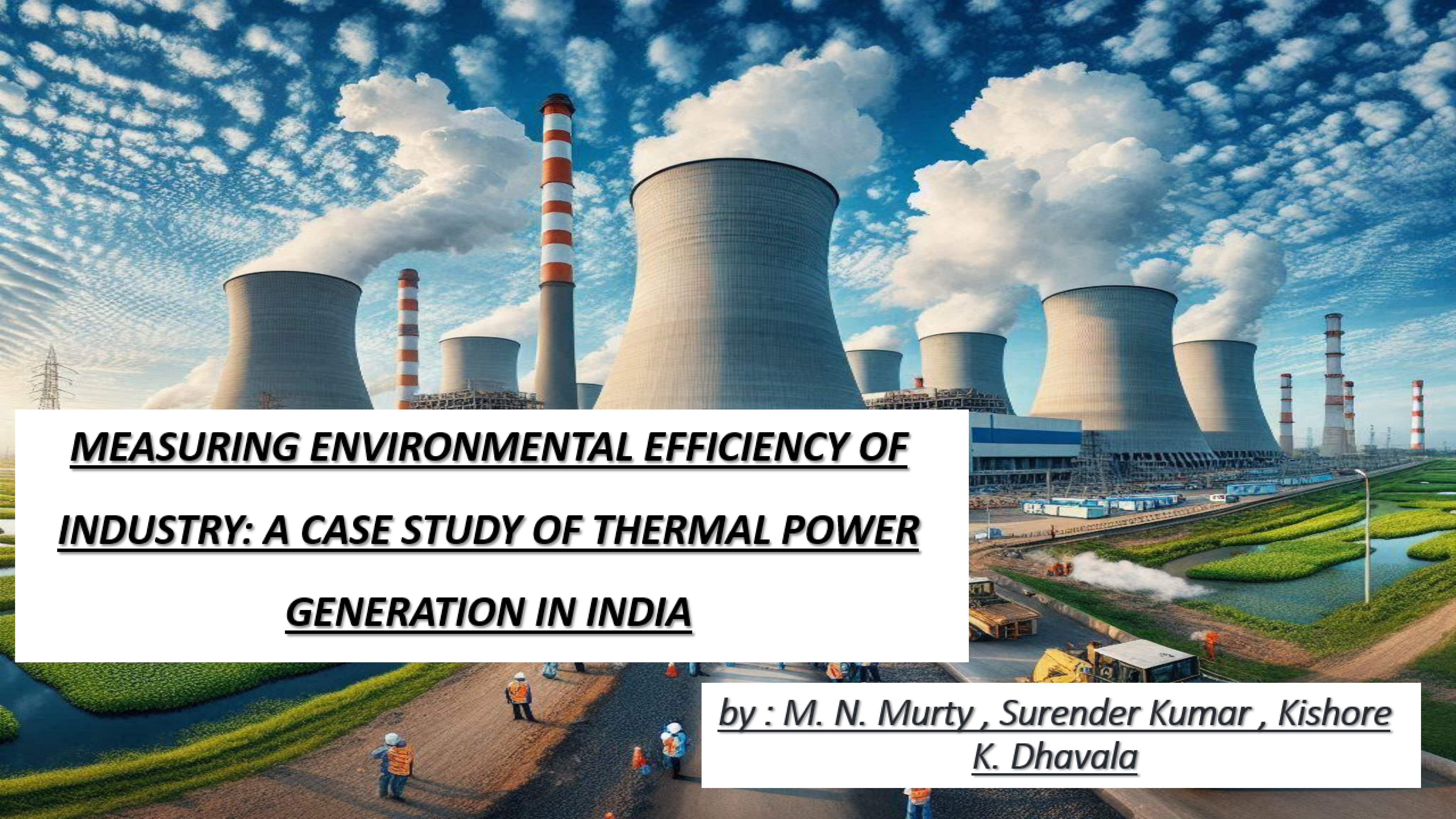
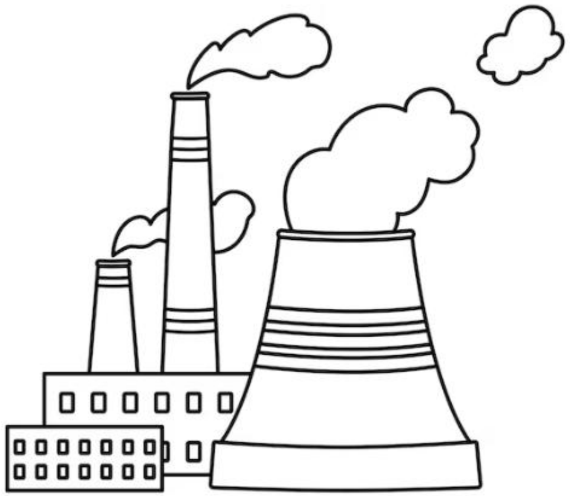


