

Peer-reviewed research

What Drives Public Spending Efficiency in the Energy Sector? Insights From Indian States

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Keywords: Efficiency, Energy sector, Public sector spending, Indian states

JEL Classifications: C14 Semiparametric and Nonparametric Methods: General, H50 General, P48 Political Economy - Legal Institutions - Property Rights - Natural Resources - Energy - Environment - Regional Studies, Q48 Government Policy

<https://doi.org/10.46557/001c.132418>

Energy RESEARCH LETTERS

Vol. 7, Issue 3, 2026

This study aims to (1) investigate the efficiency of public spending in the energy sector across Indian states and (2) examine the key factors influencing this efficiency. The findings reveal significant disparities in energy sector efficiency among states and underscore the pivotal roles of governance and education in enhancing energy sector efficiency, as opposed to economic growth and fiscal deficit. Therefore, it is suggested that enhancing governance and education should be prioritized to improve energy sector efficiency in Indian states.

I. Introduction

Governments are under pressure to optimize resource utilization and enhance transparency in delivering public goods, particularly at the regional level where resources may be limited. This requires effective allocation of resources, a topic important to both researchers and policy-makers. Measuring public spending efficiency in the energy sector contributes to Sustainable Development Goal 7 (SDG 7) by ensuring affordable and clean energy and supports the target of doubling the global rate of energy efficiency improvement by 2030. This is important for informed decision-making, meeting citizens' expectations, and delivering essential services while achieving sustainable outcomes in the energy sector. Therefore, the study aims to examine public spending efficiency in the energy sector and explore factors influencing efficiency in Indian states.

Previous studies have investigated energy efficiency across various countries, including the United States (Antunes et al., 2023), China (Li & Shi, 2014; Wang et al., 2024), South Africa (Aye et al., 2018), West Africa (Sarpong et al., 2022), and French households (Charlier, 2015). Xing et al. (2021) indicate that marketization enhances energy efficiency in China, with industrial structure upgrades as a key intermediary. Bongers (2020) discusses the rebound effect, showing that improved energy efficiency can increase energy consumption and emissions. Additionally, some lit-

erature has identified the factors influencing energy efficiency (Sadorsky, 2013; Sarpong et al., 2022).

Measuring public spending efficiency in the energy sector is important for Indian states facing specific challenges in the energy sector.¹ While global studies often focus on advanced economies with established energy markets, India is working towards universal energy access, especially in rural and underserved areas. State-level disparities in economic growth, governance quality, infrastructure, and socio-economic conditions significantly influence energy efficiency, making it difficult to generalize findings from other countries. Additionally, India's environmental challenges, such as air pollution and climate change, highlight the need for efficient public spending on renewable and clean energy. Unlike more centralized nations, India's federal structure requires tailored approaches to energy efficiency, as state-specific governance and fiscal conditions play a significant role. Key questions include whether Indian states are effectively utilizing their public spending in the energy sector and what factors influence this spending efficiency. This paper addresses these research questions.

Most research on energy sector efficiency focuses on advanced or European nations, with limited attention to the Asian region, notably India. While studies like Mohanty and Bhanumurthy (2020) have examined public expenditure efficiency in social sectors, and Mohanty et al. (2023) explored aggregate public sector efficiency, none have specif-

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¹ In 2021-22, the energy sector's share of Gross State Domestic Product (GSDP) ranges from 0.05% to 4.48% across Indian states. Over the past three years (2019-20 to 2021-22), the average public expenditure on the energy sector as a percentage of GSDP has varied between 0.03% and 4.29%.

ically addressed energy sector spending efficiency and its determinants using current data. This study fills that gap by analyzing energy spending efficiency and its determinants across Indian states. Notably, it evaluates and determines the efficiency of public sector spending in the energy sector using recent data for all Indian states. The findings emphasize the roles of governance and education in enhancing energy sector efficiency.

The rest of the paper is structured as follows: Section II discusses the data and methodology, Section III presents the empirical analysis, and Section IV provides the conclusions of the study.

II. The Data and Methodology

This study examines public spending efficiency in the energy sector across all 28 Indian states for the periods 2015-16, 2018-19, and 2021-22.² It considers key variables such as total public spending in the energy sector, per capita power availability (kilowatt-hour), installed power capacity (megawatt), economic growth, education, fiscal deficit, and governance index. Data for these variables, comprising both outlays and outputs, are sourced from reliable sources including the Handbook of Statistics on Indian States (HSIS), Reserve Bank of India (RBI), Central Statistics Office (CSO), EPWRF India Time Series, and Public Affairs Centre (PAC). Economic growth is measured by the growth rate of per capita gross state domestic product, while the educational level of states is indicated by the gross enrolment ratio for higher education. The governance index is represented by the Public Affairs Index (PAI) from the PAC. Given non-contemporaneous outlay-output relationships, the study calculates three-year averages for public spending in the energy sector and evaluates annual outputs.

