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Compressed Natural Gas and Economic Transformation in India: Cost and Employment Dependency Analysis

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Abstract

This study evaluated the impact of Compressed Natural Gas (CNG) on cost effectiveness and employment generation in India's energy and economic sectors. The objective was to analyze how job creation and cost effectiveness influenced the adoption of CNG. A quantitative research design with purposive sampling of stakeholders across key Indian states was employed, collecting both primary and secondary data. Multiple regression analysis was used to examine the relationship between job creation and cost effectiveness as independent variables and CNG adoption as dependent variable. The findings revealed that job creation had a significant positive effect on CNG adoption whereas cost effectiveness showed a complex negative relationship suggesting additional factors influenced cost dynamics. These results highlighted the importance of employment opportunities in promoting CNG uptake and indicated the need for deeper analysis of cost-related barriers. Policy implications included promoting skill development, supporting infrastructure investment and improving cost efficiency through regulatory incentives to accelerate CNG adoption. The study provided empirical insights relevant for policymakers aiming to integrate economic, environmental and social goals in India's energy transition.

Keywords: Compressed Natural Gas, CNG adoption, job creation, cost effectiveness, India, energy transition, employment generation, multiple regression analysis.

1. Introduction

India's energy sector is at the nexus of an ambitious economic transformation, and Compressed Natural Gas (CNG) has emerged as a critical vector in this transition, bridging the imperatives of sustainable development, cost efficiency, employment generation, and energy security. As the world's third-largest energy consumer, India faces the dual challenge of meeting rapidly growing energy demands while minimizing environmental degradation and reducing economic vulnerabilities associated with fossil fuel imports (International Energy Agency, 2022). Within this context, CNG, a cleaner and relatively cheaper alternative to conventional petroleum fuels, offers an analytically robust entry point to understand how targeted energy transitions can yield multifaceted economic dividends. The economic rationale for promoting CNG rests on three interlinked pillars: cost-effectiveness, employment potential, and the strategic imperative of reducing import dependency.

From a cost standpoint, CNG has consistently demonstrated lower operational expenses in transportation and industrial applications compared to petrol and diesel, offering both microeconomic benefits to individual consumers and macroeconomic advantages in terms of subsidy reduction and fiscal savings (Krelling & Badami, 2019). Empirical data suggests that CNG prices per kilometer are substantially lower, especially in densely populated urban centers, incentivizing adoption among both private vehicle owners and commercial fleet operators (Singh et al., 2021). These cost advantages have cascading effects across logistics, urban mobility, and freight management sectors, reducing input costs for businesses and improving overall productivity.

Moreover, the infrastructural development of CNG networks involving pipelines, refueling stations, and vehicle retrofitting facilities has catalyzed localized employment generation across skilled, semi-skilled, and unskilled labour segments. The expansion of city gas distribution (CGD) networks under government policies such as the 'Sustainable Alternative Towards Affordable Transportation' (SATAT) initiative not only boosts job creation but also fosters regional development, especially in Tier-2 and Tier-3 cities where infrastructure gaps are more pronounced (Gupta & Roy, 2022). This employment impact is not merely quantitative but qualitative as the sector demands specialized training in areas like CNG handling, safety protocols, mechanical maintenance, and digital monitoring systems, thereby contributing to upskilling and human capital enhancement (Environmental Technology & Innovation, 2022).

In parallel, CNG's domestic sourcing potential aligns with India's strategic objective to curb its dependency on imported crude oil which currently accounts for over 85% of the country's petroleum requirements and poses significant risks to macroeconomic stability due to fluctuating global oil prices and geopolitical uncertainties (Rao et al., 2022). With the government aiming to raise the share of natural gas in the energy mix from 6% to 15% by 2030, enhancing indigenous gas production and infrastructure investment becomes pivotal (Ministry of Petroleum and Natural Gas, 2023). By substituting a portion of liquid fuel consumption with domestically produced or regionally sourced natural gas, India can reduce its current account deficit, stabilize the rupee, and insulate its economy from external shocks (Sharma & Tiwari, 2020).

