

The Impact of Fossil Fuel Subsidies on Global Warming Externalities in Afghanistan: Evidence from IMF Data (2015–2025)

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Abstract

This exploratory study examines the association between fossil fuel subsidies and global warming externalities in Afghanistan from 2015 to 2025. Afghanistan provides a policy-relevant case for investigating whether subsidy externality relationships can be meaningfully assessed where energy and environmental data are limited. Using 11 annual observations obtained from the International Monetary Fund (IMF), the study applies descriptive statistics, trend analysis, Pearson correlation, and ordinary least squares (OLS) regression, supplemented by Augmented Dickey–Fuller tests and a stationary-transformation regression. Fossil fuel subsidies fluctuated considerably, while estimated global warming externalities generally increased. Pearson correlation indicated a positive association ($r = 0.6744$, $p = 0.0228$), and the level OLS regression produced a statistically significant positive coefficient ($\beta = 0.9725$, $p = 0.023$). After accounting for non-stationarity, however, the coefficient remained positive but was not statistically significant at the 5% level ($\beta = 0.2960$, $p = 0.089$). This weaker result suggests that the association observed in levels may partly reflect shared temporal trends, reducing confidence in the principal finding. The study therefore provides suggestive, not robust, evidence of an association and does not establish causality. Its contribution lies in documenting Afghanistan-specific trends and demonstrating how non-stationarity and a small sample constrain the interpretation of IMF-based subsidy and externality indicators. The findings support improved energy and environmental data collection and further research to inform consideration of gradual subsidy reform, targeted energy support, and cleaner energy investment.

Keywords: Fossil Fuel Subsidies, Global Warming Externalities, Climate Change, Energy Policy, Afghanistan, IMF Data.



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INTRODUCTION

Fossil fuel subsidies remain an important component of energy policy in many developing economies, particularly where energy affordability, fiscal constraints, and dependence on conventional energy sources influence government intervention in fuel markets. Such subsidies may reduce the financial burden of energy consumption for households and productive sectors, but they can also distort market prices, encourage fossil fuel consumption, and weaken incentives to adopt cleaner energy technologies. The environmental consequences extend beyond direct energy expenditures because fossil fuel combustion generates greenhouse gas emissions and associated climate damages that are not fully reflected in market prices. These unaccounted environmental costs constitute global warming externalities and represent an important consideration in evaluating the broader economic consequences of energy subsidies (Coady et al., 2018). Previous research has identified fossil fuel subsidy reform as a relevant instrument for addressing environmental degradation, improving fiscal efficiency, and supporting sustainable development, although the effectiveness and feasibility of reform depend on economic and institutional conditions (Rentschler & Bazilian, 2017).

The relationship between fossil fuel subsidies and environmental externalities has received considerable attention in energy economics and climate policy research. Davis (2017) demonstrated that fuel subsidies generate substantial external costs associated with carbon emissions, local air pollution, traffic congestion, and other environmental consequences. Kotchen (2021) further examined the economic benefits received by fossil fuel producers when environmental and public health costs remain excluded from market prices, emphasizing the distributional implications of implicit subsidies. Simanjuntak and Hartono (2024) identified a significant relationship between fuel oil subsidies and

global warming costs across lower- and upper-middle-income countries, suggesting that energy pricing policies can influence the environmental costs associated with fossil fuel consumption. Research by de Bruin and Yakut (2023) also demonstrated that removing fossil fuel subsidies may contribute to emissions reductions, although the economic consequences vary across sectors and households. These findings establish an empirical basis for examining subsidy–externality relationships while indicating that their magnitude and policy implications are sensitive to national circumstances and analytical specifications.

The measurement of fossil fuel subsidies presents an additional challenge because international institutions employ different conceptual and accounting approaches. Kojima and Koplow (2015) distinguished between price-gap measurements and inventory-based approaches, demonstrating that subsidy estimates depend on the scope of government support and the valuation methodology applied. Skovgaard (2017) identified important differences between the approaches adopted by the International Monetary Fund and the Organisation for Economic Co-operation and Development, particularly regarding the inclusion of environmental externalities in subsidy calculations. The distinction between explicit subsidies and implicit environmental costs is particularly relevant when examining their statistical association, since both indicators may be influenced by energy consumption patterns, international fuel prices, and underlying estimation assumptions. Consequently, a positive statistical relationship between subsidy estimates and global warming externalities does not necessarily establish that changes in government subsidy expenditure independently generate changes in environmental damages. Empirical assessments must consider the definitions of the indicators, the characteristics of the available data, and the limitations of the statistical methods employed.

