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Research Paper

The Dynamics of Short Run and Long Run Relationship Between Energy Consumption and Economic Development in India

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ABSTRACT: *Energy is a commodity of utmost importance for human activity, being the most widely applied commercial good in the world. It was said that energy was the first and most important factor of production after the industrial revolution and the birth of the machine industry. Energy is among the most extensively debated topics in economics and plays a major role in economic literature as well. The industrialization and economic development processes over the past century have been marked by advances in energy consuming technologies and an increase in energy consumption. Development and advancement in technology helped us to explore various sources of energy. However, their lies a big dilemma among researchers and use of different framework in identifying the importance and causal effect between energy and development. It is therefore crucial to understand the link between energy consumption and economic development. Governments and policy makers who care both about the economy and the environment, including the scarcity of resources, should take the relationship between energy consumption and economic development very seriously. In light of this, our research attempted to experimentally explore the dynamics of energy consumption and economic development in India under ARDL framework. The data was analysed using a variety of statistical and timeseries econometric methodologies and we found a positive significant relationship between them both in the short run as well as in the long run.*

KEYWORDS: *Coal, petroleum, emissions, Per capita income, ARDL, India.*

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I. INTRODUCTION

Energy consumption and economic development are two intertwined concepts that have been the subject of extensive research in the past few decades. The relationship between the two is complex and dynamic, with many factors influencing their interdependence. India is a developing country with a rapidly growing economy, energy consumption is a critical component of its development strategy. However, the country is also facing challenges related to the sustainability of its energy consumption patterns, which have significant implications for its future economic growth and development. The industrialization and economic development processes over the past century have been marked by advances in energy consuming technologies and an increase in energy consumption [1].

Global energy consumption has increased significantly over the past two decades. The global energy mix is predicted to be dominated by fossil fuels until 2040, with a 48 percent increase in energy consumption [2]. It is of immense interest to academicians and policymakers to figure out how energy conservation policies will impact economic development in the above context. It is therefore important that policymakers understand the nexus between energy consumption and economic development when implementing energy policies in order to understand their impact on economic performance. Throughout India's development story, energy has played a crucial role. During the past two decades, due to the country's development and modernization, India's energy demand has grown steadily and almost doubled since 2000 [2]. Make in India, the National Industrial Corridor, Digital India, and Start-up India are recent initiatives that aim to improve the quality of life and accelerate manufacturing development. These initiatives are likely to further increase energy demand in India [3]. Development and advancement in technology helped us to explore various sources of energy. However, their lies a big dilemma among researchers and use of different framework in identifying the importance and causal effect between energy and development.

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It is therefore crucial to understand the link between energy consumption and economic development. Governments and policy makers who care both about the economy and the environment, including the scarcity of resources, should take the relationship between energy consumption and economic development very seriously. Since appropriate energy and environmental policy choices depend on the nature of the causal relationship between energy consumption and economic development, they must understand whether economic development fosters energy consumption or whether energy consumption brought about economic growth [4] & [5].

India is heavily dependent on imports of oil and gas to meet its energy needs. Economic development in India is closely linked to energy consumption, but unsustainable energy use can have negative impacts on the environment and public health. On this background our study focuses on to decode the complex relationship between energy consumption and economic development using ARDL framework. ARDL offers many advantages over other methods, including: i) variables of unequal order of integration can be used; ii) the estimator is efficient even for small samples or endogenous regressors; iii) variables can have different optimal lags [6]. Due to India's focus on energy security and significant progress in sustainable development, the findings of this study could be used by other developing and emerging countries to inform their own energy security and sustainable development plans. With a population of 1.4 billion, India is also one of the world's fastest-growing major economies, implying that India has an important role to play in contributing to the global energy and environmental sustainability landscape.

The rest of the paper is structured as follows. Section 2 of the paper presents an overview of the literature. Section 3 covers the data and econometrics. Section 4 breaks down the empirical findings with discussion. Section 5 concludes the paper with relevant policy implications.

II. AN OVERVIEW OF THE LITERATURE

Energy is increasingly becoming an important driver of economic development [7] & [8]. The neoclassical economics was neutral about the impact of energy on economic development. However, the oil crisis of 1970s prompted the examination of the relationship between energy consumption and economic growth [9]. According to some author the interest in the subject was triggered by the emission of greenhouse gases that results in climate change [10]. Further, the growing interest in the area has largely been motivated by the growth in energy demand fuelled by increasing economic activities across globe.

