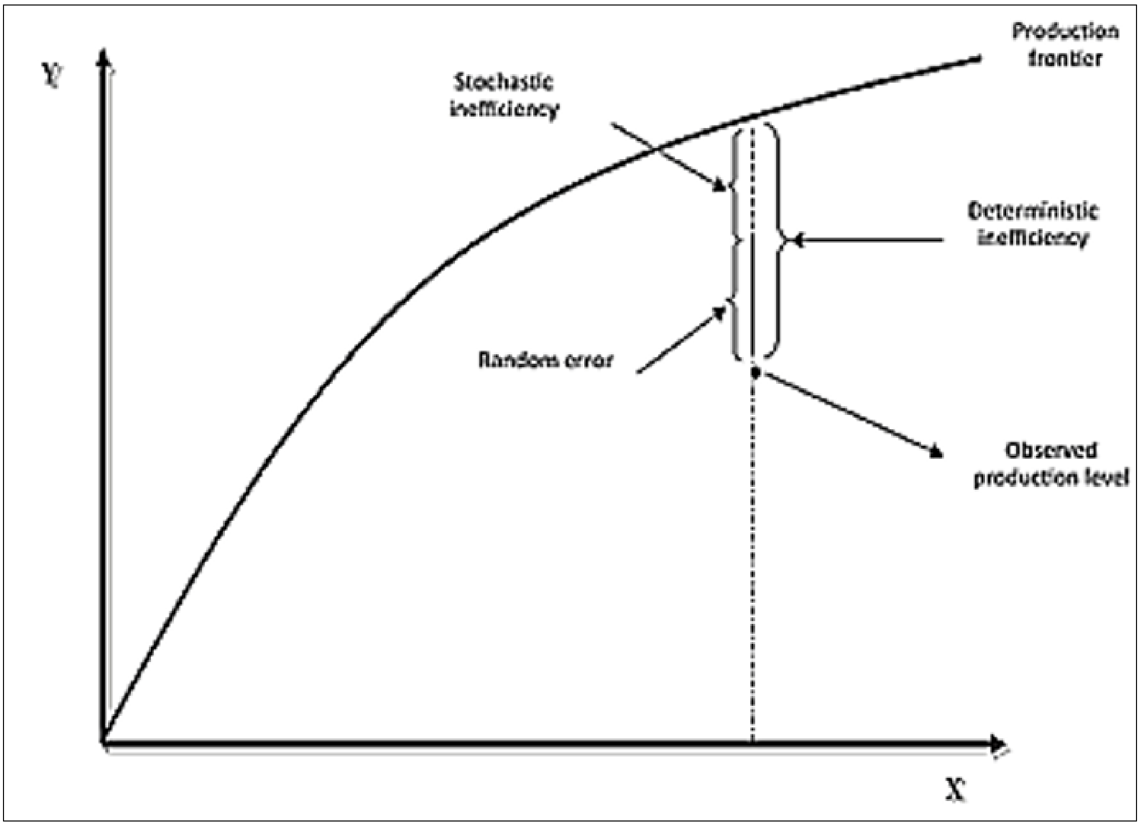


Fig 4: SFA Frontier lines and efficiency

3.2.3 Model for determining energy efficiency of the firms

We have estimated the following Energy Demand Function for firm 'i' in period't' for the companies obligated as Designated Consumers:

$$e_{it} = \beta_0 + \beta_1 y_{it} + \beta_2 k_{it} + \beta_3 l_{it} + \beta_4 m_{it} + \beta_5 p^e_{it} + \tau T + \psi_i + v_{it} + u_{it}.$$

Here, e_{it} denotes the minimum amount of energy that is necessary to produce a given level of output which is energy use from coal, electricity or gas for a firm. The measure of output y is given by annual sales of a firm deflated by industry specific WPI, k is the measure of capital represented by the net fixed assets (NFA) deflated by WPI for plant and machinery, l denotes the labor input represented by the proxy variable given by compensation of labor), m denotes the raw material expenditure deflated by industry specific WPI, p^e denotes the average energy price and T denotes the time trend variable which captures technological change. Ψ_i is a firm specific random effect and allows for time-invariant heterogeneity at the individual firm level, which is assumed to be uncorrelated with the other input factors, the prices and the time trend. (Here lowercase denotes values in logarithmic form).