Afghanistan provides a relevant national context for examining these relationships because empirical research specifically addressing fossil fuel subsidies and estimated global warming externalities in the country remains limited. The country's energy policy challenges require consideration of affordability, energy access, economic constraints, and environmental sustainability, making the relationship between fossil fuel support and environmental costs relevant to policy analysis. Nevertheless, conclusions derived from aggregate national indicators require particular caution when the available observations cover a relatively short period. Annual changes in estimated subsidies and environmental externalities may reflect broader economic developments, variations in energy consumption, changes in international energy prices, or methodological characteristics of the underlying estimates. The presence of such influences complicates the interpretation of a simple statistical association and limits the extent to which changes in environmental costs can be attributed to fossil fuel subsidies independently of other determinants.

Existing scholarship has primarily examined fossil fuel subsidies through international comparisons, general equilibrium modeling, environmental valuation, and assessments of subsidy reform. Rentschler and Bazilian (2017) emphasized the economic and institutional barriers affecting subsidy reform, while Harring et al. (2023) demonstrated the importance of public attitudes and the allocation of fiscal savings in determining the political acceptability of subsidy removal. Kalmey et al. (2025) examined the welfare consequences of explicit and implicit fossil fuel subsidies and identified differences between their economic and environmental effects. Although these contributions provide important insights into the broader consequences of energy subsidies, they do not directly establish the statistical relationship between annual subsidy estimates and global warming externalities in Afghanistan during 2015–2025. A further methodological concern arises when both indicators exhibit temporal persistence or non-stationarity, since correlations estimated from their original levels may appear statistically significant despite the absence of a stable underlying relationship. The research gap therefore concerns not only the limited Afghanistan-specific empirical evidence but also the need to evaluate whether the observed association remains statistically supported after considering the time-series properties of the indicators.

The present research examines the trends and statistical association between total explicit fossil fuel subsidies and estimated global warming externalities in Afghanistan using 11 annual observations from the International Monetary Fund covering 2015–2025. The selected period reflects the availability of a complete annual series for both indicators within the dataset used for the analysis. Three related questions guide the investigation: how the two indicators evolved during the observation period, whether they exhibit a statistically significant relationship, and how the estimated association changes when their time-series characteristics are taken into account. An exploratory quantitative design

combines descriptive statistics, trend analysis, Pearson correlation, ordinary least squares regression, Augmented Dickey–Fuller stationarity tests, and a supplementary stationary-transformation regression. The principal alternative hypothesis proposes a statistically significant positive association between fossil fuel subsidies and global warming externalities, while the null hypothesis specifies the absence of a statistically significant association. The contribution of the analysis lies in documenting Afghanistan-specific patterns and evaluating the sensitivity of the estimated relationship to alternative statistical specifications, rather than establishing a causal effect of subsidies on climate-related damages. The findings are intended to inform further empirical investigation and cautious policy consideration concerning energy affordability, fossil fuel subsidy reform, and environmental sustainability.

RESEARCH METHOD

This study used an exploratory quantitative time-series design to examine the association between total explicit fossil fuel subsidies and estimated global warming externalities in Afghanistan during 2015–2025. The analysis used 11 annual observations obtained from the International Monetary. The period selected due to verified reason for selecting 2015–2025, in which available complete data not missing, but we had more than this period but some year data found miss, that why we need a complete data period which I have found 2015-2025.

Analytical Strategy

Analysis is conducted used STATA. Descriptive statistics and trend plots summarized the distribution and annual movements of both indicators. Pearson correlation and a bivariate ordinary least squares regression were used as preliminary measures of association. The level regression is specified as:

$$GW_t = \beta_0 + \beta_1 FFS_t + \varepsilon_t$$

Where GW_t denotes estimated global warming externalities and FFS_t denotes total explicit fossil fuel subsidies in year t . The bivariate specification provided a transparent exploratory description while limiting the number of estimated parameters in a small sample. However, it did not control for other potential determinants, and its coefficient is interpreted as an association rather than a causal effect.