The empirical analysis consists of two steps. Firstly, data envelopment analysis (DEA) is employed to assess the efficiency of public spending in the energy sector, utilizing the Output-Oriented approach (Banker et al., 1984). The output efficiency score of a Decision-Making Unit (DMU) indicates proportional output increase potential without altering input. Secondly, the Tobit model is utilized to analyze the determinants of energy sector public spending efficiency, as detailed in section III B. The empirical results are subsequently presented and discussed in the following section.

III. Empirical Results

This section is divided into two parts: initially, I examine the results of the DEA analysis, and subsequently, I discuss the findings from the Tobit model analysis.

A. The results of the DEA analysis

In the DEA setup, the study utilized two outputs: per capita power availability (kilowatt-hour) and installed power capacity (megawatt) per thousand population, with total public spending in the energy sector as a percentage of GSDP³ considered as the input. [Table 1](#) presents the calculated energy efficiency scores, while [Figure 1](#) illustrates the corresponding inefficiency scores. Seven states—Goa, Gujarat, Himachal Pradesh, Kerala, Punjab, Sikkim, and Uttarakhand—were found to be energy efficient in 2021. In contrast, eastern states such as Jharkhand and Bihar, along with northeastern states like Assam and Manipur, showed lower energy performance.

Consistent positive performance was observed in Goa, Kerala, Punjab, Sikkim, and Uttarakhand across the periods of 2015, 2018, and 2021.⁴ On average, states produced only 58% of their potential energy output, indicating a significant opportunity for a 42% enhancement without increasing current energy expenditures. From 2015 to 2021, notable improvements in energy efficiency were documented in Andhra Pradesh, Arunachal Pradesh, Haryana, Rajasthan, and Telangana. The DEA analysis highlights the varied efficiency in the energy sector among Indian states. The subsequent section will discuss the factors contributing to these differences.

B. What determines public spending efficiency in the energy sector?

According to the literature, three principal factors affecting efficiency are Resources, Institutions, and Endowment (Mohanty & Bhanumurthy, 2020). The per capita GSDP growth rate and fiscal deficit serve as indicators of resources, the governance index represents institutions, and education acts as a proxy for endowment. Economic growth stimulates energy demand through industrialization and urbanization, facilitating investment in renewable energy sources. Nevertheless, rapid expansion can put pressure on resources, leading to inefficiencies. High fiscal deficits constrain government spending, indicating instability and deterring private investment. Effective fiscal management,

2 The study begins in 2015, following Telangana's formation in 2014, to avoid excluding the State. It concludes in 2021 due to data availability constraints for key variables.

3 The study context involves a single input, since total public spending can be divided into revenue and capital spending. However, capital spending on energy is zero or negligible for some states. Therefore, these components are consolidated into one input: total public spending on energy, due to the constraints of data availability. This approach is consistent with those of Antunes et al. (2023) and Mohanty et al. (2023), who have also used a single input in their DEA setup.

4 The decline in efficiency of the energy sector in Gujarat and Himachal Pradesh in 2018 might be due to reduced public spending on energy relative to GSDP, lower economic growth, and reduced installed power capacity. Additionally, shifts in public policies, like the implementation of Goods and Services Tax (GST), may have influenced private investment incentives, impacting the energy spending efficiency.

