

Multidimensional Energy Poverty and Maternal Health Outcome: Evidence from Pakistan

Kashif Raza¹ and Tusawar Iftikhar Ahmad²

<https://doi.org/10.62345/jads.2026.15.2.9>

Abstract

Energy poverty is becoming recognised as an important social determinant of health. Inadequate access to modern energy services is likely to have a detrimental influence on health-seeking behaviour, especially in women. The study investigates how household multidimensional energy poverty (MEP) and socioeconomic predictors affect the likelihood that women receive antenatal care (ANC) from a healthcare provider. A Multidimensional Energy Poverty (MEP) index based on a set of household energy deprivation indicators was constructed using nationwide survey data from Pakistan. The poverty cut off was used to categorise households into energy-poor and non-energy-poor. Binary logistic regression analyses were conducted to estimate the association between energy poverty and ANC use, and marginal effects were obtained to put the strength of these relationships into perspective. The analysis shows that women living in multidimensionally energy-poor households have a much lower probability of receiving ANC services. Mothers' education and internet use have a positive influence on ANC use, but rural living, geographic differences, and more childcare roles reduce the likelihood of seeking ANC. These findings suggest that the maternal health-seeking behaviour is influenced by structural deprivation, household conditions, and access to information. The results highlight the need to implement policy-level interventions that address both accesses to the health system and household conditions. Improving access to contemporary energy services, female education, digital connectivity and reducing regional inequalities in health infrastructure can make significant progress in improving maternal healthcare use. The paper contributes to the literature by establishing a correlation between multidimensional energy poverty and maternal healthcare use in Pakistan. It provides new evidence on the overall socioeconomic determinants of maternal access to health in developing nations by integrating household energy deprivation into the analytical model of maternal health behaviour.

Keywords: Multidimensional Energy Poverty; Maternal Healthcare Use; Maternal Education; Digital Connectivity.

Introduction

The use of maternal healthcare is an ongoing focus in the policy of public health and development, especially in low- and middle-income nations where maternal and neonatal complications, which can be prevented, are still prevalent. Antenatal care (ANC) services are very important in

¹PhD Scholar, Department of Economics, The Islamia University of Bahawalpur, Pakistan.

Email: kashif.raza@iub.edu.pk

²Associate Professor, Department of Economics, The Islamia University of Bahawalpur, Pakistan.

Email: tusawar.iftikhar@iub.edu.pk



decreasing the maternal and infant mortality, through early identification of pregnancy complications, improved nutritional counselling and prompt medical actions. Although the world has been working to expand maternal health coverage, significant gaps remain in access to and use of antenatal healthcare services. Such inequalities are often influenced by structural socioeconomic limitations, household living conditions, and unequal access to resources and information. Over the last few years, researchers have been paying more attention to the concept of energy poverty as a structural determinant of health outcomes and household welfare (Churchill & Smyth, 2021; Brown & Vera-Toscano, 2021).

Energy poverty refers to the condition in which households cannot access sufficient, reliable, and affordable energy services needed to sustain basic living conditions. It not only includes inadequate access to electricity, but also a lack of sufficient energy to heat, cool, cook, and light. The studies have proven that energy poverty is closely linked to a variety of health issues, such as respiratory diseases, cardiovascular disorders, and mental health issues (Bentley et al., 2023; Churchill & Smyth, 2021). Energy deprivation at the household level is frequently faced with poor indoor conditions, heating or cooling systems, and the use of polluting fuels, all of which lead to unfavourable health outcomes (Brown & Vera-Toscano, 2021). Data from other nations also show that poor energy access has a detrimental impact on household welfare, productivity, and quality of life (Nie et al., 2021; Phoumin & Kimura, 2019).

