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Total Energy Consumption and Economic Growth Nexus: A Panel Framework for major energy consuming States in India.

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Abstract: *This study examined the energy consumption and economic growth nexus in India in panel data framework for 20 major energy consuming States, using data for the period 1997-98 to 2018-19, and taking capital expenditure as the third variable. After employing Panel ARDL Model developed by Peseran et al. (1999) along with three-panel co-integration techniques: the Pedroni (Engle-Granger based) Co-integration Tests, the Kao (Engle-Granger based) Co-integration Tests, the Combined Individual Tests (Fisher/Johansen), study found the existence of positive and significant long term co-integration between the variables under consideration. Panel Granger causality test showed the existence of conservation hypothesis for energy consumption and economic growth, and bidirectional causality between economic growth and capital expenditure as well as between energy consumption and capital expenditure. The findings of the study suggest that policymakers may prioritise energy-saving strategies and the government should invest in ecologically friendly energy infrastructure, renewable energy sources, energy efficiency, and advanced fossil fuel technology to meet its energy needs.*

Key Words: *Energy Consumption, Economic Growth,Capital Expenditure, Panel Cointegration, Panel Granger. Causality*

1. INTRODUCTION:

Every nation has economic growth as one of its primary goals, defined as the rise in market value for goods produced over a specific period. India is emerging as the 5th major economy in the world. Population growth, economic expansion, and energy demand will significantly strain utilizing natural resources in the coming years, particularly in emerging economies. Faster economic expansion since the industrial revolution has resulted in a commensurate rise in energy consumption. (Grossman and Krueger, 1991). India's energy demand has increased over the years due to the country's rapid economic growth (Hdom & Fuinhas, 2020; Tiwari et al., 2021; Udemba et al., 2021). The importance of energy in India's economy has recently increased due to the country's rapid economic growth. Total energy consumption by ultimate consumers in India during 1997-98 was 268,657.87 Gigawatt Hour (GwH) which increased to 294,886.99 Gwh in 2005-06, 751,908.24 GwH in 2013-14, and in 979,151 GwH 2018-19 (Indiastat).As the economy grows to $8.6 trillion by 2040, the International Energy Agency (IEA) projects that energy consumption will expand to meet it, by an equivalent of 1,123 million tonnes of oil.. Renewable energy is an essential component of sustainable growth. Because non-renewable resources release a lot of CO2 into the atmosphere and cause the greenhouse effect, all nations have switched to using renewable energy sources to reduce CO2 emissions. (Shahbaz et al., 2020) Renewable energy, non-renewable energy, capital, and labor positively affect economic growth, with renewable energy consumption having a particularly positive impact in 58% of the sample countries. The long-term nature of capital expenditure, which results in the creation of assets, enables the economy to generate income for many years by expanding or upgrading production facilities and increasing operational effectiveness. Additionally, it raises the capacity of the economy to produce more in the future, increases labor participation, and evaluates the economy. Kolawole & Odubunmi (2015) analyzed that growth and government capital spending were mutually dependent, with growth and FDI establishing a single-direction causal relationship. However, government capital spending and FDI did have a Granger no-causality relationship. Further research showed that government capital spending had a very positive impact on economic expansion. Accordingly, the study advises fostering growth and drawing more FDI into the nation. The government has strongly emphasized capital spending to support the economy after the pandemic. It is anticipated that a rise in government spending will discourage private investment. In recovering the pandemic-damaged economy, capital expenditure was increased by 35.4 percent for the fiscal year 2022–23 to Rs 7.5 lakh crore.

The purpose of this study is to analyze the causal relationship between energy consumption, economic growth, and capital expenditure in order to obtain more detailed information and to add to the existing literature. The remaining portion of this paper is formatted as follows. The review of the literature is shown in section 2. The data and methodology are presented in section 3. The results and discussion were presented in section 4. And the conclusion and some recommendations were made in section 5 and Section 6, respectively.

