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Association Between Household Use of Clean Cooking Fuel and Child Stunting in Uttar Pradesh: A District-Level Analysis Using NFHS-5

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Abstract

This study attempts to examine the association between neighbourhood home clean cooking fuel use and child stunting in 60 districts of Uttar Pradesh using the recently released NFHS-5(2019–21) data. The descriptive statistic and ordinary least square regression analysis in the study reveals great disparities in child stunting, underweight and fuel among districts. The model accounted for 35.1% of the variation in stunting ($R^2 = 0.351$) and child underweight was positively and significantly associated ($\beta = 0.464$, $p < 0.001$). On the other hand, use of clean household energy for cooking was negatively associated with stunting ($\beta = -0.194$, $p = 0.003$) indicating that improved availability to household energy may reduce the risk of malnutrition. Higher prevalence of underweight was associated with higher prevalence of stunting and higher access to clean fuel was associated with lower stunting. The findings suggest a need for complementary nutrition interventions and access to clean energy. The findings can assist policymakers in Uttar Pradesh to develop district-specific programs to tackle malnutrition in children by integrating household energy interventions with nutrition policies.

Keywords

Child Stunting, Child Underweight, Clean Cooking Fuel, Linear Regression, NFHS-5, Uttar Pradesh

1. Introduction

Child malnutrition continues to be one of the most significant public health challenges worldwide, particularly in developing countries where inadequate nutrition, poor living conditions, and limited access to healthcare adversely affect children's physical and cognitive development. Malnutrition during early childhood contributes to increased morbidity and mortality, impaired learning capacity, reduced productivity in adulthood, and

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intergenerational transmission of poverty (Black et al., 2013; World Health Organization

(WHO), 2021). Consequently, improving child nutrition has become a global development priority under the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 3 (Good Health and Well-being) (United Nations, 2015).

India has made considerable progress in improving maternal and child health through programmes such as the Integrated Child Development Services (ICDS), Poshan Abhiyaan, and the National Health Mission. Despite these initiatives, child malnutrition remains a persistent concern, with significant disparities across states and districts. According to the National Family Health Survey-5 (NFHS-5), stunting, underweight, and wasting continue to affect a substantial proportion of children under five years of age, indicating the need for more targeted interventions (International Institute for Population Sciences (IIPS) & ICF, 2021). Uttar Pradesh, the most populous state in India, exhibits considerable district-level variations in child nutritional outcomes due to differences in socio-economic conditions, healthcare accessibility, maternal education, sanitation, and household living standards (NITI Aayog, 2023).

Among the various indicators of child malnutrition, stunting reflects chronic nutritional deprivation and is widely recognised as a key measure of long-term child health and development. Children affected by stunting are more likely to experience delayed cognitive development, poor educational performance, lower economic productivity, and increased susceptibility to diseases later in life (Victora et al., 2008; WHO, 2021). Therefore, identifying the factors associated with child stunting is essential for designing effective nutrition and public health policies.

Household environmental conditions have increasingly been recognised as important determinants of child health. One such factor is access to clean cooking fuel. Many rural and economically disadvantaged households continue to rely on traditional biomass fuels such as firewood, dung cakes, crop residues, and coal for cooking. The combustion of these fuels generates household air pollution, exposing women and children to harmful particulate matter and toxic gases that contribute to respiratory illnesses, adverse pregnancy outcomes, and poor child health (Bonjour et al., 2013; WHO, 2021). To address this challenge, the Government of India launched the Pradhan Mantri Ujjwala Yojana (PMUY) to promote the adoption of Liquefied Petroleum Gas (LPG) among low-income households. Although the programme has substantially expanded access to clean cooking fuel, disparities in utilisation continue to exist across districts because of differences in affordability, awareness, and socio-economic conditions (Ministry of Petroleum and Natural Gas, 2023).

Recent global evidence further highlights that improving household access to clean energy is essential for enhancing child health and nutritional outcomes. The Food and Agriculture Organization (FAO), International Fund for Agricultural Development (IFAD), UNICEF, World Food Programme (WFP) and World Health Organization (WHO) have emphasised that household food security, healthy living environments and access to clean energy collectively contribute to reducing child malnutrition and achieving sustainable development goals (FAO et al., 2024). Similarly, the Global Nutrition Report (2024) stresses that reducing child stunting requires coordinated investments in nutrition-sensitive sectors, including clean household energy, sanitation and healthcare. Furthermore, the World Bank (2024) highlights that improvements in household infrastructure and access to modern energy services are important components of human capital development and contribute to better health and nutritional outcomes among children in low- and middle-income countries.