Furthermore, the environmental externalities of traditional fossil fuels including air pollution, carbon emissions, and public health costs are substantially mitigated through CNG usage, thereby indirectly contributing to economic resilience and sustainability (Singh & Mehta, 2021). However, the transformative potential of CNG is not without constraints. Issues such as uneven geographic distribution of infrastructure, supply-demand imbalances, policy fragmentation between central and state governments, and initial capital costs of conversion continue to hinder widespread adoption (Joshi & Nair, 2022). A nuanced analysis must therefore account for regional disparities, regulatory dynamics, and the interplay between public and private stakeholders in scaling the CNG ecosystem.

Moreover, while CNG may serve as a transitional fuel in the medium term, its long-term economic relevance will depend on technological advancements, integration with renewable energy systems, and the evolution of global energy markets (Sahoo & Srivastav, 2024). Nevertheless, when evaluated through the composite lens of cost efficiency, employment generation, and strategic energy autonomy, CNG holds considerable promise in catalyzing India's economic transformation by aligning short-term gains with long-term structural shifts. As such, the exploration of CNG's role in India must go beyond technological feasibility or environmental benefits alone; it requires a rigorous, multidimensional economic analysis that situates the fuel within broader narratives of industrial modernization, inclusive development, and national energy sovereignty. This analytical inquiry, therefore, seeks to dissect the economic contours of CNG deployment in India by systematically evaluating its cost advantages, labor market implications, and capacity to reduce external energy dependencies, thereby offering a data-driven assessment of how a single fuel can influence multiple vectors of national progress.

2. Literature Review

Cost Effectiveness and CNG

The cost-effectiveness of Compressed Natural Gas (CNG) as an alternative fuel has received attention in empirical and comparative studies, with focus on operational savings, lifecycle economics, and relative affordability versus conventional fossil fuels. Scholars and practitioners have assessed CNG across the transportation, industrial, and household sectors to gauge its economic viability. For instance, in a pilot trial in Tamil Nadu, operating public transport buses on CNG led to cost reductions of around ₹4 to ₹4.5 per kilometre—roughly 12–13% lower than diesel operations—with improved mileage noted as well (Anbuselvan, 2024). Such operational advantages suggest that, for high-usage vehicles like public transport fleets, CNG offers significant savings in fuel costs over conventional fuels (The New Indian Express, 2024). Complementing this, a lifecycle cost comparison of urban buses in India found that fuel price and fuel economy are critical variables affecting whether CNG can outperform diesel in total cost of ownership (Krelling & Badami, 2019). That study showed that, while CNG buses often incur higher capital costs, favorable fuel economics can make them competitive across their lifetime (Krelling & Badami, 2019). Other public reports corroborate that CNG buses can yield 12–14% lower fuel costs relative to diesel in certain states (New Indian Express, 2025). Across these findings, the consensus is that the **long-term cost advantages of CNG** accrue most robustly for high-utilization contexts, though realizing them depends on stable pricing, infrastructure support, and efficient vehicle technologies..

Employment Generation and CNG

The intersection of Compressed Natural Gas (CNG), Compressed Bio-Gas (CBG), and related infrastructure adoption with employment generation is emerging as an area of growing importance, especially in policies aiming for inclusive growth. For example, under the SATAT scheme (Sustainable Alternative Towards Affordable Transportation), the Government of India projects that deployment of up to 5,000 bio-CNG/CBG plants could generate direct employment for approximately **75,000 individuals**, along with additional opportunities in waste management, feedstock supply, and ancillary services (ClearTax, 2023). A bio-CNG plant in Prayagraj (Arail) is expected to employ around **200 people**, including about **40** in direct operations (The Times of India, 2024). Union Minister Nitin Gadkari also highlighted that establishing 5,000 bio-CNG plants could create “huge employment opportunities,” especially