2. LITERATURE REVIEW:

This paper investigates the impacts of energy consumption and capital expenditure on economic growth in India.

Linkages between energy consumption and economic growth

Many researchers have investigated the causal relationship between energy consumption and economic growth using data from countries like the USA, Taiwan, and India (Kraft & Kraft., 1978; Chang et al., 2001; Ghosh & Kanjilal, 2020). The approaches of heterogeneous non-causality fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) are used. The empirical investigation supports a long-term link between the use of renewable energy and economic growth (Shahbaz et al., 2022). Another study studied the Granger-causal relationship between India's state and sectoral power consumption and economic growth using panel VAR-based impulse-response model . The study analyses 18 central Indian states' economic growth, industrial growth and growth in agriculture sector from 1960–1961 to 2014–2015. The findings confirm the idea that economic growth and power use are only linked in agriculture.(Ozturk, 2010; Tiwari et al., 2021). Another study looked at the BRICS taking he period 1992 to 2013 using the Im, Pesaran, and Shin panel unit root test, the Bootstrap panel causality test, and the Westerlund and Edgerton bootstrap LM panel cointegration test and found that the growth hypothesis holds in Brazil and India, but the conservation hypothesis holds in China and South Africa (Aydin, 2019).

Linkages between capital expenditure and economic growth

Expansionary public spending is a well-liked key fiscal measure when budgetary resources are limited to achieve higher economic growth with the anticipation of a more significant multiplier effect on the world's productive sectors. Bista & Sankhi (2022) employed the structural vector auto-regressive (SVAR) method to analyze time series data sets of public spending and economic growth from 1974–1975 to 2018–19 to evaluate the multiplier effects of public expenditure on economic growth in Nepal. According to the SVAR model, public, ongoing, and capital expenditures positively affect economic growth. The study used the Denison growth accounting method and concludes that social expenditure might have a sizable effect on economic activity in the short run. In a post-Keynesian growth model with a favourable saving propensity out of wages, Parui (2021)evaluated the effects of various types of government spending on aggregate demand and economic growth. Kolawole & Odubunmi (2015) analyzed that government spending and FDI are two economic factors that can impact economic growth individually or collectively. FDI could be a significant source of growth because its impact could be expanded through technological spillover, increasing the economy's aggregate productivity.

3. METHODOLOGY:

The sample period has been selected for the period 1997 to 2019 based on the data availability for 20 primary energy-consuming states. Data for Total Energy Consumption by the ultimate consumers (LTEC), Gross State Domestic Product (LGSDP) at constant prices, and Capital Expenditure (LCE) is taken from various issues of RBI handbook of Statistics on the Indian States, and Indiastat. The states under consideration are Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Goa, Tamil Nadu, Maharashtra, Orissa, Punjab, Rajasthan, Uttar Pradesh, West Bengal, Jammu & Kashmir, Delhi, and Puducherry.

The researcher has used three unit root tests—the Im et al. (2003), Levin et al. (2002), and the Fisher ADF individual unit root test—to guarantee that the data are stationary before proceeding with the Panel data analysis. In addition to the Panel ARDL Model developed by Peseran et al. (1999), three-panel co-integration techniques have been used to determine the presence of co-integration: the Pedroni (Engle-Granger based) Co-integration Tests, the Kao (Engle-Granger based) Co-integration Tests, the Combined Individual Tests (Fisher/Johansen). Additionally, the pairwise panel granger causality test has been used to examine the direction of causality.