Table 1. Public spending efficiency in the energy sector of Indian states

State	2015		2018		2021		Peer Group
	Efficiency Score	RANK	Efficiency Score	RANK	Efficiency Score	RANK	
Andhra Pradesh	0.56	14	0.71	12	0.76	12	Gujarat, Himachal Pradesh, Sikkim.
Arunachal Pradesh	0.3	21	0.29	20	0.5	18	Goa, Sikkim.
Assam	0.2	22	0.14	25	0.17	26	Gujarat, Punjab.
Bihar	0.09	28	0.1	28	0.15	27	Gujarat, Punjab.
Chhattisgarh	0.91	8	0.61	14	0.64	14	Goa, Gujarat, Sikkim.
Goa	1	6	1	1	1	4	Goa.
Gujarat	1	2	0.96	6	1	1	Gujarat.
Haryana	0.81	11	0.84	8	0.99	8	Gujarat, Punjab.
Himachal Pradesh	1	6	0.81	9	1	4	Himachal Pradesh.
Jharkhand	0.14	26	0.11	27	0.15	28	Gujarat, Punjab.
Karnataka	0.58	13	0.64	13	0.66	13	Gujarat, Himachal Pradesh, Sikkim.
Kerala	1	2	1	1	1	1	Kerala.
Madhya Pradesh	0.47	17	0.45	16	0.53	17	Goa, Gujarat, Sikkim.
Maharashtra	0.81	10	0.73	11	0.87	10	Himachal Pradesh, Uttarakhand.
Manipur	0.14	27	0.13	26	0.17	25	Gujarat, Punjab.
Meghalaya	0.37	19	0.34	19	0.44	19	Himachal Pradesh, Uttarakhand.
Mizoram	0.2	23	0.26	22	0.28	22	Goa, Sikkim.
Nagaland	0.15	25	0.16	24	0.18	24	Goa, Gujarat, Sikkim.
Odisha	0.52	15	0.38	18	0.53	16	Himachal Pradesh, Uttarakhand.
Punjab	1	1	1	1	1	4	Punjab.
Rajasthan	0.48	16	0.47	15	0.62	15	Goa, Gujarat, Sikkim.
Sikkim	1	2	1	1	1	1	Sikkim.
Tamil Nadu	0.83	9	0.77	10	0.77	11	Gujarat, Himachal Pradesh.
Telangana	0.78	12	0.84	7	0.95	9	Gujarat, Punjab.
Tripura	0.36	20	0.43	17	0.38	20	Himachal Pradesh, Uttarakhand.
Uttar Pradesh	0.2	24	0.24	23	0.28	23	Goa, Punjab.
Uttarakhand	1	2	1	1	1	4	Uttarakhand.
West Bengal	0.37	18	0.28	21	0.37	21	Himachal Pradesh, Uttarakhand.

Note: This table reports the results of the DEA analysis of public spending efficiency scores in the energy sector of Indian states for the years 2015, 2018, and 2021.

good governance, and high-quality education enhance energy sector efficiency, thus promoting sustainability.

In the Tobit model estimation, inefficiency scores are derived by subtracting the efficiency scores from one, expressed as Inefficiency (I) = 1 - efficiency score. Subsequently, all states with $I \leq 0.05$ (indicating fully efficient states) are censored, and the dependent variable (E) is set to 0 (E value = 0). For other cases, E is assigned a value of 1. This approach results in the formation of a group comprising efficient states with efficiency scores of at least 0.95. The standard Tobit model is defined as follows:

$$E_i^* = X_i\beta + \epsilon_i \quad (1)$$

$$E_i = E_i^*, \text{ if } E_i^* > 0 \quad (2)$$

$$E_i = 0, \text{ otherwise.} \quad (3)$$

where the latent variable E_i^* represents the inefficiency scores of the energy sector. X_i is a vector of explanatory variables which includes the governance index (GOVI)²⁰, economic growth (GRW), education (EDU), and fiscal deficit as a percent of GSDP (FDG). β is a vector of parameters, i represents the number of states, and ϵ_i denotes an error term. To examine both direct and indirect impacts, pairwise interaction terms, namely $GRW*GOVI$, $GRW*EDU$, $GOVI*EDU$, and $GOVI*FDG$, have been incorporated. Descriptive statistics and pairwise correlations of the selected variables are provided in Table 2.

Table 2. Descriptive statistics and pairwise correlations

Statistics	Energy_Ineff.	GRW	GOVI	EDU	FDG	GRW*GOVI	GRW*EDU	GOVI*EDU	GOVI*FDG
Mean	0.38	8.14	0.02	61.58	4.04	0.05	504.26	6.37	-0.04
Median	0.37	8.50	-0.09	61.65	3.96	-0.68	478.15	-4.55	-0.34
Maximum	0.85	12.00	1.62	94.10	10.56	17.80	935.00	137.53	5.51
Minimum	0.00	3.00	-1.42	35.80	1.75	-12.76	107.40	-71.89	-8.27
Std. Dev.	0.32	2.49	0.74	15.50	1.67	6.62	199.24	47.84	3.31
Skewness	0.12	-0.44	0.05	0.13	2.15	0.39	0.03	0.66	-0.41
Kurtosis	1.53	2.32	2.48	2.19	9.56	3.44	2.37	3.18	3.16
Observations	28	28	28	28	28	28	28	28	28
Pairwise Correlation									
Variables	Energy_Ineff.	GRW	GOVI	EDU	FDG	GRW*GOVI	GRW*EDU	GOVI*EDU	GOVI*FDG
GRW	0.07 [0.74]	1							
GOVI	-0.59 [0.00]	-0.05 [0.81]	1						
EDU	-0.70 [0.00]	0.08 [0.70]	0.48 [0.01]	1					
FDG	0.17 [0.39]	-0.12 [0.55]	-0.09 [0.66]	0.23 [0.24]	1				
GRW*GOVI	-0.51 [0.01]	0.04 [0.86]	0.97 [0.00]	0.41 [0.03]	-0.21 [0.29]	1			
GRW*EDU	-0.32 [0.10]	0.80 [0.00]	0.25 [0.20]	0.63 [0.00]	0.06 [0.78]	0.30 [0.12]	1		
GOVI*EDU	-0.54 [0.00]	-0.07 [0.73]	0.97 [0.00]	0.45 [0.02]	-0.09 [0.65]	0.95 [0.00]	0.22 [0.25]	1	
GOVI*FDG	-0.62 [0.00]	-0.22 [0.27]	0.93 [0.00]	0.42 [0.02]	-0.24 [0.21]	0.89 [0.00]	0.07 [0.73]	0.92 [0.00]	1