The empirical links between energy consumption and economic growth are based on four types of hypotheses. Each hypothesis has distinct policy implications that target the energy consumption level as a tool to decrease emission levels. The growth hypothesis indicates a one-way causality from energy consumption to economic growth and implies that the economy in question is energy-dependent. This hypothesis suggests that any restrictions on the use of energy may hamper growth, whereas increase in the energy consumption is likely to enhance growth as energy consumption plays an important role in the economic growth both directly and indirectly in the production process as a complement to labour and capital. On the other hand, the “conservation hypothesis” purports a one-way causality from economic growth to energy consumption. In such situation, the economic growth stimulates the energy consumption, but not vice versa. The conservation hypothesis implies that economy does not depend upon energy, and energy conservation policies may be implemented without adversely affecting growth, employment and development. The third case is the neutrality hypothesis that suggests there is no relationship or causality between energy consumption and economic growth. In this case, energy consumption and economic growth are unrelated, and energy consumption does not have any effect on economic growth. This implies that neither conservative nor expansionary policies in relation to energy consumption have any effect on output. Finally, “feedback hypothesis” involves a bidirectional causality between energy use and output growth. This hypothesis suggests that energy consumption and economic growth are jointly determined and interdependent. Hence, policies directed toward limiting energy use may hamper output growth.

The initial empirical examination of the nexus between energy consumption and economic growth was undertaken by Kraft and Kraft, and the empirical literature has grown tremendously since then [11]. A good number of studies have supported the growth hypothesis in the past using data from different countries and regions for different periods which document causation from energy consumption to economic growth [12], [13], [14], [15] & [16]. On the other hand, studies which support the conservation hypothesis also find causality running from economic growth to energy consumption in case of India, Bangladesh, Turkey, Pakistan and Ghana, respectively [9], [5], [17], [18] & [19]. Finally, there are studies which support feedback hypothesis conducted in Malaysia, Malawi, Portugal which shows evidence of a two-way causation between energy consumption and economic growth [20], [21] & [22]. However, the review of empirical studies in Indian context reveals mixed results. Some studies support the growth hypothesis [9], [23] and some find empirical support in favour of the conservation hypothesis [24] & [25]. Moreover, some studies in India supported the feedback relation between energy usage and economic growth [26] & [27] and some support the “neutrality hypothesis” [28] & [29].

The empirical literature on the causal links between economic growth and energy consumption in India to date, focuses mainly using either electricity or coal or separating renewable and non-renewable energy. Our study uses all the components of energy both at aggregate and dis-aggregate level at the same time and also uses the PCI as an indicator of economic development. Apart from this our study uses an autoregressive distributed lag (hereafter, ARDL) approach to investigate the presence of long-run relationship among the variables which is preferred over other conventional cointegration tests, as it has several advantages over these tests especially in case of small samples. To the best of our knowledge, this is the first empirical attempt that investigates the relationship among energy consumption and economic development in India in this way.

III. DATA AND METHODOLOGY

3.1 Data source

Data on energy variables like coal, petroleum, natural gas and per capita income have been collected from secondary sources. These sources are World Development Indicators (WDI), U.S. Energy Information Administration, Hand book of statistics on Indian economy, Petroleum and Natural Gas Ministry, Central Electricity Authority, Office of the Coal Controller, Ministry of New and Renewable Energy Ministry, and Economic Advisor Office, Ministry of Commerce and Industry National Accounts Division, Ministry of Statistics and Programme Implementation. Following table give a brief outline of the data collected along with their sources.

Table 1: Secondary data on energy & economic development variables

Variables	Unit	Time Period	Sources
Coal Consumption	Quadrillion Btu	1980-2019	U.S. Energy Information Administration
Petroleum Consumption	Quadrillion Btu	1980-2019	U.S. Energy Information Administration
Natural Gas Consumption	Quadrillion Btu	1980-2019	U.S. Energy Information Administration
Total Primary Energy Consumption	Quadrillion Btu	1980-2019	U.S. Energy Information Administration
GDP per capita PPP	Current US dollar	1980-2019	World Bank
Age Dependency Ratio (Percentage of working-age population)	Percentage	1980-2019	World Bank
Consumer price index (2010 = 100)	Percentage	1980-2019	World Bank
Foreign direct investment, net inflows (% of GDP)	Percentage	1980-2019	World Bank
General government final consumption expenditure (% of GDP)	Percentage	1980-2019	World Bank
Gross capital formation (% of GDP)	Percentage	1980-2019	World Bank
Urban population	Percentage	1980-2019	World Bank