Augmented Dickey–Fuller tests are applied to examine stationarity used lag specification, deterministic terms, and lag-selection procedure. Under the selected specifications, the tests rejected the unit-root null for the first difference of global warming externalities and the second difference of fossil fuel subsidies. These results informed an additional transformed regression:

$$\Delta GW_t = \beta_0 + \beta_1 \Delta^2 FFS_t + \varepsilon_t$$

This model used the observations after differencing and alignment. It examined the association between annual changes in global warming externalities and changes in the annual change of subsidies. Consequently, it addressed a different relationship from the level regression and was interpreted as a supplementary analysis rather than a directly equivalent estimate of the level association.

The level OLS model was assessed using the Breusch–Godfrey test for first-order serial correlation, the Breusch–Pagan/Cook–Weisberg test for heteroscedasticity, and the Shapiro–Wilk test for residual normality. Statistical significance was primarily assessed at the 5% level, with coefficients, confidence intervals, and exact p-values reported.

Methodological Limitations

The small sample substantially limits statistical precision and the ability of stationarity and diagnostic tests to detect departures from their null hypotheses. Failure to reject a null hypothesis was therefore not treated as confirmation of stationarity, absence of serial correlation, constant error variance, or normally distributed errors. The inferred integration orders were also regarded as tentative.

Non-stationarity raises concerns about misleading associations in the level regression, while differencing further reduces the sample and changes how the variables are interpreted. Omitted economic and energy-related factors, potential structural changes, and uncertainty in the IMF estimates may also influence the results. Accordingly, the findings provide preliminary evidence specific to

Afghanistan and the selected period; they do not establish causality or support broad generalization to other countries or periods.

RESULT AND DISCUSSION

This section presents the empirical results of the study on the relationship between fossil fuel subsidies and global warming externalities in Afghanistan during 2015–2025. The analysis includes descriptive statistics, trend analysis, Pearson correlation, unit-root tests, regression analysis, robustness analysis, and diagnostic tests.

Table 1. Descriptive Statistics of the Study Variables, 2015–2025

Variable	N	Mean	Std. Deviation	Minimum	Maximum
Fossil Fuel Subsidies (FFS)	11	0.1748	0.1122	0.0650	0.4002
Global Warming Externality (GW)	11	0.7012	0.1618	0.4235	0.9095

The descriptive statistics show that total explicit fossil fuel subsidies in Afghanistan had a mean value of 0.1748 during 2015–2025, with a standard deviation of 0.1122. The values ranged from 0.0650 to 0.4002, indicating considerable variation in fossil fuel subsidies over the study period. Global warming externalities recorded a mean value of 0.7012, with a standard deviation of 0.1618, ranging from 0.4235 to 0.9095. Overall, both variables exhibited variation during the study period, although fossil fuel subsidies showed greater relative variability around their mean.

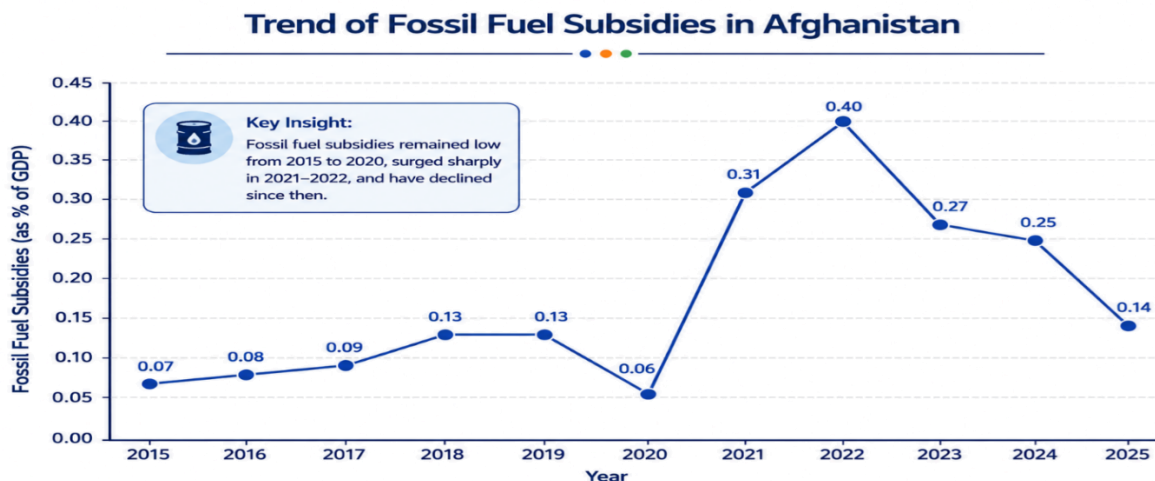


Figure 1: Fossil Fuel Subsidies

The figure 1 explain that the total explicit fossil fuel subsidies in Afghanistan fluctuated considerably between 2015 and 2025. Subsidies increased from approximately 0.065 in 2015 to 0.128 in 2019 before declining to 0.072 in 2020. A sharp increase occurred after 2020, reaching 0.307 in 2021 and peaking at 0.400 in 2022. Thereafter, subsidies declined to 0.260 in 2023, 0.246 in 2024, and 0.156 in 2025. Therefore, fossil fuel subsidies exhibited substantial year-to-year fluctuations rather than a consistent upward trend.