MEASURING ENVIRONMENTAL EFFICIENCY OF INDUSTRY: A CASE STUDY OF THERMAL POWER GENERATION IN INDIA

by : M. N. Murty , Surender Kumar , Kishore K. Dhavala

Objective of the Study

The paper aims to evaluate the technical and environmental efficiency of coal-fired thermal power plants in Andhra Pradesh, India, using a model that jointly considers the production of good outputs (electricity) and bad outputs (pollutants like SPM, SO_2, and NO_x).



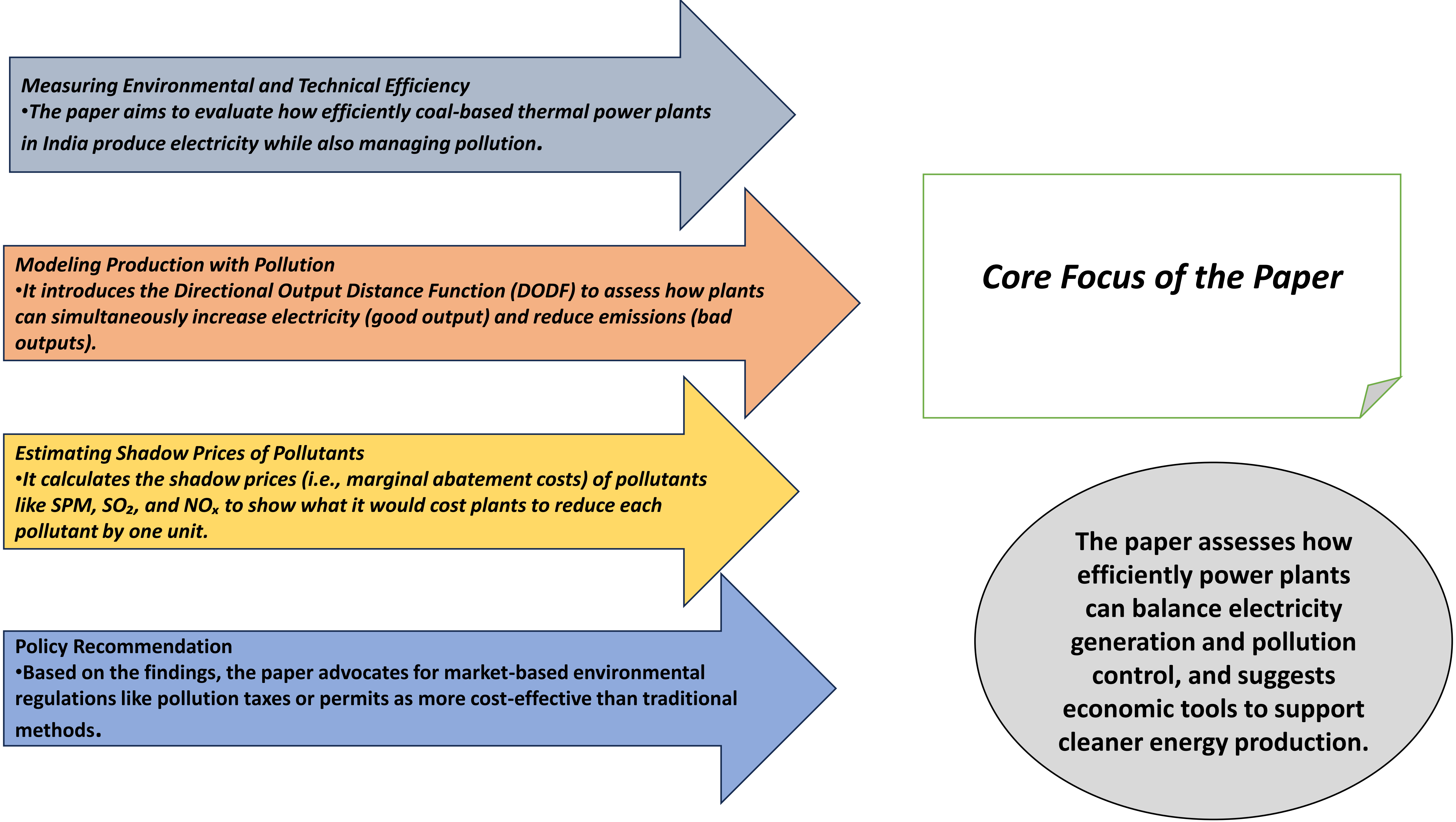
Methodology

- **Data collected from 5 coal-fired thermal power plants under APGENCO, Andhra Pradesh**