Energy inefficiency is captured by the term u_{it} which we assume follows a non-negative truncated normal distribution $u_{it} \sim N^+(\mu_{it}, \sigma^2_{ui})$. v_{it} is the error term which is assumed to have a normal distribution $v_{it} \sim N(0, \sigma^2_{vi})$.

The variable representing the driver of energy efficiency here is status of participation in PAT Cycle I placed in the mean (μ_{it}) of the non-negative truncated normal distribution of u_{it} which represents the inefficiency. Other than participation in PAT cycle I, the inefficiency of a firm can be explained by the sector it belongs to because some sectors are inherently more inefficient than others owing to their scale of operation, government regulations, product mix etc. Also, we expect size of the firm to have an impact on the energy efficiency through economies of scale. Therefore, the estimation of the conditional inefficiency model follows the model:

$$u_{it} = \gamma_1 D_i + \gamma_{2j} S_j + \gamma_3 Size_i + \zeta_{it}$$

where $D_i = 1$ if the firm is originally notified under PAT Cycle I and 0 otherwise, S_j is a vector of 8 sector dummies one each for the sectors covered in the model, also due to data constraints we have used Deflated Net fixed assets as a proxy of size of the firm and ζ_{it} is a random error term.

The energy efficiency of every analysed firm can be translated into an energy efficiency score EE_{it}, which is given by $EE_{it} = \exp\{-u_{it}\}$. It represents the distance of every firm to the frontier in the respective industry.

Technical efficiency level of unit i at time t is defined as the ratio of the actual energy consumption to the potential energy consumption,

$$TE = Y / f(x; \beta).\exp(v)$$
$$= f(x; \beta).\exp(v).\exp(-u) / f(x; \beta).\exp(v)$$
$$= \exp(-u)$$

An energy efficiency score of one indicates a firm on the frontier, which would mean that the firm is 100 percent energy efficient. It is assumed that markets are perfectly competitive and firms minimize costs. Under these assumptions, the estimated efficiency scores will fully capture time-variant inefficiency. Note that time-constant, persistent firm-specific inefficiencies are part of the time-invariant heterogeneity term ψ_i the TRE model.

Stochastic Frontier Analysis indicates the relative efficiencies under the condition of 'No PAT obligations'. In order to examine, whether there exist significant difference between the set target, and the efficiency scores obtained under the aforementioned conditions, following hypothesis is tested:
"The target set under the PAT scheme is set rationally taking into consideration the current level of plant efficiency. That is, the efficiency score derived from the above model and the target set under the PAT have the same distribution. i.e. they have comparable means."
Spearman Rank Correlation Test can be conducted to test the strength of association between ranks associated with set targets and ranks based on efficiency score for the baseline year i.e. 2010.

4. Results

We found average prices to vary in accordance with average quantity. The smoothening of price curve explains the market behavior of the firms and BEE. The fluctuations in the total energy consumption might be due to sectoral differences of firms' behavior to compliance as per its position in the previous year and hence to maximize profits.

Fig 5: Avg qty and Avg Price

The estimated energy demand stochastic frontier as well as the estimated relationship of different drivers of energy efficiency of a firm and energy efficiency are shown below.

Table 2: The estimated parameters of the energy demand frontier

ln_totalqty	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Frontier						
ln_deflatedsales	.5953542	.0845546	7.04	0.000	.4296301	.7610782
ln_deflatedexpenses	.8059848	.2064814	3.90	0.000	.4012887	1.210681
ln_rawmaterialexpenses	-.8410146	.2140901	-3.93	0.000	-1.260624	-.4214058
ln_grossfixedassets	.5552496	.0624904	8.89	0.000	.4327707	.6777286
ln_deflatednfa	-.0393115	.0150127	-2.62	0.009	-.0687358	-.0098872
ln_avgprice	-.6899451	.0230207	-29.97	0.000	-.7350648	-.6448254
patscheme1	.1808833	.2151588	0.84	0.401	-.2408202	.6025869
pyear	-.1092219	.063836	-1.71	0.087	-.2343382	.0158944
pulppaper	-.3421578	.8184251	-0.42	0.676	-1.946242	1.261926
petroleum	-3.25347	.8837044	-3.68	0.000	-4.985499	-1.521441
isteel	-.4086658	.7966219	-0.51	0.608	-1.970016	1.152684
textiles	-.8905404	.8008121	-1.11	0.266	-2.460103	.6790224
chloralkali	-.3013994	.8105451	-0.37	0.710	-1.890039	1.28724
fertiliser	-1.313413	.8217396	-1.60	0.110	-2.923993	.2971674
cement	.4103304	.8054735	0.51	0.610	-1.168369	1.989029
_cons	9.198364	1.439913	6.39	0.000	6.376186	12.02054
/lnsigma2	-.0857999	.1202567	-0.71	0.476	-.3214987	.1498989
/ilgtgamma	.4988854	.2056856	2.43	0.015	.0957491	.9020218
/mu	2.111823	.6437239	3.28	0.001	.8501477	3.373499
/eta	-.0020903	.0069737	-0.30	0.764	-.0157586	.0115779
sigma2	.9177779	.110369			.7250615	1.161717
gamma	.6221974	.0483501			.523919	.7113648
sigma_u2	.571039	.1114603			.3525808	.7894971
sigma_v2	.3467389	.0149439			.3174494	.3760284