3.1 Levin, Lin & Chu (LLC) Unit Root Test

LLC considers the following basic ADF specification

$$\Delta y_{it} = \alpha y_{it-1} + \sum_{j=i}^{p_i} \beta_{ij}\, \Delta y_{it-j} + X'_{it}\delta + \varepsilon_{it}$$

Where we assume a common $\alpha = \rho - 1$, but allow the lag order for the different terms, p_i, to vary across cross-sections. The null and alternative hypotheses for the tests may be written as follows:

$H_0 : \alpha = 0$ & $H_1 : \alpha < 0$

Also,under the null hypothesis, a modified t-statistic for the derived $\hat{\alpha}$follows an asymptotically normal distribution.

$$t_{\alpha}^{*} = \frac{t_{\alpha} - (NT)S_N \hat{\alpha}^{-2} s\epsilon(\hat{\alpha})\mu_{mT}^{*}}{\sigma_{mT}^{*}} \rightarrow N(0,1)$$

t_{α} represents the standard *t*-statistic for $\hat{\alpha} = 0$, $\hat{\sigma}^2$ represent the estimated variance of the error term $\eta, s\epsilon(\hat{\alpha})$ is the standard error, of $\hat{\alpha}$:

$$T = T - \left(\frac{\sum_i p_i}{N}\right) - 1$$

For each individual, S_N is calculated as the mean of their long-run standard deviation divided by the innovation standard deviation. Its estimate is derived using kernel-based techniques. μ_{mT}^{*} and σ_{mT}^{*} are adjustment terms for the mean and standard deviation.

3.2 Im, Pesaran, and Shin Unit Root Test

In this test, following the estimation of the individual ADF regressions, the appropriate test statistics are obtained by adjusting the average of the t-statistics for α_i derived from the individual ADF regressions, which are denoted by $t_{iT_i}(p_i)$:

$$\overline{t_{NT}} = \frac{\left(\sum_{i=1}^{N} t_{iT_i}(p_i)\right)}{N}$$

The next step is to determine the standardised t-bar statistic, which may be found by using the formula:

$$W_{\overline{t_{NT}}} = \sqrt{N}\,\frac{\left(\overline{t_{NT}} - N^{-1}\sum_{i=1}^{N} E\left(\overline{t_{\iota T}}(p_i)\right)\right)}{\sqrt{N^{-1}\sum_{i=1}^{N} Var\left(\overline{t_{\iota T}}(p_i)\right)}} \rightarrow N\,(0,1)$$

The expressions for the predicted mean and variance of the ADF regression t-statistics, $E\left(\overline{t_{\iota T}}(p_i)\right)$ and $Var\left(\overline{t_{\iota T}}(p_i)\right)$, are given by IPS for different values of T and p.

3.3 Fisher-ADF Unit Root Test

Alternatively, as demonstrated by the findings of Fisher's (1932) study, panel unit root tests can be created by adding the p-values of individual unit root tests. Choi (1999) and Maddala & Wu (1999) put forth this notion. The test statistics are given by

$$-2\sum_{i=1}^{N}\log(\pi_i) \rightarrow \chi_{2N}^{2}$$

For cross-section i, π_i displays the p-value from each unique unit root test. In addition, Choi (2006) demonstrates the following equation where the inverse of the standard normal cumulative distribution function is denoted by Φ^{-1}:

$$Z = \frac{1}{\sqrt{N}}\sum_{i=1}^{N}\Phi^{-1}\,(\pi_i) \rightarrow N(0,1)$$

3.4 Pedroni Co-integration Test

Pedroni provides a number of co-integration tests that account for the variation in intercepts and trend coefficients across cross-sections. Think about the subsequent regression;

$$y_{it} = \alpha_i + \delta_i t + \beta_{1i}x_{1i,\ t} + \beta_{2i}x_{2i,\ t} + \ldots\ldots + \beta_{Mi}x_{Mi,\ t} + \epsilon_{i,t}$$

For $t = 1, \ldots, T$; $i = 1, \ldots, N; m = 1, \ldots, M$; where y and x are assumed to be integrated of order one. Individual and trend impacts are the parameters α_i and δ_i respectively, which can be zeroed out if required. The standard procedure is to first getting residuals before testing whether they are I (1) by performing the auxiliary regression;

$$\epsilon_{it} = \rho_{it-1} + \sum_{j=1}^{p_i} \psi_{ij}\, \Delta\epsilon_{it-j} + \nu_{it}$$