- **Timeframe: 1996–97 to 2003–04 (8 years)**
- **Observations: 480 monthly data points**

Estimated <u>shadow prices</u> of pollutants and <u>Morishima elasticity of substitution</u>.

Model Used: Directional Output Distance Function (DODF)
A **distance function** measures how far a firm is from being **fully efficient**.


Measuring Environmental and Technical Efficiency
•The paper aims to evaluate how efficiently coal-based thermal power plants in India produce electricity while also managing pollution.
Modeling Production with Pollution
•It introduces the Directional Output Distance Function (DODF) to assess how plants can simultaneously increase electricity (good output) and reduce emissions (bad outputs).
Estimating Shadow Prices of Pollutants
•It calculates the shadow prices (i.e., marginal abatement costs) of pollutants like SPM, SO_2, and NO_x to show what it would cost plants to reduce each pollutant by one unit.
Policy Recommendation
•Based on the findings, the paper advocates for market-based environmental regulations like pollution taxes or permits as more cost-effective than traditional methods.
Core Focus of the Paper
The paper assesses how efficiently power plants can balance electricity generation and pollution control, and suggests economic tools to support cleaner energy production.

RESULTS OF QUANTITATIVE ANALYSES

- **The average firm-specific inefficiency was 0.06, implying that firms can increase electricity output by 6% and simultaneously reduce emissions by 6% without additional resources.**

Shadow Prices

- **SPM: ₹4777**
- **SO_2: ₹1883**
- **NO_x: ₹6725**

- **Shadow prices vary across firms and over time, indicating heterogeneous abatement costs.**

- **Most efficient plant: NTS = 0.033 (inefficiency)**
- **Least efficient plant: KTPS = 0.115 (inefficiency)**

Morishima Elasticity of Substitution (MES):

- **Electricity–SPM: –0.243**
- **Electricity–SO_2: –0.73**
- **Electricity–NO_x: –0.135**

- **It's difficult and expensive for power plants to increase electricity while reducing pollution at the same time.**

Policy Suggestions from Murty et al. (2007):

•**Use of Marginal Abatement Costs (MACs):**
Helps design pollution taxes based on cost-effective reduction.
•**Plant-Specific Emission Targets:**
Recommends avoiding uniform standards; target inefficient plants instead.
•**Link Production & Environmental Efficiency:**
Policies should encourage both cleaner and more efficient operations.
•**Support Market-Based Tools:**
Suggests pollution permits or incentives for adopting cleaner technologies.

Why This Study Stands Out

Objective

- Focused on both **technical and environmental efficiency**, making it highly relevant for policy and sustainability discussions.

Model & Data

- Applied an **advanced econometric model (DODF)** to capture real-world trade-offs between outputs and emissions.
- Used **reliable secondary data** from **actual power plant operations** (not simulated), enhancing practical relevance.

Results & Calculations

- Accurately estimated **plant-level inefficiencies** and **shadow prices** of pollutants.
- Results are **quantitative and actionable**—helpful for cost-based pollution control.

Structural Strengths of Murty et al. (2007)

- ✅ **Clear Objective: Well-defined aim linking efficiency with environmental policy**
- ✅ **Strong Methodology: Uses advanced DODF + SFA model for realistic analysis**
- ✅ **Empirical Rigor: Based on real plant-level data (480 observations)**
- ✅ **Logical Flow: Smooth progression from theory → model → results → policy**
- ✅ **Actionable Insights: Ends with clear, policy-relevant recommendations**

Where the Paper Falls Short.