Against this background, the present study examines the association between household use of clean cooking fuel and child stunting across the districts of Uttar Pradesh using NFHS-5 (2019–21) district-level data. Child underweight has been included as a control variable in the regression analysis to account for variations in child nutritional status. The findings are expected to provide evidence for policymakers in developing integrated interventions that combine nutrition programmes with improvements in household energy access to enhance child health outcomes in Uttar Pradesh.

The present study aims to examine the association between household use of clean cooking fuel and child stunting across the districts of Uttar Pradesh using district-level data from the National Family Health Survey-5 (NFHS-5, 2019–21). The specific objectives of the study are:

- To examine the district-level distribution of household use of clean cooking fuel, child stunting, and child underweight in Uttar Pradesh.
- To analyse the association between household use of clean cooking fuel and child stunting.
- To assess the influence of child underweight on child stunting while controlling for household use of clean cooking fuel.
- To suggest policy recommendations for improving child nutritional outcomes through better household energy access.

2. Literature Review

Recent literature has increasingly highlighted the role of household energy access in improving child health and nutritional outcomes. Islam et al. (2021) examined the association between household air pollution arising from cooking fuel, smoking and kitchen environment with childhood stunting in India using NFHS data. The study reported that children living in households dependent on solid fuels were significantly more likely to experience stunting than those residing in households using clean cooking fuels. The authors concluded that reducing household air pollution through the adoption of clean cooking fuel could contribute to improvements in child nutritional status.

Child malnutrition has been extensively studied as a multidimensional public health issue influenced by socio-economic, environmental, and demographic factors. Black et al. (2013) identified inadequate nutrition, repeated infections, poor maternal health, and unfavourable household environments as major contributors to child undernutrition in developing countries. The authors emphasized that reducing child malnutrition requires integrated interventions addressing both nutritional and environmental determinants.

Recent evaluations of the Pradhan Mantri Ujjwala Yojana (PMUY) have also demonstrated the importance of expanding access to clean household energy. Asharaf and Tol (2024) found that the scheme substantially increased LPG adoption among economically weaker households; however, continued reliance on traditional fuels remained common because of refill affordability and accessibility constraints. Similarly, emphasised that while PMUY has improved access to LPG, ensuring sustained utilisation remains a major policy challenge, particularly in rural areas.

Victora et al. (2008) reported that childhood stunting has long-term consequences extending beyond physical growth, including impaired cognitive development, lower educational attainment, reduced productivity, and increased risk of chronic diseases in adulthood. The study highlighted that preventing stunting during early childhood is essential for improving human capital and long-term economic development.

Environmental factors have also been recognised as important determinants of child nutrition. Dimitrova et al. (2022) reported that exposure to air pollution contributes to adverse child growth outcomes, including stunting, highlighting the need for integrated environmental and public health policies. Likewise, Basu et al. (2024) observed that cleaner household energy choices are associated with improved child survival and overall health outcomes, reinforcing the importance of transitioning from biomass fuels to cleaner alternatives.

Household environmental conditions have increasingly gained attention in nutrition research. Bonjour et al. (2013) demonstrated that dependence on solid biomass fuels exposes households to harmful indoor air pollution, increasing the risk of respiratory diseases and adverse maternal and child health outcomes. Similarly, the World Health Organization (2021) reported that household air pollution resulting from traditional cooking fuels remains a major environmental health risk in low- and middle-income countries.

In the Indian context, the introduction of the Pradhan Mantri Ujjwala Yojana (PMUY) has substantially expanded access to Liquefied Petroleum Gas (LPG) among economically weaker households. According to the Ministry of Petroleum and Natural Gas (2023), the programme has significantly increased LPG connections across rural India, although sustained utilisation continues to vary due to affordability and accessibility constraints.

The National Family Health Survey-5 (IIPS & ICF, 2021) revealed considerable inter-district disparities in child nutritional indicators and household living conditions across India. In Uttar Pradesh, differences in household access to clean cooking fuel, sanitation, maternal education, and healthcare services continue to influence child health outcomes. NITI Aayog (2023) also emphasised that reducing multidimensional poverty requires simultaneous improvements in household infrastructure, education, health, and access to clean energy.

Smith and Haddad (2015) argued that household socio-economic conditions remain one of the strongest determinants of child nutritional outcomes, while improvements in maternal education and living standards significantly contribute to reductions in child undernutrition. More recently, UNICEF (2023) highlighted that achieving sustainable reductions in child stunting requires integrated policies addressing nutrition, environmental health, sanitation, and household energy access rather than isolated interventions.