The connection between health and energy poverty is the most relevant to women, as they spend more time at home and are the ones who are primarily involved in home-related activities. This leads to the possibility of energy deprivation that disproportionately impacts the health and well-being of women. Empirical studies have revealed that multidimensional energy poverty is linked to various health risks to women such as physical and psychological health issues (Abbas, Xu, et al., 2021). On the same note, the research exploring the relationship between energy poverty and domestic health status reveals that the energy-deprived households are more prone to diverse health issues because of poor living standards and the inability to access the contemporary energy services (Abbas et al., 2021). The fact that the health impact of energy poverty can be also an indicator of gender inequalities is also supported by evidence in other contexts, with women commonly being more vulnerable to energy-related domestic hazards and limitations (Zhang et al., 2022).

In addition to having direct health impacts, energy poverty can indirectly affect healthcare utilisation by limiting household capacity and access to services. Households with a combination of various types of deprivation may face financial, mobility, and information accessibility limitations, which may impede the utilisation of formal healthcare services. In this respect, the general poverty status has been found to play a significant role in determining the utilisation of maternal healthcare. For example, multidimensional poverty has been found to decrease women's access to antenatal care services due to structural constraints associated with income, education, and living conditions (Chatata & Chirwa, 2025). Similarly, evidence from developing economies indicates that energy deprivation and lack of access to energy may exacerbate other socioeconomic imbalances, ultimately affecting health outcomes and well-being (Nyame-Baafi et al., 2025; Marcoje et al., 2026).

Although the health consequences of energy poverty are increasingly acknowledged, most existing research has focused on overall health outcomes, subjective well-being, or disease prevalence. The connection between energy poverty and physical health status, mental health, and well-being of a household has been a rich topic in the literature (Bentley et al., 2023; Churchill & Smyth, 2021; Nie et al., 2021). Nonetheless, the extent of energy poverty in the utilisation of maternal healthcare,

especially antenatal care, has received comparatively less attention. Given household living conditions, the resources available to women, and structural inequalities, the influence of energy deprivation on the determination of maternal healthcare behaviour is a significant yet understudied research field.

Another weakness of the current literature is that studies analysing poverty and maternal healthcare utilisation typically focus on income or multidimensional poverty indicators, rather than explicitly treating energy poverty as a structural constraint. Although poverty is a broad concept that describes economic deprivation, energy poverty is a narrower concept that focuses on household infrastructure and access to services, which can affect health-related behaviour in various ways. Access to energy affects household living conditions, access to information, and time allocation, which could affect women seeking healthcare services. Thus, investigating energy poverty as a structural factor shaping maternal healthcare utilisation may provide additional insights into how infrastructural deprivation influences maternal health outcomes.

This paper seeks to fill these gaps by investigating how household energy poverty correlates with the use of physician-attended antenatal care. Particularly, the conceptualisation of the study frames energy poverty in the context of structural deprivation, limiting household abilities, and household environmental conditions, which constitute the micro-level disease environment that shapes health risks. In this context, maternal healthcare utilisation is considered the most important health outcome. This study combines structural household conditions and maternal health behaviours, thereby making a significant contribution to the literature. It first expands the energy poverty-health literature by connecting the energy deprivation with maternal healthcare use as opposed to overall health outcomes. Second, it provides empirical data on the interaction between structural deprivation and socioeconomic and household factors in determining antenatal care use. Third, the paper presents a conceptual framework that distinguishes between structural deprivation (energy poverty), household environmental conditions, and maternal health outcomes, thereby providing a more detailed picture of how household living conditions can mediate the relationship between household living conditions and maternal healthcare behaviour.

Literature Review

The literature on maternal healthcare utilisation emphasises the critical roles of socioeconomic status, household factors, and information availability in determining antenatal care (ANC) use. In many developing nations, maternal health services remain unevenly utilised even after significant improvements in the provision of healthcare facilities and policy interventions. Empirical data repeatedly confirm that ANC services are conditioned by a complex interplay of economic factors, the level of education, residential area, and the quality of life in the family (Midhet et al., 2023; Towongo et al., 2023; Sakib et al., 2025). These determinants reflect, in many cases, larger structural injustices which determine the ability of women to receive the appropriate and prompt maternal care during gestation.