1. Narrow Data Scope

- Study is limited to **5 thermal plants** in **one state (Andhra Pradesh)**
- **Not representative** of India's diverse power sector

2. No Consideration of CO_2

- Focuses only on **SPM, SO_2, and NO_x**
- Omits **CO_2**, a key global pollutant in climate policy

3. No Real Policy Compliance Analysis

- Does not assess **actual environmental regulation enforcement** or compliance costs
- Unlike other studies, lacks a **regulatory performance angle**

4. Static Analysis

- Doesn't explore **dynamic changes or trends** in efficiency over time in depth
- Lacks forward-looking or **predictive insights**

What's Missing in the Study ?

•*CO_2 Emissions:* The study excludes carbon dioxide, a key greenhouse gas in global climate policy.

•*National Coverage:* Only 5 plants in Andhra Pradesh are studied – not representative of India's entire power sector.

•*Regulatory Assessment:* Lacks evaluation of actual policy enforcement or compliance behavior.

•*Dynamic Trends:* The study looks at only one time period (2000–2001) rather than tracking changes over multiple years.

Aspect	Murty et al. (2007)	Sahoo et al. (2021)
Main Focus	Measuring environmental & technical efficiency and shadow prices of pollutants	Evaluating the normalization process in India's PAT scheme for thermal power plants
Methodology	Directional Output Distance Function (DODF) with Stochastic Frontier Analysis	4-stage DEA + Tobit Regression to study effect of uncontrollable factors
Data Scope	5 APGENCO power plants, monthly data (1996–2004)	69 plants across India, PAT Cycle 1 data
Outputs Considered	Electricity (good), and SPM, SO_2, NO_x (bad)	Only electricity; focuses on energy efficiency targets, not direct pollutant emissions
Key Variables	Inputs: Coal, Capital, Wages; Outputs: Electricity & Pollutants	Inputs: Coal use, capacity, fuel quality; External factors: outages, GCV, maintenance
Pollution Treatment	Explicit modeling of pollution and marginal abatement cost	Pollution only indirectly addressed via energy efficiency and normalization criteria

Aspect	Murty et al. (2007)	Kumar & Rao (2003)
Main Focus	Measuring environmental & technical efficiency + estimating shadow prices of pollutants	Impact of environmental regulation on production efficiency of thermal power plants
Methodology	Directional Output Distance Function (DODF) + Stochastic Frontier Analysis (SFA)	Stochastic Output Distance Function using Translog functional form + inefficiency modeling
Pollution Consideration	Directly includes pollutants (SPM, SO_2, NO_x) as bad outputs	No pollutant quantities; uses a compliance dummy (ENVS) to capture regulation
Data Scope	5 APGENCO thermal plants (Andhra Pradesh), monthly data from 1996–2004	33 plants across India (CEA data, 1991–92), national coverage

What Murty et al. (2007) Can Improve

1. Broader Data Coverage

- **Current:** Only 5 plants (APGENCO, Andhra Pradesh)
- **Compared To:** Sahoo covers 69 plants PAN India; Kumar & Rao include 33 plants
- **Improvement:** Expand plant sample for **national-level generalizability**

2. Inclusion of CO_2 Emissions

- **Current:** Only models SPM, SO_2, NO_x
- **Compared To:** Sahoo addresses India's **climate policy context**
- **Improvement:** Add **CO_2** for climate relevance and international policy alignment

3. Policy Implementation Analysis

- **Current:** Suggests market tools but doesn't assess real-world compliance
- **Compared To:** Sahoo deeply critiques **PAT scheme implementation**
- **Improvement:** Analyze **policy effectiveness**, plant-level compliance costs, or incentives

4. Dynamic Trend Modeling

- **Current:** Static analysis of one time period
- **Compared To:** Kumar & Rao use panel data (1996–2000)
- **Improvement:** Use **multi-year or panel data** to study performance over time

5. Address Model Sensitivity

- **Current:** Model 3 (NO_x) fails key theoretical properties
- **Compared To:** Other studies maintain consistency
- **Improvement:** Strengthen model robustness to avoid result variation based on pollutant choice

REFERENCES

1. Environmental and Resource Economics, 38(1), 31–50. Sahoo, N. R., Mohapatra, P. K. J., & Mahanty, B. (2021). Examining the Process of Normalising the Energy-Efficiency Targets for Coal-Based Thermal Power Sector in India. Energy Policy, 156, 112386.

2.Kumar, S., & Rao, D. N. (2003). Environmental Regulation and Production Efficiency: A Case Study of the Thermal Power Sector in India. The Journal of Energy and Development, 29(1), 81–94.

Thank You

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