Trend of Global Warming Externalities in Afghanistan

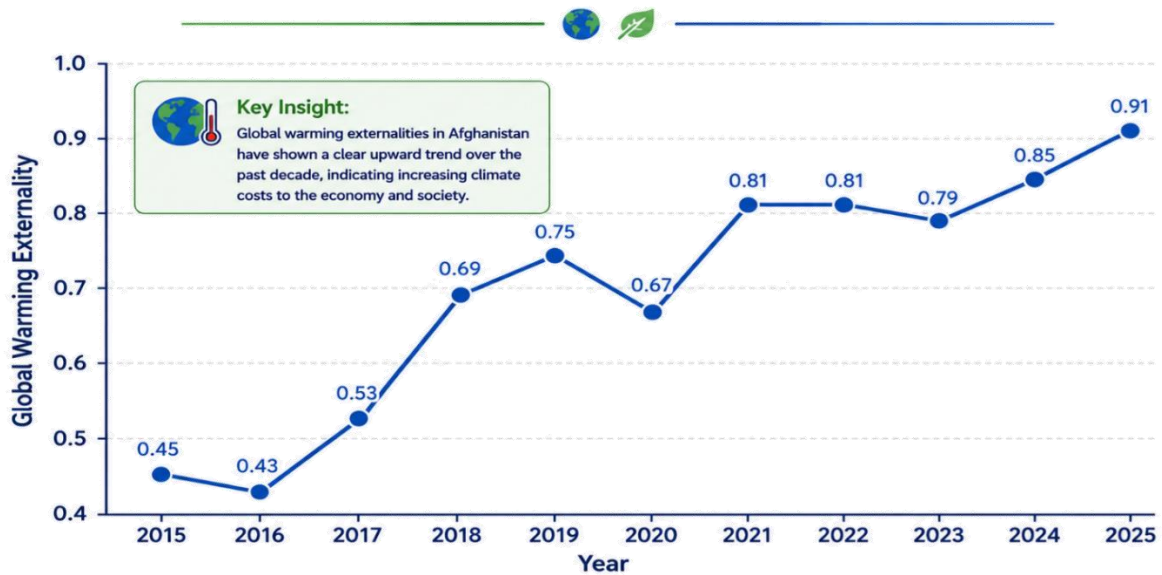


Figure 2: Global Warming Externalities

The Figure 2 stated that the Global warming externalities exhibited a clearer long-term upward tendency. The value declined slightly from 0.466 in 2015 to 0.424 in 2016 but subsequently increased to 0.754 in 2019. Following a temporary decline to 0.678 in 2020, the externality increased to approximately 0.810 in 2021 and 2022. After a small decline in 2023, it increased again to 0.845 in 2024 and reached its highest observed value of 0.909 in 2025. Overall, the findings indicate a substantial increase in global warming externalities over the study period.

Table 2. Pearson Correlation Between Fossil Fuel Subsidies and Global Warming Externalities

Variables	FFS	GW
Fossil Fuel Subsidies (FFS)	1.000	
Global Warming Externality (GW)	0.6744	1.000
p-value	0.0228	
N	11	11

Note: Correlation is statistically significant at the 5% level.

The Table 2 stated that the Pearson correlation analysis revealed a moderately strong positive and statistically significant relationship between fossil fuel subsidies and global warming externalities in Afghanistan during 2015–2025 ($r = 0.6744$, $p = 0.0228$). This indicates that years characterized by higher fossil fuel subsidies tended to coincide with higher global warming externalities. Since the p-value is below 0.05, the relationship is statistically significant at the 5% level. However, the correlation represents association and does not establish causality.