More recently, Das and Das (2026) examined the effects of indoor air pollution on child health in India and reported that dependence on solid cooking fuels increases the risk of adverse child health outcomes through prolonged exposure to household air pollution. The study recommended strengthening policies that promote clean cooking fuel adoption alongside maternal and child health programmes to improve nutritional outcomes. Collectively, these recent studies provide growing evidence that household energy access is an important component of child health; however, district-level empirical evidence linking clean cooking fuel and child stunting in Uttar Pradesh remains limited, thereby justifying the present study.

Nutritional and associated socio-economic, environmental and household factors of children and their families are reported as predictors of child stunting in the published research. It is widely acknowledged that children are more likely to be well-nourished if their moms and themselves are well-nourished, their houses have clean living surroundings and they have access to health care. For example, Black et al. (2013), Victora et al. (2008) and Smith and Haddad (2015) have pointed out the importance of household socio-economic status, maternal education and nutrition in lowering childhood undernutrition. Likewise, the World Health Organization (2021) and UNICEF (2023) asserted that coordinated interventions in environmental health, sanitation and nutrition are important for sustained progress in reducing child stunting.

A number of these research also agree that household energy is an important household environmental element influencing child health outcomes. Biomass fuels increase household air pollution (Bonjour et al., 2013) and solid cooking fuel is substantially connected with childhood stunting in India (Islam et al., 2021). A number of recent studies by Basu et al. (2024) and Das and Das (2026) have observed that better home energy benefits child health through reduced exposure to indoor air pollution. Collectively, these results provide evidence that increased uptake of clean cooking fuel may be associated with lower rates of childhood malnutrition.

S. No.	Author(s)	Year	Methodology	Major Findings	Research Gap
1	Victora et al.	2008	Longitudinal and epidemiological analysis	Demonstrated that child stunting adversely affects physical growth, cognitive development, educational attainment and future productivity.	Focused on long-term consequences rather than household environmental determinants.
2	Black et al.	2013	Global review of maternal and child undernutrition	Identified inadequate nutrition, recurrent infections and poor living conditions as major determinants of child undernutrition.	Did not examine household clean cooking fuel or district-level evidence from India.
3	Bonjour et al.	2013	Global assessment of household energy use	Traditional biomass fuels generate indoor air pollution, increasing health risks for women and children.	Did not investigate the relationship between clean cooking fuel and child stunting.

4	Smith and Haddad	2015	Cross-country econometric analysis	Household socio-economic conditions and maternal education significantly influence child nutritional outcomes.	Limited emphasis on household clean cooking fuel as a determinant of child stunting.
5	IIPS & ICF (NFHS-5)	2021	National household survey	Reported substantial district-level disparities in child nutrition and household living conditions across India.	Provided descriptive evidence without analysing regression-based relationships between variables.
6	Islam et al.	2021	NFHS-based empirical analysis	Household air pollution resulting from solid cooking fuels significantly increased the likelihood of child stunting among children under five years of age.	Did not focus specifically on district-level analysis for Uttar Pradesh.
7	Dimitrova et al.	2022	Environmental health modelling	Air pollution was associated with adverse child growth outcomes, including increased risk of child stunting.	Focused on environmental pollution rather than household clean cooking fuel adoption.
8	Ministry of Petroleum and Natural Gas	2023	Government programme evaluation	PMUY substantially increased LPG coverage among economically weaker households across India.	Did not evaluate the impact of clean cooking fuel on child nutritional outcomes.
9	NITI Aayog	2023	National Multidimensional Poverty assessment	Highlighted that improvements in housing, sanitation, education and clean energy contribute to reducing multidimensional poverty.	Did not specifically analyse child stunting using district-level NFHS-5 data.
10	UNICEF	2023	Global child nutrition report	Emphasised integrated interventions involving nutrition, sanitation, healthcare and household environment to reduce child malnutrition.	Did not provide district-level empirical evidence from Uttar Pradesh.
11	Asharaf and Tol	2024	Impact evaluation of PMUY	PMUY significantly improved LPG adoption among poor households; however, refill affordability limited sustained use.	Did not investigate child nutritional outcomes such as child stunting.
12	Basu et al.	2024	Econometric analysis	Adoption of clean cooking fuel contributed to improved child health and lower child mortality.	Focused on child mortality rather than child stunting.
13	Asharaf	2024	Policy evaluation	Expansion of LPG access under PMUY improved household energy security and reduced dependence on traditional fuels.	Did not examine the relationship between clean cooking fuel and child stunting.

