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Assessing the Link Between Renewable Energy and Economic Growth: Evidence From Indian States and Union Territories

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India's energy outlook, as a developing country, is poised for transformational change, marked by a greater emphasis on renewable energy generation. This study focuses on the supply side of renewable energy (RE) and its relationship with economic growth across Indian States and Union Territories, setting itself apart from previous literature. By applying panel regression and the generalized method of moments to annual data from selected states and union territories, the study concludes that the deployment of RE can spur innovation-led growth, thereby supporting an endogenous growth mechanism.

I. Introduction

The growth of renewable energy (RE) output at the state level has a substantial and positive effect on state GDP growth, carrying important implications for economic development and energy policy. This relationship highlights the advantages and financial soundness of adopting and expanding RE resources at the state level. Similar conclusions were reached by Aquila et al. (2017) in their study on Brazil.

A key consideration in this area is the distinctive nature of investments in RE. As noted by Martinot (2001), RE projects typically require significant capital outlays for technologies, infrastructure, and skilled personnel, all of which can drive regional economic growth and create new employment opportunities. Wen et al. (2022) further argues that these investments can generate revenue, foster innovation, and stimulate broader economic activity through multiplier effects—contributing, in part, to observed GDP growth.

Fan and Hao (2020) also discuss how the environmental benefits associated with RE can foster economic development. de Serres et al. (2010) observe that states allocating resources to RE experience reduced negative environmental impacts, leading to lower healthcare costs, increased productivity, and enhanced economic resilience to climate-related challenges. Where non-renewable energy (NRE) production at the state level fails to increase GDP, it is important to consider the underlying causes. Established industries reliant on fossil fuels and other traditional NRE sources may not offer the same levels of innovation, job

creation, and economic diversification as their RE counterparts (Masini & Menichetti, 2013). These sectors can also face issues such as resource depletion, volatile markets, and environmental concerns, all of which may hinder sustained long-term economic growth.

In India, the RE sector accounts for 46% of total installed capacity and has led to a 1.75-fold increase in power generation since 2014, benefiting both the environment and the economy. Supply-side growth in RE has reduced tariffs (e.g., Rs. 1.99/kWh in Gujarat), increased domestic output (with 40 GW of modules manufactured), and encouraged investment (such as ₹3,000 crore in Tamil Nadu). Upgrading the grid and storage has addressed efficiency losses (e.g., 8–10% reduction in Karnataka), while scaling RE technologies—such as solar, wind, and inverter technology—has reduced reliance on fossil fuels and created new jobs. Focusing on supply-side RE development is therefore critical, as it addresses key structural and infrastructural barriers limiting widespread RE adoption and its associated economic benefits.

Much of the existing literature has examined the demand side of RE (i.e., consumption) and its relationship with economic growth. For a rapidly developing nation like India, prioritising RE generation and transmission is vital. This study, therefore, concentrates on the supply side of RE (generation), rather than the demand side, aiming to fill a gap in current research by exploring its correlation with economic growth.

In summary, this study has two primary objectives: first, to examine trends in RE generation across India; and sec-

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ond, to analyse the relationship between RE and the economic growth of Indian states and union territories. To accomplish this, the study applies dynamic panel data analysis using the generalised method of moments (GMM) technique. This method was chosen because it is flexible enough to account for state-fixed effects and effectively addresses the endogeneity of independent variables using lagged internal instruments.

II. Data and Methodology

This study uses annual time series data from 30 Indian States and Union Territories (UTs)¹ spanning eight years (2014–15 to 2021–22). Data sources include the Centre for Monitoring Indian Economy – States of India (<https://state-sofindia.cmie.com/>) and energy statistics from various years published by the Ministry of Statistics and Programme Implementation (MOSPI). The analysis aims to empirically investigate the impact of renewable energy (RE) generation on the economic growth of these States and UTs over time.