Pedroni discusses various statistical construction techniques for testing the hypothesis that no co-integration exists ($\rho_i = 1$). There are two alternative hypotheses; first is the homogenous alternative ($\rho_i = \rho) < 1$ for all i (within-dimension test or panel statistics test); and second one is the heterogeneous alternative, $\rho_i < 1$ for all i (between-dimension or group statistics test). The Pedroni panel cointegration statistic $\mathfrak{N}_{N,T}$ is generated from the residuals from the given equation. Also, a total of 11 statistics with different degrees of properties (size and power for different N and T) are calculated.

$$\frac{\mathfrak{N}_{N,T} - \mu\sqrt{N}}{\sqrt{v}} \rightarrow N\,(0, 1)$$

The standardized statistic is asymptotically normally distributed, as demonstrated by Pedroni, where μ and v are correction terms produced by Monte Carlo.

3.5 Kao (Engle-Granger Based) Co-integration Test

The Kao test employs a similar fundamental methodology as the Pedroni tests, but it also clarifies cross-section-specific intercepts and homogeneous coefficients on the first-stage regressors.

Kao utilized the following statistics under the null hypothesis of no co-integration:

$$DF_\rho = \frac{T\sqrt{N}(\check{p} - 1) + 3\sqrt{N}}{\sqrt{10.2}}$$

$$DF_t = \sqrt{1.25}t_p + \sqrt{1.875N}$$

$$DF_\rho^* = \frac{\sqrt{N}T(\check{p} - 1) + 3\sqrt{N}\check{\sigma}_v^2/\check{\sigma}_{0v}^2}{\sqrt{3 + 36\check{\sigma}_v^4/(5\check{\sigma}_{0v}^4)}}$$

$$DF_t^* = \frac{t_\rho + \sqrt{6N}\check{\sigma}_v/2\check{\sigma}_{0v}}{\sqrt{\check{\sigma}_{0v}^2/(2\check{\sigma}_{0v}^2) + 3\check{\sigma}_v^2/(10\check{\sigma}_{0v}^2)}}$$

In addition to that, if $p > 0$, which is the augmented version, then

$$ADF = \frac{t_\rho + \sqrt{6N}\check{\sigma}_v/2\check{\sigma}_{0v}}{\sqrt{\check{\sigma}_{0v}^2/(2\check{\sigma}_{0v}^2) + 3\check{\sigma}_v^2/(10\check{\sigma}_{0v}^2)}}$$

3.6 Combined Individual Test (Fisher/Johansen)

Fisher (1932) established a combined test based on individual independent test results. Maddala & Wu (1999) suggest an alternative technique for examining co-integration in panel data using Fisher's findings. This technique creates a statistical test for the entire panel by combining tests from various cross-sections. Maddala and Wu's method has the advantage of being more time efficient. If the p-value obtained from an individual co-integration test for cross-section i is p_i, then the expected value for the panel, given the null hypothesis, will be

$$-2\sum_{i=1}^{n} \log(p_i) \sim \chi_{2N}^2$$

3.7 Panel ARDL Model

The Panel Autoregressive Distributed Lag model of the co-integration test is utilized to investigate the long-run equilibrium connection between the variables. This model is based on the Pooled Mean Group (PMG) estimators developed by Peseran et al. (1999). According to Peseran et al. (1999), "the panel ARDL model can be applied even if the variables follow a different order of integration, i.e., I(0) and I(1) or the mixture of both, but it is not applicable if the order of integration is greater than I(1), i.e., I(2)". This technique of panel co-integration is based on residuals, which allows for the possibility of taking into account variability in individual effects, slope coefficients, and individual linear trends between the chosen economies. Panel ARDL model can be written as;

$$\Delta Ln(LGSDP)_{i,t} = \theta_i^1 EC_{i,t} + \sum_{j=1}^{p-1} \alpha_{i,j}^1\, \Delta LGSDP_{i,t-j} + \sum_{j=0}^{q-1} \gamma_{1i,j}^1\, \Delta LTEC_{i,t-j} + \sum_{j=0}^{r-1} \gamma_{2i,j}^1\, \Delta LCE_{i,t-j} + \in_{i,t}^1$$