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14	Das and Das	2026	Public health analysis	Indoor air pollution from solid fuels adversely affected child health and recommended greater adoption of clean cooking fuels.	Did not provide district-level evidence for Uttar Pradesh using NFHS-5 data.

Table 1. Summary of Literature Review

3. Data and Methodology

3.1 Study Area

The present study focuses on Uttar Pradesh, the most populous state in India. Owing to its large geographical area and considerable socio-economic diversity, the state exhibits substantial variations in household living conditions and child nutritional outcomes. The study encompasses 60 districts of Uttar Pradesh for which NFHS-5 (2019–21) district factsheets contained complete and consistent data on child stunting, household use of clean cooking fuel and child underweight. To ensure consistency of the regression model, districts for which data was unavailable, or data was not applicable, on one or more research variables were excluded from the analysis. Thus, we perform a complete-case analysis of the relevant district-level data in this study.

3.2 Data Source

The NFHS-5 dataset at the district level was validated for completeness before the study. Only districts with complete observations in all the variables available in the regression model were retained. Districts with missing entries were excluded to avoid anomalies from limited data. The study aimed to retain all the observations common to all the analyses, and hence no imputation approach was adopted.

3.3 Variables Used in the Study

Table 2 describes the variables considered in this study with their NFHS-5 indicators, operational definitions, scales of measurement and data sources. Dependent variable: Stunting was defined as the percentage of children <5 years of age whose height-for-age was less than two standard deviations below the median of the WHO Child Growth Standards. The primary explanatory variable was Household adoption of clean cooking fuel which is the fraction of household using LPG, electricity, biogas and other clean fuels as their primary cooking fuel. As a control we also added child underweight which is the percentage of children aged under five years whose weight-for-age is below minus two standard deviations of the WHO Child Growth Standards, to account for the variation in general nutritional status of the districts. All the variables are in percentage at district level and taken from the NFHS-5 (2019–21) factsheets of Uttar Pradesh districts.

Variable	Type	NFHS-5 Indicator	Operational Definition	Measurement Scale	Source
Child Stunting (%)	Dependent	Children under 5 years who are stunted (height-for-age below	Percentage of children aged 0–59 months whose height-	Continuous (Percentage)	NFHS-5 (2019–21) Uttar Pradesh District

		−2 SD of the WHO Child Growth Standards)	for-age is below minus two standard deviations from the WHO Child Growth Standards median		Factsheets – Child Nutrition Indicators
Households Using Clean Cooking Fuel (%)	Independent	Households using clean fuel for cooking	Percentage of households using LPG, electricity, biogas, or other clean fuels as the primary source of cooking fuel	Continuous (Percentage)	NFHS-5 (2019–21) Uttar Pradesh District Factsheets – Household Characteristics
Child Underweight (%)	Control	Children under 5 years who are underweight (weight-for-age below −2 SD of the WHO Child Growth Standards)	Percentage of children aged 0–59 months whose weight-for-age is below minus two standard deviations from the WHO Child Growth Standards median	Continuous (Percentage)	NFHS-5 (2019–21) Uttar Pradesh District Factsheets – Child Nutrition Indicators

Table 2. Description of Variables Used in the Study

3.4 Analytical Techniques

Descriptive statistics were used to summarize the distribution and variability of the study variables. In addition to the mean, median, minimum, maximum, and standard deviation, the coefficient of variation (CV), skewness, and kurtosis were computed. The coefficient of variation was used to assess the relative variability of each variable, while skewness and kurtosis were examined to evaluate the shape of the distributions and to identify departures from normality. These measures provide a more comprehensive understanding of the characteristics of the district-level data prior to regression analysis**.**

3.5 Model Specification

The correct usage of clean cooking fuel reduces the probability of child stunting and underweight according to the following MLR model:

$$\text{Stunting}_i = \beta_0 + \beta_1 \text{Underweight}_i + \beta_2 \text{CleanFuel}_i + \varepsilon_i$$

where:

- $Stunting_i$ = prevalence (%) of children under five who are stunted in district i (dependent variable);
- β_0 = intercept (constant term);
- β_1 = regression coefficient for child underweight;
- $Underweight_i$ = prevalence (%) of children under five who are underweight in district i;
- β_2 = regression coefficient for household use of clean cooking fuel;
- $CleanFuel_i$ = percentage of households using clean cooking fuel in district i;
- ε_i = random error term representing the effects of unobserved factors.

The regression coefficients were obtained by the approach of ordinary least squares (OLS). A positive regression coefficient indicates that a higher value of the explanatory variable is associated with a higher prevalence of child stunting. A negative coefficient implies an inverse relationship. The statistical significance was examined at the 5% level ($p < 0.05$).