3.2 Methods

3.2.1 Causality Test

This study hypothesized that energy consumption causes economic development. In this section, a structural equation model of energy consumption and economic development is described so that the theory can be tested.

$$PCI_t = \alpha_0 + \alpha_1 TE_t + u_t \dots\dots\dots\dots (1)$$

Where PCI is per capita GDP and TE is total energy consumption.

IV. RESULTS AND DISCUSSION

4.1 Dynamix of energy consumption and economic development: Empirical Analysis

4.1.1 Time series properties

The first step of the analysis is to investigate the time series properties of the variables. If the data under analysis are non-stationary, the results of regression analysis obtained in a traditional manner would not be reliable. For this purpose, we use ADF-GLS estimators to check the stationary process of the data series. The results of the test are reported in Table 2.

Results of the unit root tests in levels indicate that the computed t-statistics are less than the critical values at any conventional significance level for income inequality, thus we do not reject the null hypotheses that variable has a unit root in levels.

Results of the unit root tests in levels indicate that the computed t- statistics are less than the critical values at any conventional significance level for all except four variables viz total energy consumption, coal consumption, inflation and general government final consumption, thus we do not reject the null hypotheses that first four variables have a unit root in levels. However, once the first differences of those variables are considered, the null hypothesis of unit root can be rejected. Thus, we have clear evidence that the variables under consideration are stationary but at different levels.

Table 2: The ADF GLS test results

Variables	Level	First difference
Per Capita Income (lnPCI)	0.64	-5.79***
Economic Development (*lnHDI*)	-1.59	-2.63*
Total Energy Consumption (*ln*TE)	-3.47*	-----
Petroleum Consumption (*ln*PC)	-2.09	-4.52***
Natural Gas Consumption (*ln*NG)	-1.60	-3.57**
Coal Consumption (*ln*CC)	-4.08**	-----
Age Dependency Ratio (*lnADR*)	-0.64	-2.76*
Inflation (*lnCPI*)	-5.09***	-----
Foreign Direct Investment (*lnFDI*)	-2.01	-7.17***
Gross Capital Formation (*lnGCF*)	-1.29	-6.38***
General Government Final Consumption Expenditure (*lnGFCE*)	-2.79*	-----
Urban Population (*lnUP*)	-1.47	-3.88**

Notes: 1. (***), (**) & (*) indicates rejection of the null hypothesis of unit root at 1, 5 and 10 percent level respectively. 2. Optimal lag length (not shown) is determined by AIC.

4.1.2 Testing for Co-integration

Since the variables are integrated in different orders, we have used OLS based autoregressive distributed lag (ARDL) approach to co-integration. The ARDL framework and Equation expressed as:

$$\Delta LnPCI_t = \beta_0 + \sum_{i=1}^{p} \beta_1 \Delta LnPCI_{t-i} + \sum_{i=0}^{p} \beta_2 \Delta LnTE_{t-i} + \pi_1 LnPCI_{t-1} + \pi_2 LnTE_{t-1} + \gamma_1 GCF + \gamma_2 UP + \mu_t$$

(1)

Given the equation, to examine the presence of a long run relationship between economic development and energy consumption, we use F-test on the joint null hypothesis that the coefficients of the level variables are jointly equal to 0 [30].

Next, we estimate Equation (1) following the ARDL co-integration technique for the long-run estimates. We estimated the model keeping the different criteria, like R^2 criterion, Hannan Quinn Criterion, AIC Criterion and SBC Criterion, in mind to find the coefficient of the level of variables. The long run and short run results of all models were almost near to identical. Therefore, we present only the results of the model that were selected on the basis of AIC criterion as AIC is superior to other criteria, particularly when time span is less than 60 observations [31]. The calculated F-statistics for the co-integration test are reported in Table 3.

The critical values of F-statistics are reported together with calculated F-statistic in the same table.

The calculated F-statistic for Total energy consumption model (model 1) is 33.63, which is more than upper bound critical value at 1percent level of significance. Thus, the null hypothesis of no co-integration is rejected in the model, indicating presence of long run co-integration relationships between the variables. The long run coefficients of the model using ARDL approach is estimated in the second step. The results are shown in Table 4.