Here, $EC_{i,t}$ is the error correction term, which means the model progressively returns to long-run equilibrium after a series of partial short-run adjustments. According to the hypothesis that the variables can be returned to their long-run equilibrium states, the coefficient of this factor θ_i^1 should have a statistically significant negative sign. This coefficient represents how quickly the model returns to long-run equilibrium after a short-term disturbance. The notation "$\gamma' s$" stands for the coefficients of LTEC, LSGDP, and LCE, where "Δ" stands for the first difference operator.

3.8 Panel Granger Causality

There are numerous methods for evaluating Granger Causality in a panel framework because it is calculated by running bivariate regressions. Generally, the bivariate regressions in a panel data context represent the form:

$$y_{i,t} = \alpha_{0,i} + \alpha_{1,i} y_{i,\ t-1} + \cdots + \alpha_{k,i} y_{i,\ t-k} + \beta_{1,i} \varphi_{i,\ t-1} + \cdots + \beta_{k,i} \varphi_{i,\ t-k} + \epsilon_{i,t}$$
$$\varphi_{i,t} = \alpha_{0,i} + \alpha_{1,i} \varphi_{i,\ t-1} + \cdots + \alpha_{k,i} \varphi_{i,\ t-k} + \beta_{1,i} y_{i,\ t-1} + \cdots + \beta_{k,i} y_{i,\ t-k} + \epsilon_{i,t}$$

Here, t denotes the panel's time, and i represents the cross-sectional dimensions. The different forms of panel causality tests differ in the assumptions about the coefficients' homogeneity across cross-sections. This study treats the panel data as one sizeable stacked data set. Then the Granger Causality test in the standard way is performed, except for not letting data from one cross-section enter the lagged values of data from the next cross-section. The following method is predicated on the idea that all coefficients are constant for all cross-sections:

$$\alpha_{0,i} = \alpha_{0,j,} \alpha_{1,i} = \alpha_{1,j}, \dots, \alpha_{l,i} = \alpha_{l,j}, \forall_{i,j}$$
$$\beta_{1,i} = \beta_{1,j}, \dots, \beta_{l,i} = \beta_{l,j}, \forall_{i,j}$$

4. RESULT AND DISCUSSION:

Table. 1 displays descriptive statistics for all variables. Statistics such as mean, median, range, skewness, kurtosis, and more are displayed in a table. For this panel data study, a total of 440 observations were collected. After transforming the data for the variables into log forms, the analysis was done.

Table. 1 Descriptive Statistics

	LGSDP	LTEC	LCE
Mean	16.83434	9.622700	4.059658
Median	17.06019	9.862092	4.144720
Maximum	19.13318	11.79524	6.796634
Minimum	13.28714	6.843633	0.405465
Std. Dev.	1.146181	1.175789	1.240790
Skewness	-0.870812	-0.461794	-0.360439
Kurtosis	3.497827	2.220646	2.744112
Sum	7407.112	4233.988	1786.250
Sum Sq. Dev.	576.7282	606.9089	675.8664
Observations	440	440	440

Source: Author's Calculation using Eviews

In the case of total energy consumption, the mean value was 9.622700, and the median value was 9.862092. The minimum and maximum values were 11.79524 and 6.843633, respectively. Similarly, in the Gross State Domestic Product case, the mean value was 16.83434, and the median value was 17.06019. Moreover, minimum and maximum values in the case of oil were 13.28714 and 19.13318, respectively. Furthermore, the Standard deviation in these cases was 1.17 and 1.14, respectively. Furthermore, the Mean and Median values in the case of Capital Expenditure were 4.059658 and 4.144720, respectively. And maximum and minimum values, in this case, were 6.796634 and 0.405465, respectively