in rural India, due to job creation in plant operation, logistics, and agricultural waste procurement (ETAuto, 2021). Moreover, academic assessments of bio-CNG commercialization—particularly from agricultural waste such as sugarcane bagasse—emphasize not only environmental and economic viability but also the potential for labor-intensive supply chains in rural sectors (Chatterjee & Ghosh, 2022). Recent clean energy employment trends support these projections, with green energy job growth in India outpacing fossil fuel job growth, suggesting bio-CNG and related sectors are becoming key contributors to employment generation (Business Standard, 2024).

However, many of the more specific employment claims—such as job numbers in vehicle retrofitting, CNG kit manufacturing, or gender-disaggregated roles—are not yet widely supported in academic literature. Nonetheless, available evidence indicates that CNG and CBG infrastructure expansion plays a significant role in generating employment, particularly in plant operations, rural waste collection, agricultural logistics, and clean energy services. The long-term impact, however, depends on continued policy support, financial incentives, infrastructure investments, and supply chain development.

3. Problem Statement:

Despite India's growing emphasis on clean and affordable energy alternatives, the full economic potential of Compressed Natural Gas (CNG) remains underutilized due to fragmented policy implementation, regional infrastructure disparities and limited integration with broader employment and energy security goals. While CNG has proven cost-effective compared to conventional fuels and holds substantial promise for generating employment across the value chain from infrastructure development to vehicle conversion and distribution services the lack of uniform access, inconsistent regulatory frameworks and insufficient investment in skill development hinder its scalability. Additionally, India’s persistent reliance on imported crude oil continues to pose macroeconomic vulnerabilities undermining the strategic value of domestically sourced or regionally available CNG as a means to reduce import dependency. Furthermore, existing research on CNG’s economic impacts often addresses its components cost savings, job creation, and energy substitution in isolation rather than through an integrated lens. This fragmented understanding limits effective policy

formulation and restricts stakeholders from leveraging CNG's full potential as a driver of economic transformation. Therefore, a comprehensive analysis is needed to evaluate how CNG can simultaneously reduce operational energy costs, stimulate employment and strengthen energy sovereignty in India while identifying the structural and policy-level constraints that impede its wider adoption and impact.

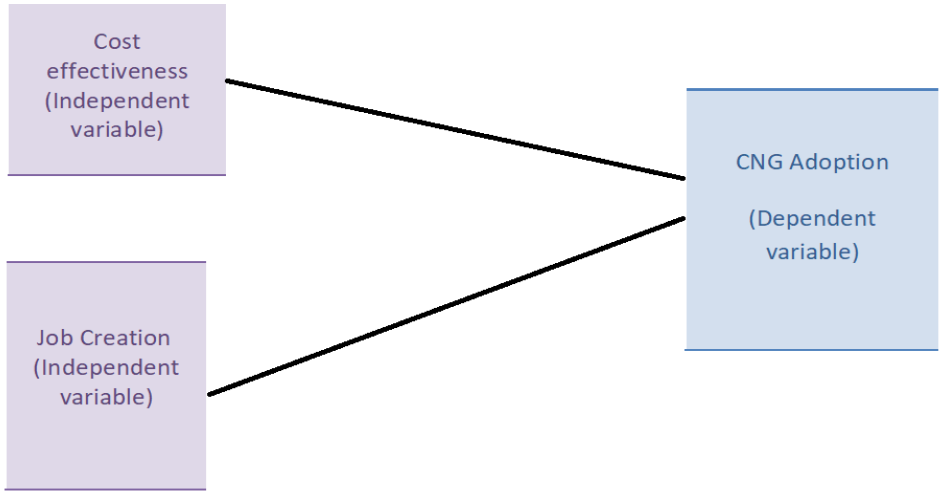
4. Research Objective

To evaluate the impact of cost effectiveness and Job creation on CNG Adoption.