An expanding body of literature has identified energy poverty as an essential aspect of household deprivation with implications for health and wellbeing. Energy poverty refers to households' inability to access reliable, affordable, and modern energy services to meet basic living requirements. Results across settings show that energy scarcity negatively affects household welfare and quality of life (Ajayi, 2023; Bahi & Paavola, 2024). Energy poverty in developing economies is closely linked to socioeconomic disparities, poor infrastructure, and limited access to modern energy services (Qurat-ul-Ann, 2021). Such building limitations are often associated with adverse health effects through modifications to indoor conditions, exposure to pollutants, and

general living conditions (Hystad et al., 2019; Nadeem et al., 2025). Empirical research also indicates that energy poverty can significantly affect household health conditions and wellbeing, which supports the overall inequity of health among populations (Mousavinik et al., 2025; Oliveras et al., 2021).

In addition to its direct health determinants, energy poverty can also influence healthcare-seeking behaviour through structural effects. Households without adequate energy access are often faced with a range of deprivations, including limited financial means, limited mobility, and limited access to information. Such restrictions have the potential to limit the access of women to professional maternal healthcare services indirectly. Poverty and maternal health studies indicate that socioeconomic deprivation is closely linked to decreased ANC utilisation (Bintabara 230 & Mwampagatwa 2023; Khanal et al., 2023). In economically disadvantaged environments, economic limitations and poor living standards often limit the ability of women to use formal health institutions during pregnancy.

Socioeconomic and demographic factors have also been highlighted in the literature on maternal healthcare utilisation. Education is always one of the most relevant predictors of ANC utilisation. Women who are more educated have better health knowledge, greater decision-making independence, and greater involvement in the formal health care system (Noh et al., 2019; Nihal and Shekhar, 2024). Similarly, income, education and access to technology are linked to better maternal health outcomes and lower maternal mortality rates in developing countries (MogaRogoz et al., 2025). Education is, therefore, an important human capital process that facilitates maternal healthcare-seeking behaviour.

Another relevant factor affecting the use of maternal healthcare is access to information and communication technologies. The increasing accessibility of digital technologies has transformed how women access health-related information and services. It is shown that using the internet and digital platforms provides pregnant women with information on pregnancy care, healthcare services, and potential health risks (Al-Dahshan et al., 2021). Telehealth services and digital health innovations have become essential resources to increase access to maternal healthcare, especially in areas with inadequate healthcare facilities (Mohamed et al., 2025). Research also shows that better internet access at the community level can supplement maternal healthcare use via telehealth processes and increased access to information (Weinstein et al., 2025).

Maternal healthcare is also highly affected by spatial and regional inequities. Women living in rural or underserved regions often face more barriers to maternal healthcare services compared to those living in urban regions. These differences have generally been associated with differences in healthcare facilities, transportation access, and socioeconomic development across regions (Awoke et al., 2024). Rural-urban disparity remains a key factor shaping maternal healthcare use in many developing countries, as rural women tend to have lower access to qualified professionals and healthcare centres (Langa & Bhatta, 2020). In the case of spatial analyses of maternal healthcare in Pakistan, it is emphasised that there are significant geographic differences in access between regions and districts (Ihsan et al., 2023).

The household's environmental conditions also affect the mother's health outcomes and wellbeing. The micro-level disease milieu, which influences household health risks, comprises water, sanitation, and hygiene (WASH) conditions. Studies show that insufficient water, poor sanitation, and insecure hygienic conditions are associated with increased health risks for mothers and children (Geere & Hunter, 2020). The environmental characteristics, including water availability, sanitation systems, and energy supply, can therefore define the broader health context in which

maternal and child health outcomes occur (Parikh et al., 2021). Unfavourable household conditions can also support socioeconomic disparities, which affect maternal health outcomes.

Besides structural and environmental factors, cultural and social factors can also mediate antenatal care utilisation. Cultural norms and beliefs, as well as perceptions of pregnancy and healthcare, shape women's choices regarding maternal healthcare (Mehboob et al., 2023). There could be situations where social expectations and family decision-making structures could restrict the autonomy of women when accessing healthcare services during pregnancy. Such cultural and social processes often interplay with the socioeconomic limitations to create inequalities in the use of maternal healthcare.