Traditional perspectives consider capital and labour as the primary drivers of economic growth (Solow, 1956), while endogenous growth theory highlights technological innovation and knowledge spillovers as essential for sustained development. By promoting innovation and technical spillovers that enhance productivity across sectors, renewable energy supports endogenous growth, primarily by increasing energy efficiency (Eliasson & Turnovsky, 2004). In the present study, the production function analysis examines the role of RE in fostering growth in emerging economies like India, rather than focusing solely on conventional factors. Following Azam et al. (2021), the production function is employed to estimate RE's influence on economic growth:

$$GSDP = f(RE, NRE, K, L) \quad (1)$$

where *GSDP* is real gross state domestic product, *RE* is renewable energy generation, *NRE* is non-renewable energy generation, *K* is gross fixed capital formation, and *L* is labour force.

To investigate the relationship between *RE* and the economic growth of Indian states/UT, the first step is to estimate the panel regression model. Further, all variables are expressed in growth rates. The equation for panel regression is as follows:

$$y_{it} = X'_{it}\beta + u_{it} \quad (2)$$

where y_{it} is dependent variable, X'_{it} represents explanatory variables, β is coefficient, u_{it} is error term, i represents each state in the panel and t denotes years in time-dimension. Thus, Equation (1) can be presented as the following panel regression model:

$$GSDP_{it} = \beta_0 + \beta_1 RE_{it} + \beta_2 NRE_{it} + \beta_3 GFCF_{it} + \beta_4 L_{it} + u_{it} \quad (3)$$

However, the issue of heterogeneity arises due to cross-sectional observations, which can lead to endogeneity problems in panel regression. These issues may result in spurious estimates, incorrect conclusions, and misleading signs for estimators (Ketokivi & McIntosh, 2017). To address endogeneity, the GMM model developed by Arellano and Bond (1991) is employed, utilising lagged explanatory variables as instruments within the GMM framework. The difference GMM estimator is particularly suitable for managing potential endogeneity, given the sample data characteristics ($T = 8 \text{ years}$ and $N = 30 \text{ states/UTs}$) used in this study. Supported by Hansen's J-test and autocorrelation tests, the GMM approach provides reliable and consistent estimators, effectively correcting for bias in dynamic panel data. Thus, Equation (2) takes the following form:

$$y_{it} = \alpha y_{i,t-1} + X'_{it}\beta_1 + \epsilon_{it}$$

$$\epsilon_{it} = u_{it} + \nu_{it}$$

where, y is GSDP (economic growth), i indexes observational units and t indexes time. X is a vector of controls, possibly including lagged values and deeper lags of y . The disturbance term has two orthogonal components: the fixed effects – u_{it} and idiosyncratic shocks – ν_{it}

III. Empirical Findings

According to the International Energy Agency report (2021), Indian States and UTs are global leaders in *RE* integration. However, the level of *RE* penetration varies greatly across these regions. As shown in Figure 1, approximately 97% of India's solar and wind electricity is generated by ten renewable-rich states: Gujarat, Maharashtra, Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Karnataka, Telangana, Kerala, Rajasthan, and Punjab (IEA/NITI Aayog, 2021).

Over the years, although there has been an overall increase in installed *RE* capacity in India, the western and southern regions have experienced the most significant growth in *RE* generation. Additionally, solar and wind energy dominate these regions (see Figure 2). Key factors contributing to this growth include state government initiatives to encourage private installations, supportive policies to attract investment, favourable terrain for renewable installations, and the availability of land. Owing to such policies, northern India has also seen an uptick in *RE* generation, as state governments have collaborated with energy corporations to boost capacity.

While the eastern region has ample opportunities for *RE* expansion—thanks to favourable terrain—a lack of political will has resulted in relatively low *RE* generation over the years. The north-eastern region, with its hilly landscape

¹ States included in this study are Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Goa, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Odisha, Punjab, Rajasthan, Sikkim, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, Uttarakhand, West Bengal, Andaman & Nicobar, Chandigarh, Delhi, Puducherry. States and Union Territories whose data are not available are excluded from the study.