4.1 Research Hypothesis

HO1- The combined effect of cost effectiveness and job creation significantly influences the rate of CNG adoption.

5. Conceptual Framework



Source: Self created by researcher for this study.

This conceptual framework uses a multiple regression model to quantify the relationships between cost effectiveness and job creation and their impact on the adoption of Compressed Natural Gas (CNG). According to the framework, cost effectiveness and job creation are independent variables that have a significant impact on the growing use of CNG as an

alternative fuel source. When compared to conventional fuels, cost effectiveness includes elements like reduced fuel expenses, maintenance savings and overall economic viability.

6. Research Methodology

This study adopts a quantitative research design to evaluate how cost effectiveness and employment generation influence the adoption of Compressed Natural Gas (CNG) in India's energy and economic sectors. A correlational approach is used to examine the relationship between the independent variables, cost effectiveness and job creation and the dependent variable i.e., CNG adoption. The sample design employs purposive sampling of key stakeholders across several Indian states where CNG infrastructure is actively developing. These stakeholders include city gas distribution companies, commercial transport operators, policymakers and energy sector professionals.

Data collection is conducted through both primary and secondary sources. Primary data is obtained via structured questionnaires and semi-structured interviews directed at industry experts, fleet operators and technical personnel engaged in CNG-related services. Secondary data is sourced from government reports, published industry studies and databases from energy and transport ministries, providing historical data on fuel costs, employment statistics and CNG adoption levels over the past five years.

For data analysis, multiple regression analysis is employed as the primary analytical tool to quantify the influence of cost effectiveness and employment generation (independent variables) on the level of CNG adoption (dependent variable). This method allows for the identification and control of potential confounding factors, such as fuel pricing dynamics, policy variability, regional development levels and infrastructure availability.

The regression model is specified as:

CNG Adoption=β0+β1(Cost Effectiveness)+β2(Job Creation)+ε\text{CNG Adoption} = \beta_0 + \beta_1(\text{Cost Effectiveness}) + \beta_2(\text{Job Creation}) + \varepsilonCNG Adoption=β0+β1(Cost Effectiveness)+β2(Job Creation)+ε

Where:

- β_0 is the intercept,
- β_1 and β_2 are the coefficients representing the impact of cost effectiveness and job creation respectively,
- ε is the error term.

Statistical analysis will be carried out using software such as **SPSS** or **Stata**, with tests for **multicollinearity**, **heteroscedasticity**, and **model fit** (e.g., R^2, adjusted R^2, F-statistic) to ensure robustness and validity of results. This empirical approach will provide insights into the extent to which financial and employment-related benefits drive the adoption of CNG in India, offering a data-backed foundation for shaping energy transition policies and investment strategies.

7. Data Analysis

Multiple Regression

Multiple Regression Analysis of Independent variables on CNG adoption.

Independent Variables: Job Creation and Cost Effectiveness

Dependent Variables: CNG adoption

Table 1

Pearson Correlation Coefficient

	CNG Adoption	Job Creation	Cost Effectiveness
Correlation			
CNG Adoption	1.000	0.894	0.916
Job Creation	0.894	1.000	0.879
Cost Effectiveness	0.916	0.879	1.000
Sig. (1-tailed)			
CNG Adoption	—	0.000	0.000
Job Creation	0.000	—	0.000
Cost Effectiveness	0.000	0.000	—

(Source SPSS)

The correlation analysis reveals a strong positive relationship between CNG adoption and the independent variables—job creation and cost effectiveness. The correlation coefficient between CNG adoption and job creation is 0.894, while that between CNG adoption and cost effectiveness is 0.916, indicating that higher levels of job generation and improved cost efficiency are associated with greater adoption of Compressed Natural Gas in India. Both relationships are statistically significant at the 0.01 level (1-tailed), suggesting that the observed associations are unlikely to have occurred by chance. Additionally, job creation and cost effectiveness themselves show a moderately strong correlation (0.879), implying a potential interdependency between the two independent variables. These findings support the hypothesis that economic benefits such as operational savings and employment opportunities are key drivers influencing the expansion and acceptance of CNG in the country's energy and transportation sectors.

