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Study energy security and sustainable economic growth in India

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Abstract
We discover that the association between GDP per capita and carbon emissions is moderated by expenditure on environmental protections. Identifying the most relevant theory for India is one of the study's aims. The data used for this research came from the World Bank database, which means it is based on secondary sources. The primary goal of this research is to establish the nature and direction of the link between economic growth and energy consumption over the long term. The researcher has used the Granger Causality series, the regression model with dummy variables and a linear trend equation with the intercept and slope dummies to analyzeTo determine the long-term link between GDP growth and power consumption. These findings highlight the need to invest more in environmental preservation and back ecologically sustainable strategies.

Keywords: Energy security, sustainable economic, growth, development and India

Introduction
In order to gauge development, pinpoint policy domains to be addressed, and analyse the efficacy of policies put into place, a thorough evaluation of sustainability is essential. To fuel economic growth, India requires vast amounts of energy. The oil import cost for India was up 42.6% in 2018 as a result of both increasing imports and rising global oil prices (The Economic Times 2018). The development of both individuals and society as a whole depends on energy. Its significance for long-term economic growth and human development has elevated it to the status of a strategic product.

There has been a long-term shift in India's primary energy balance. India continues to suffer from a severe energy deficit because its expanding energy supply has not kept pace with its expanding demand. Consequently, importing more energy is necessary to meet the demand. From 2006-07 to 2015-16, India's crude oil output increased from 33.99 to 36.95 metric tonnes. Crude oil imports increased from 111.50 MT to 202.85 MT within the same time frame. The three primary commercial energy sources-coal, natural gas, and crude oil-would continue to incur major increases in imports, leading to a hefty energy import bill. Consequently, controlling the demand side and transitioning to most efficient strategies for all company sectors is very critical in order to conserve energy and reduce energy consumption. India relies on fossil fuels for around 75% of its electrical output.

According to Energy Statistics (2017), fossil fuels are the primary cause of global warming. Using total primary energy consumption and imports from India, the researcher aims to uncover energy security in this paper. The researcher has determined energy security by looking at total energy imports. Energy insecurity is characterized by a rise in imports relative to its production, and vice versa.

Despite the government's strong commitment to developing renewable energy sources, including solar, wind, and nuclear power, the energy infrastructure in India is facing an increasing energy shortage. The majority of the United States' net primary energy consumption-approximately 90%-comes from fossil fuels. Of this, 56% comes from coal, 28% from crude oil, and 7% from natural gas. To put this in perspective, consider that India's domestic energy needs are met by importing energy (BP 2015).

Literature Review

Akhter Ali, Mohd & Kamraju, M. & Sonaji, Devkar. (2023) [1]. Finding a middle ground between economic growth, social fairness, and environmental preservation is the goal of this research study, which delves into the topic of economic policy integration in pursuit of sustainable development. It offers case studies from different locations that have successfully integrated sustainability goals into economic strategies and looks at the pros and cons of doing so. Economic policies that promote growth, social fairness, and environmental protection while also fostering sustainable development are proposed in this paper for the use of policymakers.

Brad, Stelian & Mocan, Bogdan & Brad, Emilia & Fulea, Mircea. (2016) [2]. When it comes to societal prosperity, concerns like sustainable development and economic growth are paramount. While economic growth primarily aims to enhance productivity, sustainable development seeks to utilise our planet's finite resources moderately and responsibly within economic activity. According to this view, the two foundations of prosperity are at odds with one another on both a conceptual and practical level. In light of these seeming conflicts, this article suggests a way forward that would allow both economic development and environmental sustainability to coexist. Within this context, we think of an organised framework for creatively addressing problems. Findings from this study demonstrate that firms may be guided towards new paradigms that promote economic development without compromising environmental sustainability via the use of smart measures in the economic system.