Table 3. Augmented Dickey–Fuller Unit Root Test

Variable	Form	ADF Statistic	p-value	Result
FFS	Level	-1.615	0.4754	Non-stationary

FFS	First difference	-2.554	0.1029	Non-stationary
FFS	Second difference	-3.472	0.0087	Stationary
GW	Level	-0.926	0.7792	Non-stationary
GW	First difference	-3.458	0.0091	Stationary

The Table 3 show that the ADF results indicate that global warming externalities are non-stationary at level but become stationary after first differencing, suggesting that GW behaves as an I(1) process under the applied test. Fossil fuel subsidies remain non-stationary at level and first difference but become stationary after second differencing, suggesting that FFS behaves as an I(2) process. These classifications should be interpreted cautiously because the study contains only 11 annual observations and unit-root tests have limited power in very small samples.

Ordinary Least Squares Regression

An ordinary least squares regression was initially estimated to assess the association between fossil fuel subsidies and global warming externalities.

The estimated model is: $GW_t = \beta_0 + \beta_1 FFS_t + \epsilon_t$ The estimated equation is: $GW_t = 0.5312 + 0.9725 FFS_t$

Table 4. OLS Regression Results

Variable	Coefficient	Std. Error	t-statistic	p-value	95% Confidence Interval
Fossil Fuel Subsidies (FFS)	0.9725	0.3549	2.74	0.023	0.1696–1.7754
Constant	0.5312	0.0728	7.30	<0.001	0.3666–0.6958
Model Statistic			Value		
Number of Observations			11		
R-squared			0.4548		
Adjusted R-squared			0.3942		
F-statistic			7.51		
Prob > F			0.0228		

The table 4 stated that the coefficient of fossil fuel subsidies was positive and statistically significant at the 5% level ($\beta = 0.9725$, $p = 0.023$). This indicates that, in the level specification, a one-unit increase in fossil fuel subsidies was associated with approximately a 0.9725-unit increase in global warming externalities. The R-squared value of 0.4548 indicates that approximately 45.48% of the variation in global warming externalities was associated with variation in fossil fuel subsidies. However, because both variables are found to be non-stationary at level, the level regression should be interpreted cautiously and should not be considered definitive evidence of causality.

Stationary-Transformation Robustness Analysis

To account for the non-stationarity identified by the ADF tests, an additional regression was estimated using the first difference of global warming externalities and the second difference of fossil fuel subsidies.

The model is: $\Delta GW_t = \beta_0 + \beta_1 \Delta^2 FFS_t + \epsilon_t$

Table 5. Stationary-Transformation Regression Results

Variable	Coefficient	Std. Error	t-statistic	p-value	95% Confidence Interval
Δ^2 FFS	0.2960	0.1499	1.97	0.089	-0.0584–0.6505
Constant	0.0573	0.0216	2.65	0.033	0.0062–0.1083

Model Statistic	Value
Number of Observations	9
R-squared	0.3578
Adjusted R-squared	0.2661
F-statistic	3.90
Prob > F	0.0888

The table 5 show that the coefficient of the second difference of fossil fuel subsidies remained positive at 0.2960. However, its p-value of 0.089 indicates that the association was not statistically significant at the conventional 5% level. The result is weakly significant only at the 10% level. Therefore, the positive relationship identified in the level regression becomes weaker after accounting for the stationarity properties of the variables.

Regression Diagnostic Tests

Several diagnostic tests are conducted to assess the statistical adequacy of the level OLS model.

Table 6. Regression Diagnostic Test Results

Diagnostic Test	Statistic	p-value	Conclusion
Breusch–Godfrey LM Test	$\chi^2 = 3.672$	0.0553	No significant first-order autocorrelation at 5%
Breusch–Pagan/Cook–Weisberg Test	$\chi^2 = 0.49$	0.4820	No evidence of heteroskedasticity
Shapiro–Wilk Test	W = 0.9680	0.8652	Residuals approximately normally distributed

The Breusch Godfrey LM test produced a p-value of 0.0553, indicating that the null hypothesis of no first-order serial correlation could not be rejected at the 5% significance level. However, the result was close to the conventional significance threshold and should be interpreted cautiously.

The Breusch Pagan/Cook–Weisberg test yielded a p-value of 0.4820, indicating no evidence of heteroskedasticity. Similarly, the Shapiro–Wilk normality test produced a p-value of 0.8652, indicating that the regression residuals did not significantly depart from normality.

Hypothesis Testing

The study proposed the following hypotheses:

H₁: There is a significant positive association between fossil fuel subsidies and global warming externalities in Afghanistan.

H₀: There is no significant association between fossil fuel subsidies and global warming externalities in Afghanistan.