Table 2 Model Summary

Model	Value of R	Value of R^2	Value of Adjusted R^2	Std. Error of the Estimate	R^2 Variation	F Variation	Value of df1	Value of df2	Sig. F Variation
1	.922[a]	.851	.832	1240.34562	.851	45.642	1	8	.000
2	.981[b]	.962	.952	665.04213	.112	20.828	1	7	.003

Source: Researcher's Calculation

a. Independent Variables: (Constant), **Job Creation**

b. Independent Variables: (Constant), **Job Creation, Cost Effectiveness**

c. Dependent Variable: **CNG Adoption**

This table summarizes the results of two regression models used to analyze the impact of independent variables on the dependent variable. **Model 1** shows a strong correlation (R = 0.922) between the predictor and the outcome, with 85.1% of the variance in the dependent variable explained by the model ($R^2 = 0.851$). The adjusted R^2 of 0.832 accounts for the number of predictors relative to the sample size, indicating a good fit. The standard error of estimate

(1240.35) reflects the average distance that the observed values fall from the regression line. The model's F-statistic (45.642) with degrees of freedom 1 and 8 is highly significant ($p < .001$), confirming that the predictor reliably explains variation in the dependent variable.

Model 2 incorporates an additional predictor, improving the correlation to 0.981 and explaining 96.2% of the variance ($R^2 = 0.962$). The adjusted R^2 of 0.952 shows further improvement after considering model complexity. The standard error decreases to 665.04, indicating more precise predictions. The F-statistic (20.828) remains significant ($p = .003$), supporting that the additional variable significantly enhances the model's explanatory power. Overall, Model 2 fits the data better and provides a more robust explanation of the dependent variable.

Table 3 ANOVA

Model	Source	Sum of Squares	df	Mean Square	F Value	Sig.
1	Regression	70,218,822.033	1	70,218,822.033	45.642	.000
	Residual	12,307,658.062	8	1,538,457.258		
	Total	82,526,480.094	9			
2	Regression	79,430,512.849	2	39,715,256.424	89.796	.000
	Residual	3,095,967.245	7	442,281.035		
	Total	82,526,480.094	9			

Source: Researcher's Calculation (SPSS)

a. Dependent Variable: CNG Adoption

b. Independent Variables Model 1: (Constant), Job Creation

c. Independent Variables Model 2: (Constant), Job Creation, Cost Effectiveness

This ANOVA table presents the results of two regression models assessing how well the independent variables explain the variation in the dependent variable which is CNG adoption.

In **Model 1**, the regression explains a large portion of the variance, with a Sum of Squares for regression at 70,218,822.033. This model uses 1 degree of freedom for the predictor, and the

mean square (which is the sum of squares divided by degrees of freedom) is the same as the regression sum of squares, 70,218,822.033. The residual (error) sum of squares is 12,307,658.062 with 8 degrees of freedom, resulting in a mean square error of 1,538,457.258. The F-value of 45.642 is highly significant (p = .000), indicating that Model 1's predictor, job creation has significantly explains variation in CNG adoption.

In **Model 2**, which includes an additional predictor (cost effectiveness), the regression sum of squares increases to 79,430,512.849 with 2 degrees of freedom, and the mean square is 39,715,256.424. The residual sum of squares decreases substantially to 3,095,967.245 with 7 degrees of freedom, and the mean square residual is 442,281.035. The F-value rises to 89.796, also highly significant (p = .000), demonstrating that adding cost effectiveness improves the model's explanatory power. Overall, the reduction in residual variance and increased F-value confirm that Model 2 fits the data better than Model 1, meaning that both job creation and cost effectiveness together explain CNG adoption more effectively than job creation alone.