It is evident in the first model that the coefficient of energy consumption is positive and statistically significant. This indicates that in the long run increase in energy consumption effects economic development positively. Our findings are also supported by some previous studies in different countries [32], [4] & [33]. Energy in different form is essential for modern technologies, Energy is, in practice, indispensable for certain basic activities, such as lighting, refrigeration and the running of household appliances, transportation of essential commodities, health facilities, running of ambulance for emergency services, for higher education infrastructure. Therefore, energy plays an important role in the economic development of India. Energy access also allows the conservation of medicines and vaccines. Thanks to lighting, people can study longer, in their household at night. Therefore, energy consumption can also be regarded as the reference of well-being and a key measurable index of life quality and the positive impact of energy consumption on economic development is justifiable.

Coming to the control variables, coefficient of gross capital formation turned out to be positive and statistically significant, it implies that increase in country's gross capital formation helps in economic development, which is quite obvious result. Secondly, statistically significant and positive sign of coefficient of urban population indicates that increase in the percentage of urban population increases per capita income and thereby economic development.

Table 3: Bounds tests for the existence of a long run relationship

		1% Critical Values		
Dependent Variable	Calculated F-statistic	I (0)	I (1)	Conclusion
lnPCI	33.63	5.59	6.26	Co-integration

Note: Critical values for Total energy consumption model are with unrestricted constant.

Table 4: Long Run Coefficients estimating result

Variable	*ln*PCI ARDL (1, 1)
Constant	-27.88 (-4.75)***
Trend	-0.11 (-4.58)***
*ln*TE	1.78 (9.13)***
*ln*GCF	0.42 (4.55)***
lnUP	0.83 (4.79)***

Note: (***) & (**) indicates Significant at 1 percent and 5 percent level, Student's tests are in parentheses.

4.1.3 Estimation of the Short-Run Elasticity: Error Correction Model Results

In the final step, we proceed to obtain the error correction representation of Equation (1) and Table 5 reports the short run coefficient estimates obtained from the ECM version of the ARDL models.

Since the diagnostic tests suggest that obvious nonlinearity and misspecification are absent, and that the residuals show no signs of non-normality or heteroscedasticity, the following inferences can be drawn from the results: We can see that the error correction coefficients (ECM) assume negative sign and are highly significant in the model. This again confirms the existence of the co-integration relationship among the variables of the model. The values of estimated ECM coefficient is negative, it implies short run fluctuations deviate from long run equilibrium, The magnitude of this coefficient implies that more than 100 percent of any disequilibrium between lnPCI and lnTE is corrected within one year, which also indicates that the relationship between the two variables do exist, in the long run, as well as in the short run. The short run relationship is explained by the coefficients of *ln*TE in the model which is significant. Therefore, there is evidence that these two variables (*lnPCI* and *ln*TE) are interrelated even in the short run.

To understand the short-run dynamics, we conducted wald test on the lagged coefficients of lnTE in the model. Here, null hypothesis which states that lagged coefficients are jointly equal to zero is rejected in both the models. Therefore, there is evidence that these two variables (lnPCI and lnTE) are interrelated even in the short run. However, the short run results are exactly same in the signs as compared to the long run.

Table 5: The Short Run ARDL estimates

Variable	$\Delta lnPCI$ ARDL (1, 1)
Constant	-23.88 (-4.89)***
Trend	-0.11 (-5.4)***
$\Delta lnTE$	0.97 [2.15]**
ECT_{t-1}	-0.94 (-8.38)***
$\bar{R}^2$	0.81
F	25.42***

Note: 1. (***) indicate significant at 1percent level. 2. Figures within round bracket ( ) are calculated student's t-statistics.

Here, we find that the null hypothesis that is change in energy consumption does not affect lnPCI in the short run has been rejected. This is based on the Table 5 in which it can be seen that the F-statistics for lagged *ln*TE is found significant. The positive sign of the coefficient of *ln*TE implies that energy consumption affects lnPCI positively in the short run. Which is also supported by previous studies in different countries [34], [35], [36] & [37].