4. Results and Discussion

4.1 Descriptive Statistics

Variable	N	Mean	Median	Standard Deviation	Minimum	Maximum
Child Stunting (%)	60	39.3	40.3	7.65	8.8	52.1
Household Using Clean Cooking Fuel (%)	60	47	45.6	13.2	20.3	78.3
Child Underweight (%)	60	31.9	32.7	7.14	1.9	49.8

Table 3. Descriptive Statistics of the Study Variables
Source: Computed by the authors using NFHS-5 district-level data (2019–21)

Interpretation of Descriptive Statistics

Table 3 presents the descriptive statistics of the variables in the study. Beside the parameter of central tendency and dispersion (mean, median, minimum, maximum and standard deviation), the coefficient of variation, skewness and kurtosis are also presented for the purpose of giving a more thorough description of data distribution. The coefficient of variation is used to compare the relative variability of data sets and skewness and kurtosis are used to quantify the degree of asymmetry and peakedness of the distributions, respectively. These are useful statistics in assessing whether in fact the data meet the assumptions for the subsequent regression modelling.

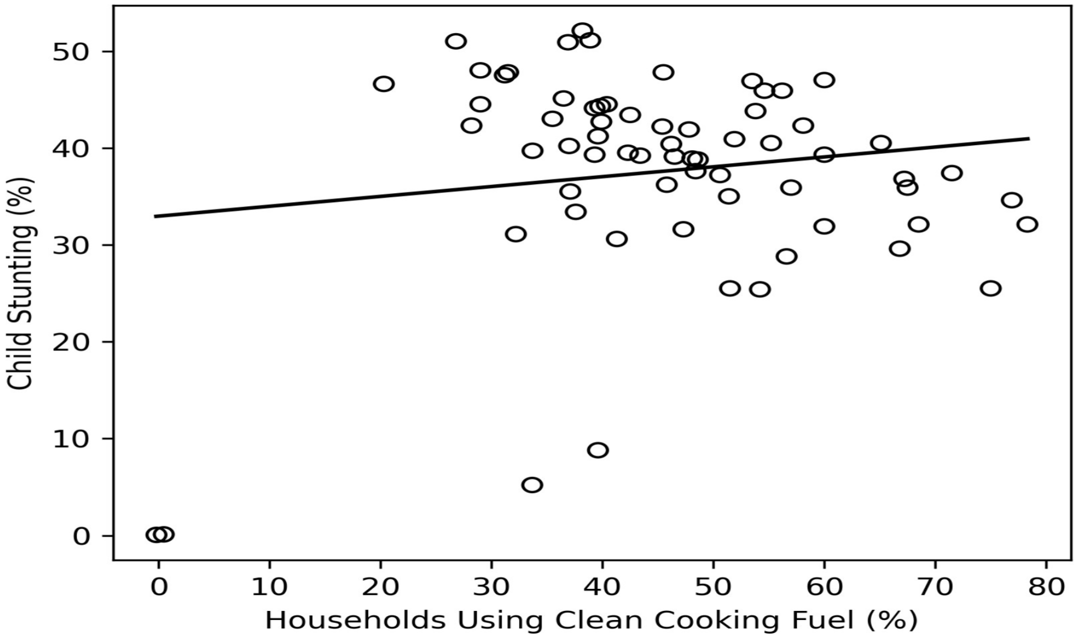

Figure 1. Scatter plot

4.2 District-wise Distribution

District level estimates are summarised in the body of the research for ease of understanding. Table A1 in Appendix A contains the complete data for each district. The summary highlights top and lowest child stunting, household clean cooking fuel and child underweight districts thereby revealing the geographical variance in these variables across Uttar Pradesh and does not disrupt the flow of the article.

Indicator	Highest District	Value (%)	Lowest District	Value (%)
Child Stunting	Bahraich	52.1	Etah	8.8
Households Using Clean Cooking Fuel	Lucknow	78.3	Lalitpur	20.3
Child Underweight	Banda	49.8	Ambedkar Nagar	1.9

Table 4. Summary of District-Level Indicators
Source: Computed by the authors using NFHS-5 (2019–21) Uttar Pradesh district factsheets.