Bali Swain, Ranjula. (2017) [3]. Some have argued that the lofty sustainable development goals (SDGs) set forth by the United Nations are inconsistent, hard to measure, and impossible to keep tabs on. Negative research points to possible incoherence dis the SDGs, especially between the objectives of social and economic growth and environmental sustainability. The critics also bring up concerns about how the SDGs, in their broadest sense, can be measured and tracked. Each nation is required to develop its own national or regional strategies in response to these non-binding targets. Additionally, there is a lack of clarity on the origin and level of funding for the SDGs. Inconsistencies in the SDGs are examined and quantified in this chapter. It goes even beyond by looking at the environmental, social, and economic pillars to see which ones work best for sustainable development. Data analysis shows that industrialized nations should not lose sight of their social and environmental policy objectives. Developing nations would do well to prioritise short-term economic and social policies above environmental ones, even if the latter are crucial to long-term sustainable development.

Rout, Prangya & Verma, Akshaya & Bhunia, Puspendu & Surampalli, Rao & Tyagi, R.D. & Brar, S.K. & Goyal, Manish. (2020) [7]. Sustainable development, or sustainability, is an abstract idea. The words "sustainability" and "sustainable development," which come before them, have varied meanings depending on who you ask. The many facets of sustainability are attempted to be explained in this chapter. This chapter provides an overview of sustainability, explains some key terms and their definitions, traces the development of sustainable development and related topics, discusses the difficulties sustainability has encountered, and offers some possible solutions. In this chapter, we also cover resilience, which is a bottom-up movement, and adaptation, which is a top-down movement, both of which contribute to sustainability. Integrating the processes of environmental functioning with the surrounding social system's operation is a critical problem of sustainability. As a result, this chapter delves into the complex system's nature, shedding light on sustainable development from many angles, including economic, ecological, social, technical, and systems.

Lele, Sharachchandra. (1991) [5]. A new development buzzword, "Sustainable Development" (SD), has emerged in recent years. It has been adopted as the new standard for development by several governmental and non-governmental organisations. A survey of the works written on SD, however, reveals that different people have different ideas about how to use it. More importantly, the concept's present articulation by the majority of SD thought includes serious limitations, despite the concept's all-encompassing breadth giving it political power. A partial understanding of the issues surrounding poverty and environmental degradation is one of them. Other examples include a lack of clarity on the function of economic development, the meaning of sustainability, and the need of active engagement. By looking at international commerce, agriculture, and forestry, we can see how these shortcomings may cause inconsistencies and inadequate policymaking. Some argue that logical clarity and rigour should take precedence over politically convenient fuzziness if SD is to make a real difference.

Materials and Methods

In order to investigate the connection between, the researchers consulted data spanning time that showed the impact of energy consumption growth on GDP growth. Economic expansion, gross domestic product, and overall primary energy use. Investigating the data's dynamics or temporal structure in great detail is what time series analysis is all about. To examine the aims of this thesis, the researcher has used the Granger causality series, a dummy variable regression model, and a linear trend equation with intercept and slope dummies.

Results

Trends in energy security with production, consumption and imports of energy components: Using regression model with dummy variables

More over 1.3 billion people call India home, making it the world's second most populous nation. By the year 2030, experts predict that India's population would have risen to 1.5 billion. The Indian economy is already one of the world's fastest-growing, and this helps keep it that way. The average GDP growth rate over the last seven years has been 7.3%, and experts predict that it will be somewhere around 7.9% during the next five years (IMF 2018). The study's author employed the ideas of energy security in terms of production (ESIP) and imports (ESIM) to achieve this goal. A reduction in energy reliance and an increase in energy security are shown by the rising energy security in production (ESIP) and falling energy security in imports (ESIM).

This was accomplished by dividing the research period into three distinct time frames: 1980-1981, 1989-90, 1990-1991, and 1999-2000. Then, from 2000-2001 to 2015-2016, the study was conducted. The incorporation of intercept and slope dummies in a linear trend growth model allowed for the verification of any trend changes. Both the energy security indicator in terms of production (ESIP) and the energy security indicator in terms of imports (ESIM) relate to the link between total energy consumption and energy output, respectively. Reducing ESIM and increasing ESIP are necessary for energy security.