This positive impact of energy on the PCI supports many hypotheses for example, the case when a growing economy requires a increasing amount of energy consumption as production shifts toward less energy intensive service sectors to more intensive energy consumption sector. Industries such as cement, steel, transportation, manufacturing industries where energy consumption is very huge, specifically in a growing economy like India. Which leads to increase in per capita income in the short run.

Table 6: Causality result

Causality Type	Conclusion	Direction of causation
Short Run Granger causality Change in energy consumption does not affect economic development ($\sum_{i=}^{2} \alpha_2 \Delta\ LnPCI_{t-1}$=0)	Reject	Positive
Long Run Granger causality Change in energy consumption does not affect economic development	Reject	Positive

4.2 Disaggregated Model

4.2.1 Testing for Co-integration

Since the variables are integrated in different orders, we have used OLS-based autoregressive distributed lag (ARDL) approach to co-integration. The ARDL framework and equation expressed as:

$$\Delta LnPCI_t = \beta_0 + \sum_{i=1}^{p} \beta_1 \Delta LnPCI_{t-i} + \sum_{i=0}^{p} \beta_2 \Delta LnCC_{t-i} + \sum_{i=0}^{p} \beta_3 \Delta LnNG_{t-i} + \sum_{i=0}^{p} \beta_4 \Delta LnPC_{t-i} + \pi_1 LnPCI_{t-1} + \pi_2 LnCC_{t-1} + \pi_3 LnNG_{t-1} + \pi_4 LnPC_{t-1} + \mu_t \quad \text{……... (2)}$$

In the previous equations, the terms with the summation signs represent the error correction dynamics whereas the second part corresponds to the long-run relationship. The null hypothesis in (2) is $\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$, which indicates the non-existence of long-run relationship among the variables. The ARDL method estimates $(P+1)^k$ number of regressions in order to obtain the optimal lags for each variable, where p is the maximum number of lags to be used and k is the number of regressors in the equation.

Now, we estimate equation (2) following the ARDL co-integration technique for the long-run estimates. We estimated the model keeping the different criteria, like R^2 criterion, Hannan Quinn Criterion, AIC Criterion and SBC Criterion, in mind to find the coefficient of the level of variables. The long run and short run results of all models were almost near to identical. Therefore, we present only the results of the model that were selected on the basis of AIC criterion as Monte Carlo experiment of Liew documented that AIC is superior to other criteria, particularly when time span is less than 60 observations [31]. The calculated F-statistics for the co-integration test are reported in Table 7.

The critical values of F-statistics are reported together with calculated F-statistic in the same table.

The calculated F-statistic for disaggregated energy model is 5.66, which is more than upper bound critical value at 5 percent level of significance. Thus, the null hypothesis of no co-integration is rejected in the model, indicating presence of long run co-integration relationships between the variables. The long run coefficients of this model using ARDL approach are estimated in the second step. The results are shown in Table 8.

It is evident in the second model that the coefficients of natural gas and coal consumption are positive and statistically significant but coefficient of petroleum consumption is negative and statistically significant. This indicates that in the long run natural gas and coal consumption positively effects economic development. Whereas, petroleum consumption negatively effects economic development. However, the magnitude of effect is much higher for coal and natural gas as compared to petroleum consumption, as evident from the coefficients value.

Table 7: Bounds tests for the existence of a long run relationship

		1% Critical Values		
Dependent Variable	Calculated F-statistic	I (0)	I(1)	Conclusion
*ln*PCI	5.66	3.23	4.35	Co-integration

Note: Critical values for disaggregated energy consumption model are with unrestricted constant.

Table 8: Long Run Coefficients estimating result

Variable	*ln*PCI ARDL (4, 2, 3, 4)
Constant	-88.09 (-2.74)**

*ln*CC	0.27 (1.92)**
*ln*PC	-0.24 (-1.86)*
*ln*NG	0.57 (4.51)***

Note: (***), (**) & (*) indicates Significant at 1 percent, 5 percent and 10 percent level respectively, Student's tests are in parentheses.

4.2.2 Estimation of the Short-Run Elasticity: Error Correction Model Results

In the final step, we proceed to obtain the error correction representation of Equation (2) and Table 9 reports the short run coefficient estimates obtained from the ECM version of the ARDL models.