Notes: This table presents selected descriptive statistics and a pairwise correlation matrix of the energy inefficiency score (Energy_Ineff), economic growth (GRW), governance (GOVI), fiscal deficit (FDG), and the pairwise interaction terms (GRW*GOVI, GRW*EDU, GOVI*EDU, and GOVI*FDG). Figures in parentheses are p-values.

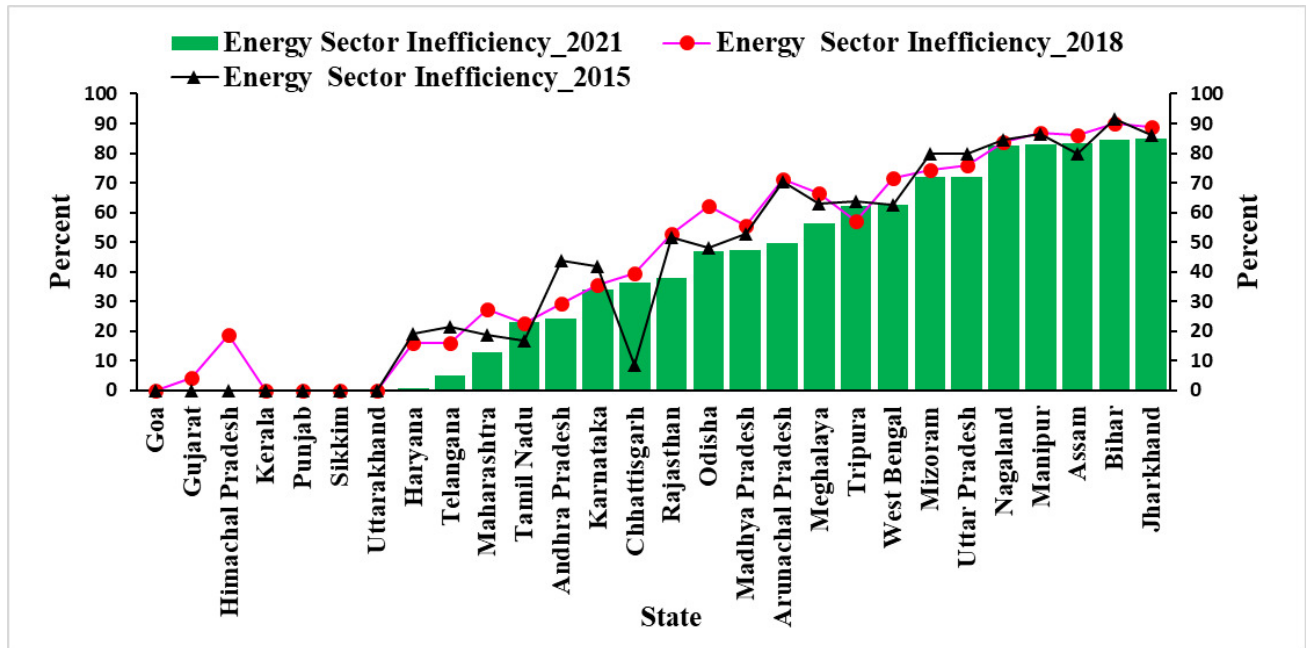


Figure 1. Public spending inefficiency in the energy sector of Indian states

Note: This figure displays the public spending inefficiency in the energy sector of Indian states for the years 2015, 2018, and 2021.