Interpretation of the table

Table 4 presents the mean scores of the study variables of each district, Uttar Pradesh. All three variables are highly variable The highest prevalence of child stunting was observed in Bahraich (52.1 %) and the lowest in Etah (8.8 %). Lucknow had the highest household use of clean cooking fuels (78.3 per cent) while Lalitpur had the least (20.3 per cent). The prevalence of underweight children was also highly heterogenous across districts ranging from 49.8% in Banda to 1.9% in Ambedkar Nagar . This shows that there are large spatial inequalities in household energy and child nutrition in the state . Overall, districts with better clean cooking fuel coverage (e.g. Lucknow, Kanpur Nagar and Gautam Buddha Nagar) tend to have relatively lower child stunting while poor clean fuel coverage (e.g. Lalitpur and Banda) districts likely to have relatively higher child stunting and underweight. These district level patterns also provide some preliminary evidence of a negative association between clean cooking fuel and child stunting, explored further in the multiple linear regression.

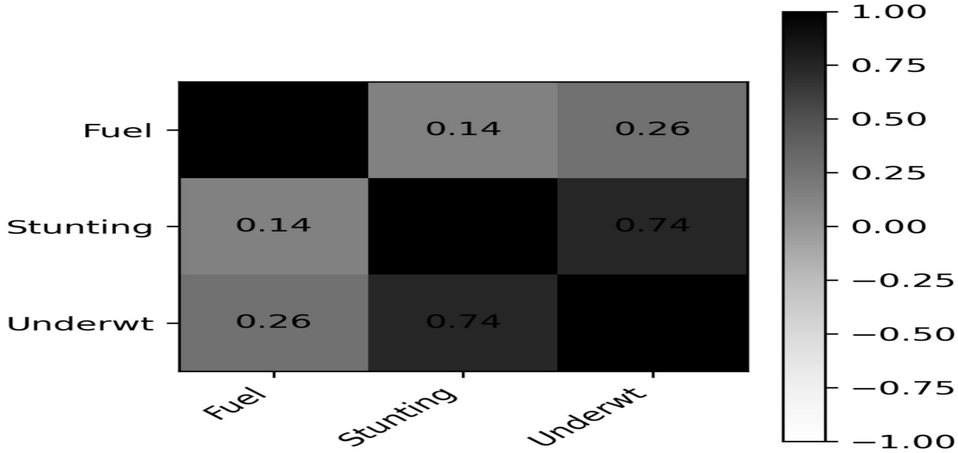

Figure 2. Correlation Matrix

4.3 Multiple Linear Regression Analysis

Model Fit Measures		
Model	**R**	**R^2**
1	0.593	0.351
Note. Models estimated using sample size of N=60		

Table 5. Model Fit Measures of the Multiple Linear Regression Model
Source: Computed by the author using Jamovi and district-level data from the National Family Health Survey-5 (NFHS-5), 2019–21.

Interpretation

The above table presents the model fit measures for the multiple linear regression analysis. The model produced a correlation coefficient (R) of 0.593, indicating a moderate relationship between the dependent and independent variables. The coefficient of determination (R^2) is 0.351, suggesting that approximately 35.1% of the variation in child stunting across the districts of Uttar Pradesh is explained jointly by household use of clean cooking fuel and child underweight. The remaining 64.9% of the variation may be attributed to other socio-economic, demographic and environmental factors not included in the present model. Overall, the model demonstrates a moderate explanatory power and is suitable for examining the relationship between the selected variables.

Model Coefficients - Child Stunting NFHS5				
Predictor	**Estimate**	**SE**	**t**	**p**
Intercept	33.672	5.2101	6.46	<.001
Child_Underweight_NFHS5	0.464	0.1163	3.99	<.001
COOKING FUEL (NFHS-5)	-0.194	0.063	-3.08	0.003

Table 6. Multiple Linear Regression Coefficients for Child Stunting in Uttar Pradesh.

Source: Computed by the author using Jamovi and NFHS-5 (2019–21) district-level data

Interpretation

Linear regression results show that clean cooking fuel use at household level is adversely and significantly associated with stunting of children under five at district level in Uttar Pradesh but child underweight is positively associated with child stunting. That is, a 1 percent increase in household access to clean cooking fuel reduces child stunting by 0.194 percent points, while a 1 percent increase in child underweight increases child stunting by 0.464 percent points. The model explained 35.1% of the variation between districts in child stunting, suggesting that although family energy availability and child underweight are both used to predict stunting, child nutrition is also influenced by other socio-economic, environmental and demographic factors.

The findings are in line with the findings of Islam et al. (2021) who reported that children living in solid cooking fuel using households were more likely to be stunted than those children who lived in clean cooking fuel using houses. Both publications also point to the potential for improved child nutritional outcomes by reducing exposure to household air pollution through the use of clean cooking fuels. However, the present study concentrated on district-level ecological analysis using district factsheets of NFHS-5, while Islam et al. (2021) analysed household-level NFHS data. Therefore, they should be interpreted as correlations on the district level rather than as evidence of causal effects on the household level.