Energy security in natural gas: Prodution, consumption and imports

The primary concern for emerging nations is finding a middle ground between meeting their demands for affordable energy, energy security, and more sustainable energy usage. By 2022, with a projected population of almost 1.4 billion, India is expected to have surpassed China as the most populous nation in the world, leading to a greater need for energy. India was seen as a stubborn nation at the 2015 Paris Climate talks (COP-21), although its contribution was deemed crucial for achieving its carbon reduction goals. India's goal, as outlined in its planned national contribution (INDC), is to reduce carbon concentration from 33% to 35% of GDP from 2005 levels by 2030, independent of the Paris Agreement.

Production, consumption and imports of natural gas: Regression model with dummy variables

To examine energy security, the researcher in this study employed a regression model containing dummy variables. The first step is to summarise the model.

Table 1: Model Summary of Key Variables for Natural Gas

Variables	Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	F	Sig.
Production	1	.856[a]	.732	.716	.26484	45.153	.0001**
Consumption	1	.880[a]	.774	.761	.26619	45.153	.0001**

***Source*:** Author's Calculations

Table 1 demonstrates the robust relationship between the dependent variable and the model. The multiple correlation coefficient (R) measures the degree to which the dependent variable model's predictions align with the observed values. A tight association is indicated by the score of 0.856. The squared value of the multiple correlation coefficient is known as R Square, the coefficient of determination. It reveals that the model accounts for 0.732% of the variation in consumption and 0.732% of the variation in output. A 'corrected' version of the R-squared statistic, the adjusted R-squared penalises models that have many parameters. To compare and contrast many models, we use these statistics in conjunction with the estimate's standard error. For production, the standard error of the estimate is 0.26484, and for consumption, it is 0.26619, indicating the lowest values. The improved model fit is seen by the higher R square values of 0.732 for production and 0.774 for consumption.

The z- and T-tests were created in the twentieth century. They were extensively used in statistical analysis until the technique of analysis of variance was developed by Ronald Fisher in 1918. One statistical method is the analysis of variance (ANOVA), which separates the total variability in a dataset into its systematic and random components. Unlike random variables, the former do impact the provided data set statistically. In a regression analysis, the researcher found the impact of the independent variables on the dependent variable by calculating the significance value and value F.

Energy Security in terms of Production and Consumption of Natural Gas

Table 2: Production and Consumption of Natural Gas

Variables	1980-89	1990-99	2000-16
Production	2.05	2.77	3.06
Consumption	2.03	2.76	3.17

***Source*:** Author's Calculations

R-Square is 0.732 and Adjusted R-Square is 0.716 with extremely tiny Std., according to the compound growth rate calculation, which is based on the linear regression equation. The estimated error is 0.265. In addition, the p-value is lower than the stages of consequence, indicating that the growth rate coefficients are statistically significant, according to the analysis of table variation.

Yt = 2.055 + 0.711D1 + 1.010D2 is the energy security equation for production, while Yt = 2.025 + 0.735D1 1.142D2 is the equation for total consumption. For the years 1980-1989, we may use D1 = 0 and D2 = 1, for 1990-1999, we can use D2 = 0 and D1 = 1, and for 2000-2015, we can use D1 = 0 and D2 = 1, therefore Yt = energy security.

Energy Security in Coal: Production, Consumption and Imports

Production, Consumption and Imports of Coal: Regression Model with Dummy Variables

Table 3: Model Summary of Variables for Coal

Variables	Model	R	R Square	Adjusted R Square	Std. Error of The Estimate	F	Sig.
Production	1	.938[a]	.879	.872	.07936	120.301	.0001**
Consumption	1	.933a	.870	.862	.09725	110.489	.0001**
Imports	1	0.947	.897	.890	.31630	143.017	.0001**

***Source*:** Author's Calculations

Production, consumption, and imports all show a significant association with the highest values of R, which are 0.938, 0.933, and 0.947, respectively. As shown in Table R, the model accounts for 0.799% of the variance in output, 0.870% of the variance in consumption, and 0.897% of the variance in imports. Methods with many variables are penalized by the rectified square R, a corrected version of the "square R" statistic. When deciding between many models, these statistics, in conjunction with the approximation's standard error, are more useful as comparison metrics. The minimal amount of error for production, consumption, and imports is 0.31630, 0.9725, and 0.7936, respectively, for the estimate's standard error.