Despite ample evidence in the literature on the determinants of ANC utilisation, most studies are based primarily on socioeconomic factors, including education, income, and residential location. Although these are serious factors, the role of energy poverty as a structural determinant of maternal healthcare utilisation has received comparatively little attention. The study of energy poverty has been dominated by research on its contribution to overall health outcomes, wellbeing, and household living conditions (Ajayi, 2023; Oliveras et al., 2021; Mousavinik et al., 2025). At the same time, even the research on maternal healthcare utilisation tends to concentrate on the issue of poverty and socioeconomic inequality, without necessarily considering energy deprivation as a separate structural determinant.

The originality of this study lies in the fact that it combines the energy poverty-health literature with the maternal healthcare utilisation literature. In this regard, the paper defines energy poverty as a structural deprivation that can affect women's ability to access antenatal care. The study provides new empirical data on the influence of household infrastructural deprivation on maternal healthcare behaviour by investigating the interdependence among household energy poverty, environmental conditions, and ANC utilisation. The combination of this worldview adds to the academic discourse by highlighting the importance of household energy conditions as a significant but hitherto under-researched predictor of maternal healthcare utilisation.

Theoretical Framework

The research is based on a structural deprivation perspective that links household living conditions to maternal healthcare use. The framework conceptualises energy poverty as a form of structural deprivation that limits households' capabilities, and household environmental conditions constitute the micro-level disease environment, which affects health risks. In this construct, the use of antenatal care (ANC) provided by a physician is considered the main maternal health outcome. The framework suggests that individual characteristics should not be taken as the sole determinants of women's healthcare-seeking behaviour, but that household infrastructure, access to resources, and other socioeconomic disparities should also be considered (Midhet et al., 2023; Sakib et al., 2025).

Energy poverty is a structural bottleneck that may affect maternal healthcare behaviour in various ways. Households without access to quality, affordable energy services tend to have poor indoor living conditions, limited mobility, and limited access to communication technologies. Such circumstances may limit women's access to healthcare services, especially when household chores rely heavily on energy availability. Energy deprivation is thus considered a kind of infrastructural inequality that can affect household wellbeing and health-related behaviour (Ajayi, 2023; Quratul-Ann and Mirza, 2021). Empirical data also show that poor household energy conditions contribute to poor health through indoor pollution and poor living standards (Hystad et al., 2019;

Nadeem et al., 2025), suggesting that energy poverty can indirectly affect the use of maternal healthcare.

The micro-level disease environment, in which maternal and child health outcomes are expressed, is household environmental conditions, especially water, sanitation, and hygiene (WASH). Poor sanitation, water supply, and hygiene increase the risk of infectious diseases and adverse household conditions (Geere & Hunter, 2020). Household environmental conditions, in turn, determine the health hazards faced by women and children, which may affect attitudes towards health susceptibility and the need for medical services. Previous research has emphasised the importance of incorporating environmental factors, such as WASH and household energy environments, into the study of health outcomes (Parikh et al., 2021).

Besides structural and environmental factors, the framework includes socioeconomic and informational pathways that determine maternal healthcare use. Maternal education is a channel of human capital, as education increases health awareness, women's autonomy, and their skills to access healthcare services (Noh et al., 2019; Nihal & Shekhar, 2024). Higher levels of education are also associated with better maternal health outcomes, maternal mortality is lower in developing nations (MogaRogoz et al., 2025). Similarly, the informational access channel is the access to information through digital technologies. The use of the Internet and digital connectivity could enhance awareness of pregnancy care, healthcare facilities, and maternal health risks (Aluldahshan et al., 2021), and telehealth and online services could expand access to maternal healthcare (Mohamed et al., 2025; Weinstein et al., 2025).