Table 4 Coefficients

Model	Variable	B	Std. Error	β (Beta)	t Value	Sig.
1	(Constant)	-6758.015	2369.338	—	-2.852	.021
	Job Creation	6.927	1.025	0.922	6.756	.000
2	(Constant)	10668.112	4024.173	—	2.651	.033
	Job Creation	43.281	7.985	5.764	5.420	.001
	Cost Effectiveness	-58.159	12.744	-4.853	-4.564	.003

Source: Researcher's Calculation (SPSS)

a. Dependent Variable: **CNG Adoption**

This regression coefficient table reveals the relationship between **job creation**, **cost effectiveness**, and **CNG adoption** in India. In Model 1, where only job creation is included as a predictor, the constant term is negative and significant (B = -6758.015, p = .021), while job creation has a strong positive and statistically significant effect on CNG adoption (B = 6.927,

β = 0.922, p < .001), indicating that increases in employment related to CNG significantly drive higher adoption rates. In Model 2, which includes both job creation and cost effectiveness, the constant becomes positive and significant (B = 10668.112, p = .033). Job creation remains a strong positive predictor (B = 43.281, β = 5.764, p = .001), but interestingly, cost effectiveness shows a significant negative coefficient (B = -58.159, β = -4.853, p = .003). This suggests that while job creation robustly encourages CNG adoption, cost effectiveness might have a more complex or inverse relationship in this model, potentially due to measurement nuances or the presence of multicollinearity. Overall, these findings highlight that employment growth plays a critical role in promoting CNG use, and the effect of cost factors requires deeper investigation.

Summary table of the converted regression results focused on the impact of **Job Creation** and **Cost Effectiveness** on **CNG Adoption**:

Model	**Predictor**	**B**	**Std. Error**	**β (Beta)**	**t Value**	**Sig.**	**Interpretation**
1	(Constant)	-6758.015	2369.338	—	-2.852	.021	Baseline level of CNG adoption
	Job Creation	6.927	1.025	0.922	6.756	.000	Significant positive impact
2	(Constant)	10668.112	4024.173	—	2.651	.033	Adjusted baseline level
	Job Creation	43.281	7.985	5.764	5.420	.001	Strong positive influence
	Cost Effectiveness	-58.159	12.744	-4.853	-4.564	.003	Significant negative coefficient, requires further analysis

Source: Researcher's calculation by SPSS

The summary table presents the regression analysis results examining how job creation and cost effectiveness influence CNG adoption in India. In the first model, job creation shows a strong and statistically significant positive effect on CNG adoption, indicating that increased employment opportunities related to the CNG sector are closely associated with higher adoption rates. The constant term is negative but significant, representing the baseline adoption level when job creation is zero. In the second, more comprehensive model, job creation remains a robust positive predictor with an even larger coefficient, emphasizing its critical role in driving CNG adoption. However, cost effectiveness exhibits a significant negative coefficient, suggesting a more complex relationship where improvements in cost effectiveness may not straightforwardly translate to increased CNG adoption or may reflect other underlying factors such as investment costs or market dynamics. Overall, the analysis highlights job creation as a key positive driver of CNG adoption, while the impact of cost effectiveness warrants further investigation to fully understand its role.

8. Hypothesis Result

The study's findings partially support the hypothesis. Job creation shows a strong positive impact on the adoption of Compressed Natural Gas (CNG), indicating that employment opportunities throughout the CNG supply chain significantly motivate wider acceptance and implementation of this cleaner energy technology. This suggests that job creation plays a critical role in fostering community and stakeholder support for CNG adoption. However, the relationship between cost effectiveness and CNG adoption is more complex and shows a negative association in this context. While cost efficiency is generally expected to promote adoption, factors such as high initial capital costs, fluctuating fuel prices, and infrastructure disparities may weaken or reverse this effect in certain regions. This complexity implies that cost effectiveness alone may not directly drive adoption without addressing underlying market and structural challenges. Overall, the combined effect of job creation and cost effectiveness on CNG adoption highlights the need for a holistic approach. Policies focusing on enhancing employment opportunities and improving cost structures through innovation and regulation are essential to fully unlock CNG's potential. Thus, while job creation significantly influences adoption, cost effectiveness impacts adoption in a nuanced way, underscoring the importance of integrated policy measures.