Energy Security in terms of Coal Production, Consumption and Imports

Table 4: Production, Consumption and Imports of Coal in India

Variables	1980-89	1990-99	2000-16
Production	5.23	5.49	5.73
Consumption	5.21	5.49	3.87
Imports	5.73	5.79	4.92

Source: Author's Calculations

The R-squared value is 0.879 and the corrected R-squared value is 0.872, both with a relatively small standard deviation, when computing the compound growth rate using the linear regression equation. In terms of output, the estimation error is 0.079. The consumed scenario has an R-squared value of 0.870 and an adjusted R-squared value of 0.862. Because the p-value is lower than the threshold of significance, the growth rate coefficients are statistically notable, as seen more clearly in the table.

Coefficients D1 and D2 have 0.0001 values, which indicate that they are significant.

Yt = 5.234 + 0.252D1 + 0.493D2 for energy security, Yt = 5.214 + 0.272D1 + 0.576D2 for consumption, and Yt = 2.772 + 1.098D1 + 2.143D2 for imports. For the years 1980-1989, we may estimate energy security by setting D1 = 0 and D2 = 1, for 1990-1999, by setting D2 = 0, and for 2000-2015, by setting D1 = 0 and D2 = 1, and finally, by setting Yt = energy security.

Energy Security in Oil: Production, Consumption and Imports: Because of its indispensable function in transportation, crude oil is of paramount importance, especially for a large nation like India. The system's oil scarcity is a sign that it can't keep up with the rising demand. Rising reliance on imported fuels is very important to meet India's massive energy demands, giving the country unbeatable energy security. As a result of its growing reliance on imports, India is more vulnerable to global price fluctuations and geopolitical uncertainties.

Energy Security in Oil Production: Regression Model with Dummy Variables

Table 5: Model Summary of Variables for Oil

Variables	Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	F	Sig.
Production	1	.898[a]	.806	.794	.03799	68.526	.0001**
Consumption	1	.939a	.883	.876	.08679	124.103	.0001**
Imports	1	.931a	.868	.858	.16895	88.439	.0001**

Source: Author's Calculations

For output, consumption, and imports, respectively, the R-squared value is 0.806, 0.883, and 0.868. The greater the R-squared number, the better the model fits the data. A high degree of correlation is shown by values of 0.898, 0.939, and 0.931. The minimal standard errors for production (0.03799), consumption (0.08679), and imports (0.18885) are as follows.

In order to determine whether a link exists between more than two groups at once, the researcher has used the F and significant values. In regression analysis, the total of squares is a statistical tool for resolving data point dispersion, which in this case implies measuring the data's proximity to the fitted regression line. In multiple regression, it is referred to as the coefficient of multiple determination or the coefficient of determination. All levels of significance are shown by the model, with production and consumption both showing values of 0.0001%.

Energy security in terms of oil production, consumption and imports

Table 6: Production, Consumption and Imports of Oil in India

Variables	1980-89	1990-99	2000-16
Production	2.69	2.81	2.86
Consumption	2.92	3.20	3.47
Imports	2.23	2.83	3.39

Source: Author's Calculations

In terms of production, consumption, and imports, the energy security equations are Yt= 2.686+0.119D1+0.179D2, Yt= 2.921+.275 D1+.547 D2, and Yt= 2.234+.592 D1+ 1.159 D2, respectively. To calculate energy security from 1980 to 1989, we need D1=0 and D2=1. From 1990 to 1999, we need D2=0 and D1=1. From 2000 to 2015, we need D1=0 and D2=1. Finally, we need Yt=energy security.

In addition to its pledge to combat climate change, India should prioritise social and economic growth to end energy poverty. The immediate answer to India's energy challenges is not to promote indigenous energy technology while actively seeking to use local resources effectively. However, this might improve energy security in the long run.