The spatial and residential attributes represent structural differences in healthcare. The rural-urban divide and regional disparities continue to dominate as the determinants of maternal healthcare utilisation in developing countries. Women living in underserved or rural areas often face greater barriers to accessing healthcare facilities, including transportation difficulties, limited healthcare infrastructure, and a shortage of qualified healthcare professionals (Awoke et al., 2024; Langa and Bhatta, 2020). Pakistan data also indicates a severe geographic inequality in the accessibility of maternal healthcare across the districts and regions (Ihsan et al., 2023).

Motherhood factors that could also impact maternal healthcare behaviour are household factors (family size) and childcare. Women with more than one young child often lack time and caregiving responsibilities, which reduce their ability to visit healthcare facilities during pregnancy (Towongo et al., 2023; Sakib et al., 2025). Such domestic-level restrictions can consequently influence trends in maternal healthcare use.

In general, the theoretical model combines structural deprivation, household environmental conditions, and socioeconomic capabilities to elucidate ANC use. The framework provides a holistic perspective on the effects of household living conditions on maternal healthcare behaviour by connecting energy poverty (structural deprivation), WASH conditions (micro-level disease environment), and socioeconomic pathways such as education and digital access. This integrative method allows for studying how structural household conditions are translated into inequalities in maternal healthcare consumption.

Data and Methodology

The current study uses the micro-level data based on the Pakistan Demographic and Health Survey (PDHS) 2017-2018, the latest nationally representative data to provide detailed information on maternal health, household, and living conditions in Pakistan. This dataset contains information on demographic traits, maternal healthcare use, household amenities, and socioeconomic variables, and is therefore very appropriate for analysing the linkages between household living

conditions and maternal health outcomes. Other studies that have used PDHS data have examined maternal healthcare utilisation and socioeconomic determinants of such utilisation in Pakistan (Midhet et al., 2023; Noh et al., 2019; Rahaman et al., 2024). The study unit of analysis is a married woman of reproductive age who provided pregnancy-related healthcare information in the survey. The main aim of the research is to examine how multidimensional energy poverty (MEP) affects maternal healthcare utilisation in Pakistan. Energy poverty is a form of structural deprivation that indicates households' inability to access quality, modern energy services necessary to maintain basic living conditions. Socioeconomic disparities, inadequate infrastructure, and limited access to modern household facilities are closely linked to energy deprivation in developing countries (Ajayi, 2023; Quratulann & Mirza, 2021). It has also been proven earlier that poor household energy conditions can negatively impact health outcomes, including indoor air pollution, poor living conditions, and limited household resources (Hystad et al., 2019; Nadeem et al., 2025). Based on this literature, the current study will analyse the effects of energy deprivation on maternal healthcare use.

The empirical analysis will be informed by the Andersen-Newman healthcare utilisation model, which elucidates health service utilisation as a process shaped by predisposing, enabling, and need-related factors. In this context, demographic factors, socioeconomic resources, and structural conditions that enable or limit access to healthcare services define healthcare utilisation. The use of maternal healthcare is consequently affected by household resources, access to information, education, and environmental conditions (Towongo et al., 2023; Sakib et al., 2025). Energy poverty is incorporated into this model as a structural factor that may drive maternal healthcare utilisation in several interrelated ways. The inability to access modern energy services increases the time burden on women, as they use traditional fuels, experience higher levels of indoor air pollution, and have limited access to information technologies. Energy deprivation can also be an indicator of broader infrastructural constraints, including transportation limitations and greater distances to health care services. These processes are used in conjunction with socioeconomic factors, such as education, wealth, and geographic healthcare inequalities.

Maternal healthcare utilisation is theorised using the Andersen-Newman framework as a function of socioeconomic variables, household conditions, and energy poverty. Maternal healthcare utilisation is measured using two indicators: antenatal care (ANC) and postnatal care (PNC) coverage. These are commonly acknowledged as proxies of maternal healthcare utilisation and maternal health status in the empirical studies (Midhet et al., 2023; Towongo et al., 2023). Antenatal care is the use of medical services during pregnancy, whereas postnatal care is the use of medical services after giving birth.