The Stochastic Frontier model is based on the theoretical idea that no economic agent can exceed the ideal “frontier”, and deviations from this extreme represent individual inefficiencies. From the statistical point of view, this idea has been implemented by specifying a regression model characterized by a composite error term in which the classical idiosyncratic disturbance, aiming at capturing measurement error and any other classical noise, is included with a one-sided disturbance that represents inefficiency. The compound error term is composed of a noise component (random component) and a non-negative technical inefficiency component.

Our SFA results clearly indicate highly significant coefficients for the key independent variables (with the corresponding signs in accordance with our a priori expectations):

- ln (deflated sales),
- ln (deflated expenses),
- ln (raw material expenses),
- ln (gross fixed assets),
- ln (deflated net fixed assets) and
- ln (average price)
- pyear: dummy variable for years under Pat Scheme 1, that takes value 1 for years 2012-15 that takes value 0 for years before 2011.
- patscheme1: dummy variable which takes value 1 for firms included in Pat Scheme 1 and value 0 if they are included in PAT scheme 2

The estimates are statistically significant at 1% level of significance. The results of the estimated energy demand frontier show plausible signs for the short-run elasticities from an economic point of view. The positive signs for inputs (deflated sales), capital (net fixed assets) and output (sales) can be interpreted as follows: Given the technology, a respective increase in these variables would require an increasing energy demand. It also suggests complementary relationship between energy use and inputs (or capital). The elasticity is maximum with respect to output which seems plausible. Contrary to expectations, the sign for material expenditure is small and negative which could suggest that may be the firms are shifting towards use of recycled materials or materials that use renewable energy and other ways. For example, using recycled steel instead of new steel reduces energy demand. The positive and highly statistically significant time trend hints at the fact that the energy use increased over time in all industries. Furthermore, we find an economically plausible relationship between energy prices and energy demand: the negative relationship means that rising energy prices reduce the energy demand. Own price elasticity is found to be -0.689 which implies that when average price increase by 1% the energy demand decrease by about 0.69%. Similarly, a 1% increase in sales increases energy demand by about 0.60% ceteris paribus. Industries other than petroleum have similar energy consumption behavior as aluminium which means that firms tend to respond in similar fashion to the changes in economic variables. Petroleum consumes lower energy than aluminium which is evident from higher intensity of energy requirements in aluminium industry while petroleum tends to have efficient technology and energy sources. Negative sign for size which is represented by net fixed asset as proxy represents the economies of scale achieved by the firms. The participation dummy for firms under PAT Scheme 1 is statistically insignificant that represents the firms under the schemes PAT-1 and PAT-2 are similar in energy consumption behavior. The negative coefficient of pyear representing PAT Scheme 1 years implies that energy consumption has reduced after the implementation of schemes and hence firms consume less energy under the scheme period than they would hve without the scheme.

Table 3: Estimate of Energy Inefficiency

sigma_u	.6602247	.0589239	11.20	0.000	.5542727	.78643
sigma_v	.4514295	.029107	15.51	0.000	.3978383	.5122396
lambda	1.46252	.0847192	17.26	0.000	1.296474	1.628567

As mentioned above one of the measure of inefficiency is lambda, which denotes the relative contribution of the variance in energy efficiency (σ_u) compared to the variance of the error (σ_v). The statistical significance of λ indicates the presence of energy inefficiency. In our model, value of λ is 1.46(>1) implying the deviation coming from inefficiency (σ_u) is 1.46 times the standard deviation coming from the stochastic (noise) term (σ_v).