Table 2 presents the Levin, Lin & Chu test results at a level and at first difference. The automatic lag length has been selected based on the SIC criterion. At the level (Individual effects and Individual linear trends), mixed results were found, i.e., Total Energy Consumption (LTEC) was non-stationary considering individual effects and stationary considering individual linear trends. Gross State Domestic Product (LGSDP) was found to be non-stationary, considering individual results, and stationary considering individual linear trends. However, all the concerned variables were stationary at the first difference at a 1 percent significance level.

Table. 2 Levin, Lin & Chu Unit Root Results

Variables	level				First Difference			
	Individual effects		Individual linear trends		Individual effects		Individual linear trends	
	stat	p-value	stat	p-value	stat	p-value	stat	p-value
LTEC	0.50596	0.6936	2.31505	0.0103	11.4055	0.0000	10.0652	0.0000
LCE	2.19587	0.0141	4.42467	0.0000	18.4946	0.0000	16.3126	0.0000
LGSDP	2.12173	0.9831	-5.16480	0.0000	-10.3771	0.0000	- 8.07356	0.0000

Source: Author's calculations using Eviews

Table 3 displays the results of the Im et al. test for the stationarity of the variables. The outcomes showed data and p-values for all factors. The automatic lag length has been selected based on the SIC criterion. Looking at both the cumulative effects and the linear trends of individuals, we found that total energy consumption (LTEC) was not stationary. However, LGSDP and LCE were shown to be non-stationary when individual impacts were considered but stationary when individual linear trends were considered. At the 1% significance level, however, it was discovered that all the relevant variables were indeed stationary at first.

Table. 3 Im, Pesaran, and Shin Unit Root Results

Variables	level				First Difference			
	Individual effects		Individual linear trends		Individual effects		Individual linear trends	
	stat	p-value	stat	p-value	stat	p-value	stat	p-value
LTEC	6.25053	1.0000	0.26531	0.6046	11.8791	0.0000	10.4096	0.0000
LCE	3.60044	0.9998	4.03456	0.0000	17.2790	0.0000	15.7178	0.0000
LGSDP	8.78260	1.0000	-6.32163	0.0000	-11.4424	0.0000	-8.34807	0.0000

Source: Author's calculations using Eviews

Results of the unit root test provided by Maddala and Wu (1999) are shown in Table 4, with the associated p-values for the ADF-Fisher Chi-square value, and the ADF-Chou Z-stat displayed. The automatic lag length has been selected based on the SIC criterion. The level statistics for both individual effects and linear trends indicated that the level log of total energy consumption (LTEC) was not stationary. However, LGSDP and LCE were shown to be non-stationary when individual impacts were considered but stationary when individual linear trends were considered. At the 1% significance level, however, it was discovered that all the relevant variables were stationary at first.

Table. 4 Fisher-ADF Unit Root Results

Variables	level				First Difference			
	Individual effects		Individual linear trends		Individual effects		Individual linear trends	
	stat	p-value	stat	p-value	stat	p-value	stat	p-value
LTEC	14.096* 6.133**	1.0000 1.0000	40.078* 0.3132**	0.4668 0.6230	202.654* 10.416**	0.0000 0.0000	18.942* 67.241**	0.0000 0.0000
LCE	20.461* 3.834**	0.9956 0.9999	88.006* -3.725**	0.0000 0.0001	309.064* -13.968**	0.0000 0.0000	249.739* -12.626**	0.0000 0.0000
LGSDP	2.999* 8.715**	1.0000 1.0000	106.210** -4.873**	0.0000 0.0000	196.659* -10.175**	0.0000 0.0000	138.668* -7.258**	0.0000 0.0000