The general empirical specification derived from the Andersen–Newman framework can be expressed as:

Maternal Health = f (Predisposing Factors, Enabling Factors, Illness Factors) + MEP

The predisposing factors include demographic and sociological factors, e.g., education level and family structure. Enabling factors are the household resources/access to information, which includes multidimensional poverty status and internet access. Illness-related factors refer to health need that stimulates the use of healthcare services. Under this theoretical construct, multidimensional energy poverty (MEP) is factored in as a critical structural factor that affects the use of maternal healthcare. Based on this framework; the following econometric model is estimated to examine the relationship between energy poverty and maternal healthcare utilization:

$$ANC = \alpha + \beta_1 MEP + \beta_2 MEDU + \beta_3 INTERNET + \beta_4 REGION + \beta_5 AREA + \beta_6 CHILD_U5 + \beta_7 HYGIENE + \mu$$

The description of the variables used in this model is given in the table below.

Table 1: Definition of Variables Used in the Antenatal Care (ANC) Model

Variable	Description	Measurement / Coding	Expected Effect
Antenatal Care Utilization (ANC)	Dependent variable indicating whether a pregnant woman received antenatal care services from a doctor during pregnancy	Binary variable: 1 = Received antenatal care from a doctor; 0 = Did not receive antenatal care from a doctor	—
Multidimensional Energy Poverty (MEP)	Key explanatory variable capturing whether the household suffers from multidimensional energy deprivation based on the MEPI framework	Binary variable: 1 = Energy poor; 0 = Energy non-poor	Negative
Mother's Education (MEDU)	Educational attainment of the mother reflecting human capital and awareness of healthcare services	Categorical variable: No education (reference), Primary, Middle, Secondary, Higher	Positive
Internet Use (INTERNET)	Access to digital information through the internet which may improve awareness of healthcare services and maternal health information	Binary variable: 1 = Uses internet; 0 = Never used internet	Positive
Region of Residence (REGION)	Geographical location capturing regional disparities in healthcare infrastructure and service access	Binary variable: 1 = Other provinces/regions; 0 = Punjab or Islamabad (reference category)	Ambiguous
Area of Residence (AREA)	Location of residence reflecting urban–rural differences in healthcare accessibility	Binary variable: 1 = Urban; 0 = Rural (reference category)	Positive
Number of Children Under Five (CHILD_U5)	Number of children aged five years or below in the household, representing childcare burden and time constraints	Categorical variable: 1 child (reference), 2 children, ≥ 3 children	Negative
Hygiene Practices (HYGIENE)	Household sanitation behavior measured through disposal practices of child feces	Binary variable: 1 = Safe disposal; 0 = Unsafe disposal (reference category)	Positive

Note: Reference categories (RC) are used in the econometric estimation to interpret the marginal effects relative to the baseline group.

The Multidimensional Energy Poverty Index (MEPI) used in this paper is built as per the framework put forward by Nussbaumer, Bazilian and Modi (2012) using the Alkire-Foster (AF) approach. The method is a way to contrive energy poverty by defining a variety of aspects of household energy poverty, which jointly affect wellbeing and living standards. Unlike the conventional single-indicator measures, the multidimensional approach covers multiple aspects of access to modern energy services in the household that is considered to be vital in supporting minimum living standards.

According to the scheme described in Table 2, the MEPI includes six indicators of energy, which can be explained as five dimensions in total, namely, cooking, lighting, household appliance

services, entertainment/education, and communication. These indicators are all indicative of the availability and use of household energy services which are essential. The individual indicators and their weights are as follows, modern cooking fuel (0.20), indoor pollution caused by cooking practices (0.20), electricity access (0.20), household appliance ownership (0.13), entertainment/education appliance ownership (0.13), and telecommunication access (0.13). These elements put together reflect a wide range of the complexity of household energy deprivation, such as cooking energy, lighting, energy-dependent appliances, access to information, and communication services.