Table 3 presents the results from 11 Tobit models utilized for robustness checks. The findings indicate that governance consistently exerts a significant negative impact on inefficiency across all models, corroborating Antunes et al. (2023), who observed a strong influence of political factors, such as governance, on energy efficiency. Similarly, Li & Shi (2014) emphasized the critical role of government regulations in enhancing energy efficiency.

Furthermore, the results reveal that economic growth, except in Model 4, does not significantly affect public spending inefficiency. This finding contrasts with studies by Sarpong et al. (2022) and Sadorsky (2013), where economic growth played a more consistent role in energy intensity and efficiency. However, the interaction between governance and economic growth is negative and statistically significant in Models 2 and 5, suggesting that while economic growth alone may not reduce inefficiency, improved governance enhances resource allocation and utilization in high-growth contexts. This supports the literature positing that governance is central to efficient public spending (Mohanty & Bhanumurthy, 2020). Additionally, education consistently reduces inefficiency, underscoring the importance of human capital, as evidenced by Mohanty and Bhanumurthy (2020) in the context of social sector efficiency.

In contrast, fiscal deficits are associated with increased inefficiency in Models 7, 8, and 11. Nevertheless, the interaction between governance and fiscal deficit is negative and significant, indicating that effective governance can counteract the inefficiencies typically associated with fiscal strain. This finding challenges the prevalent assumption that high fiscal deficits inevitably result in inefficiency and

contributes to the literature by emphasizing how governance can alleviate fiscal challenges, an area not thoroughly examined in prior studies such as those by Sarpong et al. (2022), Sadorsky (2013), and Mohanty and Bhanumurthy (2020).

IV. Conclusion

The study investigates public spending efficiency in the energy sector and the factors influencing this efficiency in Indian states. The DEA approach identifies significant variations in energy sector efficiency among Indian states. Results from the Tobit model analysis indicate that governance and education play important roles in enhancing energy sector efficiency, highlighting the importance of quality governance and education. The negative and statistically significant coefficients of the interaction terms suggest that energy sector efficiency increases with improved governance and education. Consequently, states that engage the public in energy conservation campaigns and promote awareness about sustainable energy practices may experience enhanced energy efficiency.

Acknowledgement

The author would like to thank the anonymous referees and the editor for their useful comments and suggestions. However, the errors, if any, are mine.

Submitted: January 28, 2024 AEDT. Accepted: December 24, 2024 AEDT. Published: April 01, 2026 AEDT.

Table 3. Factors affecting public spending inefficiency in the energy sector

Variables	1	2	3	4	5	6	7	8	9	10	11
GRW	0.013 [0.026]	0.018 [0.028]	0.024 [0.022]	0.116** [0.044]	0.027 [0.022]	0.024 [0.022]			0.013 [0.026]	-0.004 [0.026]	0.028 [0.019]
GOVI	-0.325*** [0.091]		-0.157* [0.08]	-0.198** [0.088]			-0.122 [0.074]		-0.318*** [0.091]		-0.1 [0.074]
EDU			-0.015* [0.004]		-0.017*** [0.004]	-0.016*** [0.004]	-0.017*** [0.004]	-0.017*** [0.004]			-0.018*** [0.004]
FDG							0.066** [0.028]	0.052* [0.029]	0.023 [0.037]	-0.008 [0.038]	0.072** [0.027]
GRW* GOVI		-0.032** [0.011]			-0.015* [0.009]						
GRW* EDU				-0.002* [0.001]							
GOVI* EDU						-0.002* [0.001]					
GOVI* FDG								-0.032* [0.016]		-0.076*** [0.021]	
Constant	0.23 [0.228]	0.181 [0.239]	1.088*** [0.273]	0.209 [0.199]	1.134*** [0.273]	1.149*** [0.271]	1.130*** [0.221]	1.151*** [0.207]	0.13 [0.277]	0.398 [0.282]	0.953*** [0.243]
LR chi2	11.66***	8.57**	24.68***	19.42***	24.01***	24.13***	28.49***	29.47***	12.05**	12.78**	30.84***
N	28	28	28	28	28	28	28	28	28	28	28
Left-cens. observations	8	8	8	8	8	8	8	8	8	8	8

Notes: The figures in parentheses represent standard errors, and *, **, and *** denote significance levels of 10%, 5%, and 1%, respectively. This table presents the results of the Tobit analysis, which examines the impact of *GRW*, *GOVI*, *EDU*, *FDG*, as well as the pairwise interaction terms such as *GRW*GOVI*, *GRW*EDU*, *GOVI*EDU*, and *GOVI*FDG* on public spending inefficiency in the energy sector.



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