Source: Author’s calculation using Eviews , * ADF - Fisher Chi-square, ** ADF - Choi Z-stat

Table. 5 represents the results of the Johansen Fisher Panel Co-integration Test. One advantage that can be obtained from using the Johansen Fisher panel co-integration is its adaptability. The Johansen Fisher panel co-integration also provides results that are attractive to the eye and is simple to use. According to the Johansen Co-integration test results, the p-value (trace test & max Eigen test) for the null hypothesis is less than 0.05. So, the null hypothesis is rejected and represents the presence of, at most, one co-integrating equation.

Table. 5 Johansen Fisher Panel Co-integration Results

Trend assumption: Linear deterministic trend Lags interval (in first differences): 1 1				
Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)				
Hypothesized	Fisher Stat.*		Fisher Stat.*	
No. of CE(s)	(from trace test)	Prob.	(from max-eigen test)	Prob.
None	136.1	0.0000	98.36	0.0000
At most 1	73.46	0.0010	69.47	0.0026
At most 2	45.66	0.2485	45.66	0.2485

Source: Author's calculations using Eviews

The outcome of the co-integration test using the Kao Residual is displayed in Table. 6. This test puts the alternative hypothesis—that co-integration exists—against the null hypothesis—that it does not. Considering that the p-value is 0.0053, the test concludes that the variables in question are co-integrated over the long term.

Table. 6 Kao Residual Co-integration Results

Trend assumption: No deterministic trend User-specified lag length: 1				
Newey-West automatic bandwidth selection and Bartlett kernel				
			t-Statistic	Prob.
ADF			-2.555482	0.0053
Residual variance			0.005788	
HAC variance			0.007338	

Source: Author's calculations using Eviews

Results of Pedroni co-integration tests are represented in Table.7 and Table.8. Two different kinds of residual-based tests are suggested by Pedroni (1999). Concerning the first kind, four tests—the "panel v-statistic, panel r statistic, panel PP-statistic, and panel ADF-statistic"—are based on pooling the residuals of the regression for the within-group and are distributed as being standard normal asymptotically. Three tests, the group "r-statistic, group PP-statistic, and group ADF-statistic," are also distributed asymptotically as standard normal for the second type but are based on pooling the residuals for the between-group.

Table. 7 Pedroni Residual Co-integration Results

Trend assumption: No deterministic trend User-specified lag length: 1				
Alternative hypothesis: common AR coefs. (within-dimension)				
			Weighted	
	Statistic	Prob.	Statistic	Prob.
Panel v-Statistic	1.975659	0.0241	2.413813	0.0079
Panel rho-Statistic	-0.169472	0.4327	-0.580951	0.2806
Panel PP-Statistic	-1.775658	0.0379	-2.579140	0.0050
Panel ADF-Statistic	-0.801038	0.2116	-1.848423	0.0323
Alternative hypothesis: individual AR coefs. (between-dimension)				
	Statistic	Prob.		

Group rho-Statistic	0.198075	0.5785
Group PP-Statistic	-3.788504	0.0001
Group ADF-Statistic	-2.675117	0.0037

Source: Author's calculations using Eviews

A minimum significance of 6 out of 11 statistics is required to accept the long-term co-integration connection in this test. Indeed, this investigation followed the same pattern. Seven out of eleven tests for statistical significance indicated a long-run co-integrating relationship between the variables.