In the contemporary cooking fuel classification, a house is defined as deprived when it uses any fuel type other than electricity, liquefied petroleum gas (LPG), kerosene, natural gas or biogas as cooking fuel. Indoor pollution deprivation occurs when the cooking is carried out on a stove or an open fire without a hood or chimney and using other fuels besides electricity, LPG, natural gas, or biogas. Electricity deprivation is a concept that is used to describe the lack of access to electricity in the home. Household appliances deprivation is indicated by the absence of a refrigerator. The deprivation of entertainment or education appliances is reflected in the absence of the radio or television possession, and communication deprivation in the absence of landline or mobile phone possession.

Table 2: Dimensions and Indicators Used in the Multidimensional Energy Poverty Index (MEPI)

Dimension	Indicator (Weight)	Variable Description	Deprivation Cut-off (Energy Poor if...)
Cooking	Modern cooking fuel (0.20)	Type of cooking fuel used in the household	Household uses any fuel other than electricity, LPG, kerosene, natural gas, or biogas
Cooking	Indoor pollution (0.20)	Cooking method and ventilation system	Cooking is done on a stove or open fire without a hood/chimney while using fuels other than electricity, LPG, natural gas, or biogas
Lighting	Electricity access (0.20)	Access to electricity in the household	Household does not have access to electricity
Household Appliance Services	Household appliance ownership (0.13)	Ownership of refrigerator	Household does not own a refrigerator
Entertainment / Education	Entertainment or education appliance ownership (0.13)	Ownership of radio or television	Household does not own a radio or television
Communication	Telecommunication means (0.13)	Access to communication devices	Household does not own a landline or mobile phone

Source: Adopted from Nussbaumer, Bazilian, and Modi (2012) and author's compilation using PDHS 2017-18 data.

Poverty cutoff level is used to declare households as energy poor. As per Crentsil et al. (2019), the cut-off is established at ≥ 0.33 , meaning that households whose weighted deprivation' score is the same or greater are considered multidimensionally energy poor. Any household with a deprivation

score that is below this level is considered to be energy non-poor. The approach allows recording several dimensions of household energy deprivation at the same time and identifying households with overlapping energy services deficiencies. The resultant binary measure of multidimensional energy poverty (MEP) is used as the main explanatory variable in the empirical study of maternal healthcare utilization.

Binary logistic regression is used to estimate the empirical relationship between energy poverty and the use of maternal healthcare, as the dependent variable, which is antenatal care (ANC), is dichotomous. Logistic regression is widely used in health economics and other public-health studies to model health care-utilization behaviors in which the outcome variable is binary (Towongo et al., 2023; Sakib et al., 2025). The odds ratios obtained by the use of the logistic model are initially used to interpret the estimates of the coefficients, implying the likelihood of the maternal healthcare utilization to change with changes in the explanatory variables. Also, average marginal effects (AMEs) are calculated to make the results easier to interpret by having an indicator of the change in the predicted probability of using maternal healthcare services which is attributed to a unit change in all explanatory variables.

Since the analysis is based on the survey data, the estimates of the empirical analysis must be taken as the statistical relationships, not as the causal effects. The logistic regression analysis coupled with marginal-effects analysis provides the relative likelihood measures as well as probability-based explanations of the effect of structural deprivation (energy poverty), household environmental conditions, and socioeconomic characteristics on maternal healthcare utilization in Pakistan.

Results

Logistic Regression Analysis

The logistic regression analysis determines the structural and socioeconomic factors that determine the use of antenatal care (ANC) by a physician. Based on the conceptual framework, the energy poverty is the structural deprivation, households' environmental condition (WASH) is the micro-level disease environment, and the utilization of the maternal health services is the health outcome. Control variables reflect the impact of human capital, access to information and structural inequality.

ANC utilization has a negative and significant relation with energy poverty. Women living in energy-poor households also have odds ratio of 0.656 ($p < 0.001$) which reveals that women living in energy-poor households are about 34 per cent less likely to receive antenatal care by a physician, compared to that of women living in energy non-poor households. This finding indicates that energy poverty is a structural factor that hinders access to maternal healthcare services, which is likely to be manifested in the context of the overall socioeconomic deprivation and insufficient infrastructure.