Trends in future energy security in India

Both energy security in production (ESIP) and energy security in imports (ESIM) were considered by the researcher. Energy security in terms of production (ESIP) has gone up while energy security in terms of imports (ESIM) has gone down, both of which indicate less reliance on energy. An increase in energy security is strongly suggested by this. Here, we employ these ratios in conjunction with a liner trend equation that includes intercept and slope dummies to ascertain the evolution of energy security during the research period. Here is the model that was used:

$$L\,n\,Y = \alpha + \beta_t + (\alpha_1 - \alpha)\,D_1 + (\alpha_2 - \alpha_1)\,D_2 + (\beta_1 - \beta)\,D_{1t} + (\beta_2 - \beta_1)\,D_{2t}$$

The indicator of energy stability is L n Y. For the time span from 1980 to 1989, D1 is 0, and for the rest of the period, it is 1. Similarly, for the time span from 1990 to 1999, D2 is 0, and for the rest of the period, it is 1. The intercept and slope parameters, which represent the growth rate, are α and β, respectively, for the 1980 to 1989 period, and for the 1990 to 1999 period, they are α1 and β1, respectively. The same holds true for α 2 and β 2, which cover the years 2000 to 2015. A measure of energy consumption, L n Y is the natural logarithm of Y.

(α1- α) represents the differential intercept for the second sub-period, whereas (α2- α1) symbolizes the same for the third sub-period.

$(\beta_1 - \beta)$ = change in slope (pace of increase) during the second time interval

(β_2- β_1) = rate of increase during the third sub-period, which is the differ
ential slope coefficient = time.

Table 7: Energy Security Trends in India

Variables	1980 to 1989	1990 to 1999	2000 to 2015
ESIM	1.1	1	1.1
ESIP	0.134	0.078	0.07719

***Source*:** Author's Calculations

The first subperiod saw a rise of 1.1% for ESIM, the second had a growth of 1%, and the third saw a gain of 1.1%. In the first sub period, ESIP increases by 0.14%, while in the second sub period, it decreases by 0.078. Import increase outpaces output growth, according to the researcher's analysis of the data shown in the table above. This shows that India is seeing an increase in energy insecurity.

(a) Energy Security and Energy Imports in India

Energy insecurity and the need to import energy go hand in hand. A rise in energy insecurity is parallel to the growth in energy imports. The researcher follows this up by using the same technique to analyse patterns in India's energy imports. Various forms of energy have been used for this objective and during the duration of this research. To calculate the directional growth rates, the following model was used:

$L_n\, y_t = \alpha + \beta_t + (\alpha_1 - \alpha)\, D_1 + (\alpha_2 - \alpha_1)\, D_2 + (\beta_1 - \beta)\, D_{1t} + (\beta_2 - \beta_1)\, D_{2t}$

Where t is the unit of time and Ln yt is the natural logarithm of coal. The preceding explanation explains the significance of other coefficients. Rates of increase for energy imports from several sources, including coal, are shown below:

Table 8: Growth Rate of Energy Consumption in India

Energy Source	1980 to 1989	1990 to 1999	2000 to 2015
Natural gas	2.9	2.6	2.6
Primary Coal	2.5	2.5	2.5
Crude oil	3.4	2.2	2.4

***Source*:** Author's Calculations

According to the data in the table above, natural gas imports were 2.9% on average during the first quarter. In the second sub period, it shows a growth of 2.6% and in the third sub period, it has remained steady at 2.6%. India imports the most energy from coal and oil combined. Throughout India's energy production subperiod, coal consumption remained constant at 2.5%. Despite a 2.2% drop in the second sub period and a 2.4% increase in the third sub period, oil has been increasing at an average rate of 3.4%. This demonstrates that India is importing crude oil at a higher rate.

Conclusion

This paper concludes that energy security in India, measured in terms of imports (ESIM) rather than production (ESIP), is insufficient One of the world's most rapidly expanding and developing economies is India, which is a well-known fact. One of the main characteristics of India's growing energy insecurity is its reliance on foreign energy sources, which is caused by the country's limited fossil fuel reserves and its ability for static production on a local level. Despite relatively flat domestic output, demand for Indian oil has increased dramatically over the last decade. Being a significant net oil importer, the country's output can only meet about 25% of the national oil needs. India is facing challenges in achieving energy surplus due to factors such as energy demand, supply interruptions, reliance on imports, and shortages. India's rapidly expanding urban population is putting a strain on the country's energy infrastructure, its natural resources, and the economy as a whole, and the advent of supply interruptions poses a serious threat to this progress.

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