The Pearson correlation analysis showed a statistically significant positive association between fossil fuel subsidies and global warming externalities ($r = 0.6744$, $p = 0.0228$). Similarly, the level OLS regression produced a positive and statistically significant coefficient for fossil fuel subsidies ($\beta = 0.9725$, $p = 0.023$).

Therefore, based on the correlation and level regression results, the null hypothesis is rejected and the alternative hypothesis is supported.

However, the stationary-transformation regression produced a positive but statistically insignificant coefficient at the 5% level ($\beta = 0.2960$, $p = 0.089$). Therefore, although the findings provide evidence of a positive association, the relationship is not robustly significant after accounting for non-stationarity.

The findings indicate a positive association between fossil fuel subsidies and global warming externalities in Afghanistan during 2015–2025. The trend analysis showed that fossil fuel subsidies fluctuated considerably, while global warming externalities generally increased over the study period.

Pearson correlation confirmed a moderately strong and significant positive relationship ($r = 0.6744$, $p = 0.0228$), while the level OLS regression also showed a significant positive association ($\beta = 0.9725$, $p = 0.023$). These findings are broadly consistent with the economic and environmental literature suggesting that fossil fuel subsidies can encourage fossil fuel consumption by lowering energy costs and thereby contribute to greenhouse gas emissions and climate-related externalities. In this respect, the evidence from Afghanistan supports the general argument that maintaining fossil fuel subsidies may conflict with environmental and climate objectives. However, the robustness analysis provides a more cautious conclusion. After accounting for non-stationarity, the relationship remained positive but was not statistically significant at the 5% level ($\beta = 0.2960$, $p = 0.089$). Thus, while the level analysis supports the hypothesis of a significant positive association, the transformed model provides only weaker evidence. This difference highlights the importance of considering time-series properties when evaluating the relationship.

CONCLUSION

This exploratory study examined fossil fuel subsidies and estimated global warming externalities in Afghanistan using 11 annual IMF observations from 2015 to 2025. Subsidies fluctuated considerably, while estimated global warming externalities generally increased. The central finding is that the evidence depends on the model specification: Pearson correlation and the level OLS regression indicated a statistically significant positive association ($r = 0.6744$, $p = 0.0228$; $\beta = 0.9725$, $p = 0.023$), whereas the transformed regression provided weaker evidence and was not statistically significant at the 5% level ($\beta = 0.2960$, $p = 0.089$). Because the transformed model relates first differences of externalities to second differences of subsidies, it also measures a different relationship from the level specification. The results therefore do not establish a consistently supported positive association across models. The study's contribution is limited to documenting Afghanistan-specific trends and showing how the interpretation of the observed association changes when time-series properties are considered. The small sample, uncertain stationarity classifications, and omission of other relevant determinants constrain the reliability and generalizability of the findings. The analysis cannot establish whether subsidies directly increase global warming externalities or whether subsidy reform would reduce them. Longer, consistently measured datasets and stronger research designs are needed before causal conclusions or claims about policy effectiveness can be justified.

Gradual Reform of Fossil Fuel Subsidies: The Afghan authorities should consider gradually reviewing and reforming fossil fuel subsidies, particularly those that may encourage inefficient fossil fuel consumption. Any reform should consider energy affordability and the needs of vulnerable households. **Promote Cleaner Energy Sources:** Greater attention should be given to renewable and cleaner energy sources, particularly solar, wind, and other locally appropriate alternatives, to reduce dependence on fossil fuels and their associated environmental externalities. **Targeted Energy Support:** Instead of broad fossil fuel subsidies, support could be better targeted toward low-income households and essential sectors. This may help protect vulnerable groups while reducing incentives for excessive fossil fuel consumption. **Integrate Environmental Considerations into Energy Policy:** Policymakers should consider the environmental costs associated with fossil fuel use when designing energy and subsidy policies. Energy affordability, economic development, and environmental sustainability should be addressed together. **Improve Energy and Environmental Data:** Relevant institutions should strengthen the collection and reporting of consistent data on fossil fuel subsidies, fuel consumption, greenhouse gas emissions, renewable energy, and environmental externalities. Better data would support more reliable policy analysis. **Further Research:** Future studies should use longer time periods and include additional variables such as GDP, fossil fuel consumption, carbon emissions, population growth, energy intensity, and renewable energy use. More comprehensive econometric models could help determine whether the observed association represents a causal relationship.

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