Table. 8 Pedroni Residual Co-integration Results

Trend assumption: Deterministic intercept and trend Automatic lag length selection based on AIC with a max lag of 3				
Alternative hypothesis: common AR coefs. (within-dimension)				
			Weighted	
	Statistic	Prob.	Statistic	Prob.
Panel v-Statistic	7.459321	0.0000	11.81169	0.0000
Panel rho-Statistic	1.634730	0.9489	0.976494	0.8356
Panel PP-Statistic	-0.763353	0.2226	-2.387128	0.0085
Panel ADF-Statistic	-5.799029	0.0000	-5.251078	0.0000
Alternative hypothesis: individual AR coefs. (between-dimension)				
	Statistic	Prob.		
Group rho-Statistic	2.094919	0.9819		
Group PP-Statistic	-4.191096	0.0000		
Group ADF-Statistic	-5.123524	0.0000		

Source: Author's calculations using Eviews

Table 9 represents the ARDL results showing the long- and short-run relationships between the concerned variables. The negative sign of the co-integration equation and the p-value less than 0.05 showed a significant co-integrating relationship. The long-run equation revealed the co-integrating relationship between the variables under consideration. 1 percent change in total energy consumption leads to a positive and significant 1.04 percent change in economic growth. Moreover, a 1 percent change in capital expenditure results in a positive and meaningful change in economic growth in 20 major energy-consuming States in India.

Table 9. ARDL Results

Dependent Variable: D(LGSDP) Maximum dependent lags: 2 (Automatic selection) Model selection method: Akaike info criterion (AIC) Dynamic regressors (2 lags, automatic): LTEC LCE Selected Model: ARDL(1, 1, 1)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.***
Long Run Equation				
LTEC	1.045621	0.082467	12.67932	0.0000
LCE	0.137551	0.044664	3.079676	0.0022
Short Run Equation				
COINTEQ01	-0.064871	0.017877	-3.628637	0.0003

D(LTEC)	-0.035369	0.084549	-0.418322	0.6760
D(LCE)	-0.000834	0.007751	-0.107607	0.9144
C	0.462412	0.107051	4.319552	0.0000

Source: Author's calculation using Eviews

If long-term co-integration between the relevant variables has already been established, testing for causation is the next logical step. For the 20 selected States of India presented in Table 10, we conducted a Panel Pairwise Granger Causality test to investigate the association between the dependent variable (LGSDP) and the independent variables (LTEC, LCE, and LSE).

Table. 10 Pairwise Granger Causality Tests

Null Hypothesis:	**Obs.**	**F-Statistic**	**Prob.**
LTEC does not Granger Cause LGSDP	400	1.64366	0.1946
LGSDP does not Granger Cause LTEC		5.13527	0.0063
LCE does not Granger Cause LGSDP	400	6.80470	0.0012
LGSDP does not Granger Cause LCE		7.33630	0.0007
LCE does not Granger Cause LTEC	400	9.43151	0.0001
LTEC does not Granger Cause LCE		2.73949	0.0658

Source Author's calculations using Eviews

Results of Panel Granger causality revealed the existence of unidirectional causality running from LGSDP towards LTEC (p-value- 0.0063), i.e., the economic growth that Granger causes total energy consumption. The study also found the bidirectional causality between economic growth and capital expenditure at a 1 percent significance level and between total energy consumption and capital expenditure. Thus, the study showed the existence of a conservation hypothesis for 20 primary energy-consuming States in India.

5. CONCLUSION:

This paper has examined the relationship between total energy consumption and economic growth in India's major 20 energy-consuming states. The study found a long-term co-integrating relationship between the variables under consideration. The study also revealed the existence of the conservation hypothesis in the case of energy consumption and economic growth, which means that economic growth is the driving force for energy consumption. The results are consistent with the studies done by Ghosh (2002) and Bhattacharya & Bhattacharya (2013) in the context of India.

6. RECOMMENDATIONS:

1. Energy efficiency methods are needed to reduce energy use and meet citizens' energy needs. Also required is infrastructure for renewable energy services.
2. The study suggests policymakers prioritise energy-saving strategies. Reducing import bills and customer subsidies can save a lot of foreign reserves.
3. India's government should invest in ecologically friendly energy infrastructure, renewable energy sources, energy efficiency, and advanced fossil fuel technology to meet its energy needs.

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