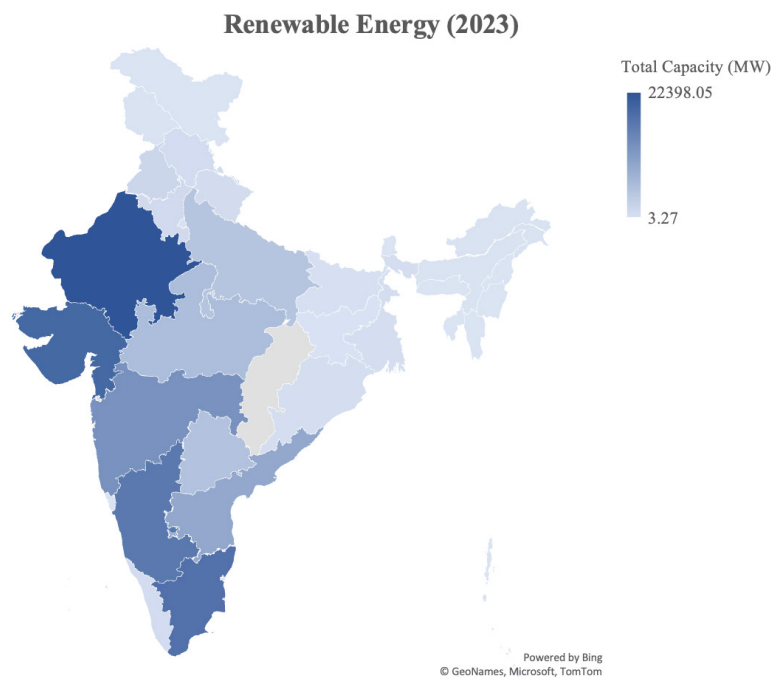


Figure 1. Regional RE cumulative capacity in India

Note: This figure reveals that RE capacity is concentrated in Gujarat/Rajasthan while eastern India lags, which calls for region-focused planning to achieve national objectives. The data is sourced from Energy Statistics 2024.

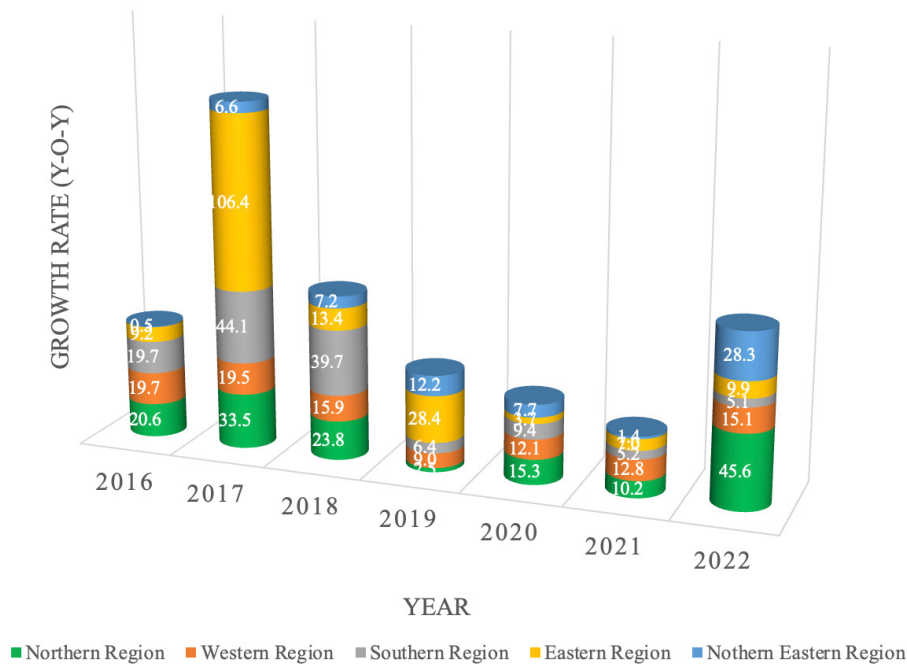


Figure 2. Trends in cumulative installed capacity of grid interactive renewable power