These results are consistent with Basu et al. (2024) found that the use of clean cooking fuel improves child health and reduces child mortality. While Basu et al. is primarily about child mortality not child stunting, both research are indicative of the larger health benefits of cleaner household energy. Further, the closeness of the findings suggests that minimising exposure to household air pollution may enhance on various facets of child health including nutrition. However, these disparities in endpoint factors and methodological approaches were the reasons why the projected effects were not directly comparable.

This observed association among smokers was also similar with the findings of Dimitrova et al. (2022) who documented that exposure to air pollution hindered child growth and led to higher risk of stunting. This study is different from the present in the evaluation of cooking fuel. However, Dimitrova et al. used environmental health modelling to estimate ambient air pollution rather than home air pollution from cooking fuel consumption. While the technique is different, both studies do indicate that environmental exposures have a significant effect on infant growth and nutrition. The two findings are congruent and may suggest that household environmental improvements, such as more access to clean cooking fuel, can be a target of environmental health interventions more broadly.

The positive correlation between child underweight and child stunting is also consistent with the previous research in nutrition especially Black et al. (2013) and Victora et al. (2008) who considered chronic undernutrition as a main cause of poor child growth. This new finding of a strong correlation further confirms the complexity of child malnutrition indicators and

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gives more weight to the need for integrated nutrition programs and to the improvement of household energy availability.

The differences of the present study's findings with the previous research may be related to differences in geographical areas, units of analysis and research methods. Most previous research has been on household surveys, longitudinal approaches or national data. The present study is an ecological study using district level data of NFHS-5 (2019-2021) of Uttar Pradesh . Home level studies enable us to focus on individual risk factors while district level studies can reveal spatial inequities and can provide a basis for area-specific policy suggestions. Besides the heterogeneity of explanatory variables, population samples and estimation technique could explain the variation in the magnitude of effects across studies.

Overall, the findings contribute to an expanding literature on the health benefits of increased access to clean cooking fuel for children. It does so by providing district specific evidence for Uttar Pradesh and thereby filling a gap in the existing literature and by providing key insights that are policy-relevant for suggesting a possible integration of clean household energy interventions with child nutrition programme in districts with a high child malnutrition burden.

5. Policy Implications

The findings of the present study suggest that reducing child stunting requires policy interventions that integrate improvements in household energy access with nutrition and public health programmes. The World Health Organization has emphasised that reducing household air pollution through the adoption of clean cooking fuels is an essential strategy for improving maternal and child health, particularly in low- and middle-income countries (WHO, 2023). Similarly, the United Nations Development Programme (UNDP, 2023) highlights that universal access to affordable, reliable and clean energy is fundamental to achieving sustainable development and reducing multidimensional poverty. Therefore, strengthening access to clean cooking fuel, alongside targeted nutrition and healthcare interventions, can play a significant role in improving child nutritional outcomes in Uttar Pradesh.

First, increasing access to clean cooking fuel through schemes such as the Pradhan Mantri Ujjwala Yojana (PMUY) should remain a priority, particularly in districts with low adoption of clean cooking fuel and high prevalence of child stunting. Ensuring the sustained use of LPG through affordable refills and improved distribution networks can further reduce household dependence on traditional biomass fuels.

Second, interventions aimed at reducing child underweight should be strengthened through improved maternal and child nutrition programmes, regular growth monitoring, nutrition education and enhanced healthcare services. Since child underweight was found to be a significant predictor of child stunting, integrated nutrition interventions are essential for improving child health outcomes.

Finally, district-specific policies should be adopted to address regional disparities in both household energy access and child nutrition. Coordinated efforts involving the health,

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nutrition and energy sectors can contribute to reducing child malnutrition and promoting sustainable development in Uttar Pradesh.

6. Limitations of the Study

The study uses NFHS-5 data at district level so connections are ecological not causal. The ecological fallacy may be an issue for inferences at the household level. Limiting causal inference, important variables like as wealth, maternal education, sanitation, food and healthcare were not adjusted for. Future work should use household-level data with more broad socioeconomic and demographic characteristics.

The analysis has been on model fit and coefficients and without testing OLS assumptions. Diagnostic checks such as VIF, residual normality, homoscedasticity and influence statistics were not performed. The size of the coefficients should be treated with caution and future studies should include full diagnostic checks for reliability.