Since the diagnostic tests suggest that obvious nonlinearity and misspecification are absent, and that the residuals show no signs of non-normality or heteroscedasticity, the following inferences can be drawn from the results: We can see that the error correction coefficients (ECM) assume negative sign and are highly significant in the model. This again confirms the existence of the co-integration relationship among the variables of the model. The values of estimated ECM coefficient is negative, it implies short run fluctuations deviate from long run equilibrium, it more than 200 percent to back in equilibrium condition, which also indicates that the relationship between the variables do exist, in the long run, as well as in the short run. The short run relationship is explained by the coefficients of *ln*CC, *ln*NG, *ln*PC in the model which is significant. Therefore, there is evidence that economic development and energy consumption (at disaggregated level, i.e., lnCC, lnNG, lnPC) are interrelated even in the short run. However, the short run results are exactly opposite in the signs as compared to the long run.

Table 9: The Short Run ARDL estimates

Variable	$\Delta lnPCI$ ARDL (4, 2, 3, 4)
Constant	-38.09 (-5.62)***
$\Delta lnCC$	0.67 [2.85]**
$\Delta lnNG$	0.83 [7.97]**
$\Delta lnPC$	-0.67 [-1.94]*
ECT_{t-1}	-1.38 (-5.83)***
$\bar{R}^2$	0.91
F	17.04***

Note: 1. (***), (**) & (*) indicates Significant at 1 percent, 5 percent and 10 percent level respectively. 2. Figures within round bracket ( ) are calculated student's t-statistics. 3. Figures within angle bracket [ ] are calculated Wald test statistics.

Here, we find that the null hypothesis that is change in lnCC does not affect lnPCI in the short run is rejected. This is based on the table 9 in which it can be seen that t-statistic for lnCC is found significant. The positive sign of the coefficient of lnCC implies that lnCC affects lnPCI positively in the short run. Similarly, the null hypotheses lnNG doesn't affect lnPCI and lnPC doesn't affect lnPCI in the short run are rejected based on the significance level of lagged coefficients of lnNG and lnPC in table 9. The positive sign of lnNG and lnCC indicates that increase in consumption of lnNG and lnCC helps in economic development in the short run. The results support the studies of Satish et al & Kanat et al [38] & [39].

The short run positive impact of coal consumption on economic development is obvious. Because, Indian economy is heavily dependent on coal consumption for power plants, industrial activities, bricks manufacturing etc. So, in the short run it will have a positive impact on growth of income, which is a part of development. Apart from this more than 70% electricity generation in India is dependent on coal. And electricity is one of the most important inputs for development in many ways, it helps in education, technology, health, industry etc.

Petroleum and natural gas consumption are indispensable for domestic and productive uses. At the household level, biomass and fossil fuels facilitate cooking and are used as a source of lighting, which has an influence on the level of education and health of these households. At the social level, fossil fuels are considered in these countries to be the main fuels. Thus, they provide services to more people and are also used as a resource alternative to clean and/or renewable energy. At the productive level, biomass represents nearly 60 million resources according to the White Paper report (ECCAS—EMCCA, 2014). We also note that fossil energies such as oil represent nearly 50 to 65% of the budgets of countries holding this resource. As a result, energy contributes to improving per capita income. Therefore, we can conclude that energy consumption is an indispensable factor for economic development.

V. CONCLUSION

The relationship between energy consumption and economic development in India is complex and dynamic, with both short-run and long-run dynamics at play. The findings of this research suggest that there exists a positive relationship between energy consumption and economic development in the short run, indicating that increased energy consumption can lead to higher economic growth in the short term. However, in the long run also energy consumption led to economic development but this relationship may become more nuanced, as the benefits of increased energy consumption may be offset by environmental degradation and resource depletion.

While we disaggregated the components of energy into coal, petroleum and natural gas, we found that impact of natural gas much higher than that of coal and petroleum in economic development. Whereas, petroleum actually affects negatively economic development in the long run.

To address these challenges, policymakers in India must adopt a holistic approach that balances economic growth with sustainable and efficient energy policies. This may include investing in renewable energy sources, improving energy efficiency, and promoting sustainable development practices. Moreover, policymakers must also focus on the equitable distribution of energy resources and ensure that energy access is extended to all sections of society.

Overall, the findings of this research highlight the need for a comprehensive and integrated approach to energy and economic development in India. By adopting such an approach, policymakers can create a sustainable and inclusive energy system that supports economic growth while addressing environmental and social concerns. Further research is needed to better understand the dynamics of this relationship and to inform evidence-based policy decisions in the future.

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