Note: Temporal evolution of zone-wise installed capacity for grid-interactive renewable power systems in India. The data is sourced from Energy Statistics of various years.

and perennial rivers, holds untapped potential for both solar and hydro energy. Since 2019, both the central and local governments have renewed their focus on harnessing this potential, introducing new policies to attract and encourage more private sector participation.

Results from the baseline regression, presented in [Table 1](#), indicate that both *RE* and non-renewable energy (*NRE*) generation have positive and significant effects on economic growth in Indian States/UTs, with *RE* exerting a stronger influence. Conversely, the Generalized Method of

Table 1. Panel regression estimates - Dependent Variable – GSDP

Panel Regression		Differenced GMM	
Variables	Coefficients	Variables	Coefficients
<i>RE</i>	0.11*	<i>GSDP</i> (-1)	0.57*
<i>NRE</i>	0.05**	<i>RE</i>	0.04*
<i>LF</i>	-0.03	<i>NRE</i>	0.18*
<i>GFCF</i>	0.00	<i>LF</i>	0.02
<i>Constant</i>	12.35*	<i>GFCF</i>	0.00
Robustness			
R Square	0.47	Hansen-Sargan J-test	29.67
Durbin Watson	1.85	Prob (J-statistic)	0.45
Prob. (F-statistic)	0.00	AR (1)	0.00
		AR (2)	0.94
		Observations	180

Notes This table reports panel regression (Fixed effect) and first difference GMM based results. * and ** denotes statistically significant at 1% and 5% levels, respectively.

Moments (GMM) results show that *NRE* generation has a greater positive and significant impact on economic growth than *RE*. Specifically, a one percent increase in *RE* generation is associated with a 0.04 to 0.18 percent rise in economic growth in the States/UTs.

The positive coefficient for *RE*, combined with the insignificant effects of labour and capital, supports the endogenous growth mechanism—implying that *RE* deployment encourages development through innovation spillovers rather than traditional inputs. These findings are consistent with studies like Azam et al. (2021), Ohler & Feters (2014), and Apergis & Payne (2011, 2012), all of which found that both *RE* and *NRE* positively influence economic growth rates. However, contrary to Azam et al. (2021), this study suggests that *RE* has a greater impact on economic growth than *NRE*.

Unexpectedly, both labour force and gross fixed capital formation (GFCF) show no significant relationship with economic growth in the States/UTs, diverging from previous research. This could be attributed to India's large informal sector, where unregistered labour and activities may skew the estimation of factor shares.

The reliability of GMM estimators hinges on the use of valid lagged explanatory variables and the absence of serial correlation in the error term. The Arellano and Bond (AR) statistics test residual serial correlation, while the Hansen-Sargan (J-statistics) test ensures instrument validity. The models in this study pass both the AR and J-statistics tests, confirming no serial correlation among first-order residuals and validating the instruments used.

IV. Conclusion

Unlike previous studies, this research emphasises the supply side of renewable energy (RE) and its connection to the economic growth of Indian States/UTs by using panel regression and GMM models. The results demonstrate that *RE* deployment promotes growth through innovation-driven spillover effects rather than traditional inputs, thereby supporting the endogenous growth mechanism. The empirical evidence suggests that India's transition to *RE* is vital for achieving energy security, fulfilling climate commitments, and fostering sustainable development. To accelerate this progress, State and UT authorities might consider implementing strategies such as targeted incentives, skills training for workers, streamlined licensing processes, international partnerships, and increased regional subsidies.

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