Districts with missing data were omitted. This might bias results, if excluded regions differ systematically. Limited generalisability Few districts were excluded . Future studies should either include all districts or utilise methods to account for missing data to enhance validity.

7. Conclusion

Using NFHS-5 (2019-21) data, the study examined the association between the use of household clean cooking fuel and child stunting and the control of child underweight in 60 districts of Uttar Pradesh. Descriptive results showed significant district level variations in access to fuel, stunting and underweight, suggesting differential living conditions. Regression analysis showed a significant and negative association between clean cooking fuel use and child stunting, while a positive association was observed between clean cooking fuel use and child underweight, indicating the interlinkages among malnutrition indicators. The model explained a moderate part of the variation in stunting indicating that other socio-economic and environmental factors also contribute. The findings are consistent with the research on health effects of reducing household air pollution . We also find lower stunting in districts with more clean fuel adoption. However, the ecological design implies that the data are interpreted as trends at the district level and not as causalities at the family level. Future research should incorporate household-level longitudinal or multi-level data to better establish causal links between access to renewable energy and child nutrition outcomes.

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Appendix A

DISTRICTS	COOKING FUEL (NFHS-5)	Child Stunting NFHS5	Child_Underweight_NFHS5
AGRA	67.5	35.9	26.2
ALIGARH	51.4	35	26.3
AMBEDKAR NAGAR	32.2	31.1	1.9
AURAIYA	33.7	39.7	32.6
AZAMGARH	37.6	33.4	28
BHAGPAT	51.5	25.5	26
BAHRAICH	38.2	52.1	38
BALIA	53.8	43.8	42.5
BALRAMPUR	39.6	41.2	37.2
BANDA	26.8	51	49.8
BARABANKI	47.8	41.9	31.9
BAREILLY	54.6	45.9	35.2
BASTI	57	35.9	39.2
BIJNOR	45.8	36.2	21.9
BULANDSHAHR	48.4	37.6	26.5
CHAUNDALI	42.3	39.5	29.9
CHITRAKOOT	31.2	47.5	41.8
DEORIA	67.2	36.8	39.4
ETAH	39.6	8.8	30.6

ETAWAH	48.6	38.8	24.3
FAIZABAD	41.3	30.6	27.5
FARRUKHABAD	45.5	47.8	31.1
FATEHPUR	38.9	51.1	38
FIROZABAD	53.5	46.9	25.6
GAUTAM BUDDHA NAGAR	75	25.5	21.9
GHAZIPUR	39.3	39.3	38.3
GONDA	56.2	45.9	28
GORAKHPUR	66.8	29.6	33.7
HAMIRPUR	29	48	36.3
HARDOI	29	44.5	33
JALAUN	36.5	45.1	36.1
JAUNPUR	55.2	40.5	30.3
JHANSI	51.9	40.9	39.3
JYOTIBHA PHULE NAGAR	45.4	42.2	35.4
KANNAUJ	35.5	43	33.5
KANPUR DEHAT	39.3	44.1	32.8
KANPUR NAGAR	76.9	34.6	27.8
KAUSHAMBI	37	40.2	36.8
LALITPUR	20.3	46.6	34.8
LUCKNOW	78.3	32.1	25.5
MAHAMAYA NAGAR	46.5	39.1	24.5
MAHARAJGANJ	65.1	40.5	37.4
MAHOBA	28.2	42.3	33.4
MAINPURI	39.8	44.3	33.6
MATHURA	47.3	31.6	21.3
MAU	54.2	25.4	30.3
MEERUT	68.5	32.1	23.7
MIRZAPUR	42.5	43.4	27.6
PILIBHIT	48.1	38.9	39.4
PRATAPGARH	37.1	35.5	27.7
RAMPUR	46.2	40.4	32.1
SAHARANPUR	56.6	28.8	26.7
SANT KABEER NAGAR	58.1	42.3	34.2
SANT RAVIDAS NAGAR (BADOHI)	39.9	42.7	26.5
SHAHJAHANPUR	40.4	44.5	34.7
SIDDHARTHNAGAR	50.6	37.2	36.3
SHRAVASTI	36.9	50.9	40.8
SITAPUR	31.5	47.8	37.9
UNNAO	43.4	39.2	29.3
VARANASI	71.5	37.4	39

Table 4. District-wise Distribution of Household Use of Clean Cooking Fuel, Child Stunting and Child Underweight in Uttar Pradesh (NFHS-5, 2019–21)

Source: Computed by the author using NFHS-5 (2019–21) district factsheets, International Institute for Population Sciences (IIPS) and ICF