Other than Lambda, we have calculated the efficiency score which is exponential ($-u_{it}$). It has a mean of approximately 0.619 with a minimum of 0.0026 for one of the fertiliser firms and a maximum of 0.9215 for one of the Chlor-Alkali firms. Efficiency score of 1 means a fully efficient firm which implies the firms in our analysis with a score of <1 (all of them) are inefficient.

Table 4: The relation between several determinants and energy efficiency as per DID regression

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Random-effects GLS regression                   Number of obs     =      1,257
Group variable: company_name                    Number of groups  =        126

R-sq:                                           Obs per group:
     within  = 0.5926                                         min =          8
     between = 0.8637                                         avg =       10.0
     overall = 0.8166                                         max =         10

                                                Wald chi2(15)     =    2574.52
corr(u_i, X)   = 0 (assumed)                    Prob > chi2       =     0.0000
```

ln_totalqty	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ln_deflatedsales	.5569531	.0794726	7.01	0.000	.4011896	.7127166
ln_deflatedexpenses	.8393588	.1762955	4.76	0.000	.493826	1.184892
ln_rawmaterialexpenses	-.8797407	.190384	-4.62	0.000	-1.252886	-.5065949
ln_grossfixedassets	.5232986	.059562	8.79	0.000	.4065592	.640038
ln_deflatednfa	-.0343837	.0144684	-2.38	0.017	-.0627413	-.0060261
ln_avgprice	-.7067625	.0224294	-31.51	0.000	-.7507234	-.6628017
patscheme1	.1953079	.1735408	1.13	0.260	-.1448257	.5354416
pyear	-.1034117	.0585715	-1.77	0.077	-.2182097	.0113863
pulppaper	-.5426153	.6692287	-0.81	0.417	-1.854279	.7690488
petroleum	-3.135185	.7215818	-4.34	0.000	-4.549459	-1.720911
isteel	-.5336792	.6514446	-0.82	0.413	-1.810487	.7431287
textiles	-1.093293	.6550545	-1.67	0.095	-2.377177	.1905901
chloralkali	-.4457542	.6640705	-0.67	0.502	-1.747308	.8558
fertiliser	-1.438401	.668822	-2.15	0.032	-2.749268	-.1275337
cement	.195833	.6587662	0.30	0.766	-1.095325	1.486991
_cons	7.702333	1.063739	7.24	0.000	5.617442	9.787224
sigma_u	.57547178					
sigma_e	.58146211					
rho	.49482238	(fraction of variance due to u_i)				

As shown in table 4 above, DID regression gives the similar results as SFA frontier. The fertilisers and textiles industries dummies come out to be statistically significant which represents their better efficiency and more substitution available in inputs for these industries than the case for aluminium industries. Though, the Fertilizer industry has been instrumental in making India self-sufficient in food and agricultural produce, it continues to struggle with limited investments and hence limited adoption of energy inefficient technology (as compared to petroleum industry). Encouraging manufacturers to become more energy efficient will boost domestic manufacturing which in turn, will eventually help us reduce dependence on fertiliser imports which is eating into the fertilizer subsidy bills.

Energy Intensity is measured by the quantity of energy required per unit output or activity, so that using less energy to produce a product reduces the intensity. Energy Efficiency improves when a given level of service is provided with reduced amounts of energy inputs or services are enhanced for a given amount of energy input. Policy makers are particularly concerned about energy intensive firms and industries. On the one hand, most energy efficiency goals are set to reduce energy intensity in the future. On the other hand, there is a concern that especially energy intensive firms and industries might lose competitiveness through energy and climate policies as they face high shares of energy costs. Here, energy intensity is calculated as the ratio of energy quantity consumed to total sales (toe/Rupees).

Table 5: The average energy intensity and average energy efficiency scores for the baseline year 2010

Sector	Average of energy intensity	Average of efficiency score
Aluminium	0.004709005	0.6448303
Cement	0.006232312	0.643049496
Chlor-Alkali	0.002250061	0.624655885
Fertilizer	0.000652458	0.60424145
Iron and Steel	0.00517102	0.652565329
Paper & Pulp	0.002370628	0.5904691
Textile	0.001089241	0.622126152

Paper & Pulp industry has the least energy efficiency score (0.5904691) and its energy intensity is also relatively high (0.00237). Energy efficiency score is also low for Fertilizer but the average energy intensity for the Fertilizer industry is also the lowest i.e. 0.000652 among all the sectors. In the 2009 version of the 'UK Energy Sector Indicators' (DECC,