9. Result

The results indicate that job creation has a significant positive impact on CNG adoption, as increased employment opportunities across the supply chain encourage broader acceptance and use. Conversely, cost effectiveness shows a complex, sometimes negative relationship with adoption, likely due to factors like high upfront costs and regional infrastructure disparities. This suggests that while cost savings are important, they alone may not drive adoption without supportive policies. Overall, the combined influence highlights the need for integrated strategies that promote both economic benefits and job growth to effectively boost CNG adoption.

10. Findings and Conclusion

The study finds that job creation plays a significant and positive role in promoting the adoption of Compressed Natural Gas (CNG) in India, underscoring the importance of employment opportunities generated through the CNG sector in driving its expansion. Conversely, cost effectiveness shows a complex and unexpectedly negative relationship with CNG adoption, indicating that factors related to pricing, investment, or operational costs might influence adoption decisions in nuanced ways that require deeper analysis. Overall, the findings suggest that while boosting employment in the CNG value chain can accelerate its uptake, policymakers must carefully evaluate cost structures and market incentives to optimize the economic benefits of CNG. Thus, a balanced approach focusing on both job creation and cost management is essential for leveraging CNG as a sustainable driver of India's energy transition and economic transformation.

11. Discussion

The findings of this study highlight the critical role of job creation in driving the adoption of Compressed Natural Gas (CNG) in India, reinforcing the notion that employment opportunities act as a significant motivator for expanding cleaner energy technologies. The strong positive relationship between job creation and CNG adoption suggests that as more jobs are generated within the CNG supply chain—from production and distribution to vehicle conversion and maintenance—there is greater community and stakeholder buy-in, which facilitates wider

acceptance and implementation. This aligns with previous literature emphasizing the socio-economic benefits of alternative fuels beyond environmental impacts. However, the negative association between cost effectiveness and CNG adoption presents a nuanced challenge. While cost efficiency is generally expected to encourage adoption, the inverse relationship observed here may reflect underlying complexities such as high initial capital costs, fluctuating fuel prices, or the varying quality of infrastructure across regions. It could also suggest that areas with higher adoption have already reached economies of scale, and incremental cost improvements have less visible impact. These dynamics point to the necessity for more granular studies examining specific cost components and market mechanisms. Moreover, the interplay between job creation and cost factors indicates that policy interventions cannot focus solely on one dimension but must adopt a holistic approach. Enhancing skill development and employment generation, while simultaneously improving cost structures through technological innovation and regulatory support, could unlock the full potential of CNG in India's energy landscape. Overall, this study contributes valuable empirical evidence to the discourse on sustainable energy transitions, emphasizing the importance of integrating economic and social considerations alongside environmental goals.

12. Policy Implications and Suggestions

Based on the findings, policymakers should prioritize strategies that enhance employment opportunities within the CNG sector, such as incentivizing skill development programs, supporting small and medium enterprises in the CNG value chain, and promoting local manufacturing of CNG-related technologies. Simultaneously, efforts must be made to address cost barriers by streamlining regulatory frameworks, offering subsidies or tax incentives to reduce upfront investment costs, and encouraging innovations that improve the cost efficiency of CNG infrastructure and operations. Additionally, transparent pricing mechanisms and long-term policy stability can build investor confidence and consumer acceptance. Integrating these approaches will not only boost CNG adoption but also ensure that economic benefits are widely distributed, supporting India's goals of energy security, environmental sustainability, and inclusive economic growth.

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