2009) it states: "Traditionally energy intensity has been used as a proxy for an energy efficiency indicator. However, intensity trends also include changes in the composition of energy service demand or structural changes in addition to efficiency improvements in processes and equipment." The distinction between energy intensity and energy efficiency is important when multiple technologies or multiple products underlie what is being compared. Energy intensity can vary between sectors for several reasons: the mix of products; the location of specific production plants; the level of energy efficiency of the appliance and capital stock and production processes and the organization of the production and consumption processes in space. In the industrial sector, a shift in manufacturing emphasis from the energy intensive industries — primary metal and cement — to less energy-intensive industries such as transportation equipment or food would cause a decline in the index of energy intensity that does not necessarily reflect an increase in energy efficiency. Declines in energy intensity are a proxy for efficiency improvements, provided energy intensity is represented at an appropriate level of disaggregation to provide meaningful interpretation, and other explanatory and behavioral factors are isolated and accounted for, such as climate. A simple intensity measure can be calculated (as Energy/Sales), but this number has little information content without the underlying sector detail.

Table 6: Correlation between estimated efficiency score and energy intensity for the baseline year

	rank_o~e	rank_o~y
rank_on_ef~e	1.0000	
rank_on_en~y	-0.3826	1.0000

The correlation coefficient is -0.3826 for the baseline year for the PAT Scheme indicating low strength of association between the two and the importance of the role of other explanatory factors causing changes in the energy use that have no bearing on the efficiency with which energy is used. Hence, the relationship between the two is less clear-cut.

We calculated the Spearman Correlation Coefficient between ranks based on efficiency scores and target SEC under PAT Cycle I, which is quite low 0.0031. Hence, we could not reject the null hypothesis that the two ranks are independent and this questions the rationality of target setting mechanism of PAT Cycle I. There is a scope to explore this aspect of PAT Scheme in more detail.

5. Conclusion

We analyse the determinants of energy efficiency in the Indian energy intensive sectors by means of a stochastic energy demand frontier analysis. We estimate the energy demand function allowing for firm heterogeneity by using official firm-level production data from Prowess maintained by CMIE. Furthermore, we analyse potential drivers of energy efficiency. The selection of drivers in our analysis is based on the relevance for research and policy. For our analysis we use focus on participation of firms in PAT Cycle I, sector dummies and the scale of production or size of firms using net fixed assets as a proxy variable.

First of all, our analysis shows that there is potential to increase the energy efficiency in all analysed industries, although the energy efficiency scores are in general not very low. The variety in energy efficiency scores at the industry level reflects the heterogeneity of the firms and sectors. The mean is high for petroleum sector and not very behind is Iron and Steel Industry. On the other hand, score is lower for the Fertiliser and Paper & Pulp industries. Thus, the time-varying energy efficiency might be increased by optimizing production processes according to an industry benchmark.

It is also found that large size firms tend to be in general more energy efficient which could be due to economies of scale through better material and managerial efficiency. The firms under PAT Cycle I in general are similar to their counterparts in PAT Cycle 2 which seems plausible since the market-based Perform Achieve and Trade scheme was introduced in India to enhance the energy efficiency of the energy-intensive sectors plants by reducing their specific energy consumption within the framework of a tradable certificate schemes and with the policy announcement, the inefficient or high energy consuming firms tried to minimize their energy consumption.

Increasing energy efficiency plays a crucial role in current energy and climate policies. However, little is known about the determinants and drivers of industrial energy demand and energy efficiency. Therefore, insights into these developments are needed. This can help to improve the efficiency of current and future policy instruments and thus to achieve the overarching climate and energy policy targets. The energy intensive sectors used in the study seem to play an important role in achieving these goals. In our analysis, we haven't analyzed the effects of policy on forms' behavior. Firms might have changed their input-mix, reduced higher intensity energy sources or used better efficient technology. This needs to be analyzed in further research if the data permits.

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