Table 3: Findings of Logistic Regression Analysis

	Antenatal Care Use (from Doctor)	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]
MEP Status	ME Non-Poor (RC)	1	.	.	.	.	.
	ME Poor	0.656	0.078	-3.56	0	0.52	0.827
Mother's Education	No Education (RC)	1	.	.	.	.	.
	Primary	2.272	0.319	5.84	0	1.725	2.993
	Middle	4.508	0.961	7.07	0	2.969	6.845
	Secondary	4.781	1.026	7.29	0	3.139	7.282
	Higher	7.304	2.065	7.03	0	4.197	12.711
Use of Internet	Never Used (RC)	1	.	.	.	.	.
	Using Internet	3.66	1.395	3.4	0.001	1.734	7.724
Region of the Residence	Punjab or Islamabad (RC)	1	.	.	.	.	.
	Other	0.712	0.081	-2.98	0.003	0.57	0.89
Area of Residence	Rural (RC)	1	.	.	.	.	.
	Urban	1.585	0.178	4.11	0	1.273	1.974
No of Children ≤ 5	1 (RC)	1	.	.	.	.	.
	2	0.707	0.089	-2.75	0.006	0.552	0.905
	≥ 3	0.647	0.081	-3.49	0	0.506	0.826
Hygiene (Disposal of Child Feces)	Unsafe (RC)	1	.	.	.	.	.
	Safe	1.013	0.101	0.13	0.895	0.833	1.233
	Constant	5.034	0.91	8.94	0	3.532	7.175

The education of mother has a strong and positive gradient with ANC utilization. The women with primary education have over 2 times higher chances of getting physician-based antenatal care than the women who have no education (OR= 2.272, $p= 0.001$). It is a significantly stronger positive effect with the higher education levels: secondary education (OR = 4.781), middle education (OR = 4.508), and tertiary education (OR = 7.304), all significant at the 1 per cent level. Such results highlight the importance of education as a human-capital pathway to the improvement of health awareness, decision-making, and the use of formal maternal healthcare services.

The use of the internet also contributes to the probability of using ANC in a significant way. The odds ratio of women that are internet users is 3.660 ($p = 0.001$), which proves that women who use the internet are more likely by far to receive a physician-led antenatal care than non-users. This affirms the informational access channel, which means that digital connectivity increases health knowledge and awareness of the accessible maternal healthcare services.

The use of ANC is also further modulated by regional disparities. Women living beyond Punjab or Islamabad have lower likelihoods of receiving physician based antenatal care (OR = 0.712, $p = 0.003$), which is equivalent to a reduction of about 29% in the probability as compared to women

in Punjab or Islamabad. This outcome indicates the inequity of healthcare infrastructure and service access based on the regions.

An urban living condition is a significant predictor of ANC use. The odds ratio of urban women who receive antenatal care by a physician are 1.585 times higher than rural women ($p < 0.001$). This trend probably indicates increased access to healthcare amenities, better transportation and access to more health information in the urban areas.

Childcare burden at home also affects the use of maternal healthcare. When there are two children below the age of five, the odds of ANC use are lower ($OR = 0.707$, $p = 0.006$), whereas when there are three or more young children, the odds of ANC use are even lower ($OR = 0.647$, $p < 0.001$) than those with one young child. This trend implies that the more care giving duties a woman has, the less opportunity she is likely to get to access antenatal healthcare services.

Conversely, the hygiene variable that is safe child feces disposal is non-significant ($OR = 1.013$, $p = 0.895$). This implies that the household WASH conditions have not a statistically significant effect on ANC usage following the adjustment of the structural and socioeconomic variables. In turn, the micro-level disease environment can be found to be more relevant to child health outcomes than to maternal health-seeking behavior.

In general, the findings demonstrate the primacy of structural deprivation, human capital, access to information, and spatial disparities in influencing the use of antenatal care, and household environmental hygiene does not seem to have a direct impact on maternal healthcare use in this framework.

Marginal-Effect Estimates

The marginal-effect estimates reflect the changes in the likelihood of a woman to obtain antenatal care (ANC) by a physician that is caused by each explanatory variable holding all other covariates constant. Compared to odds ratios, marginal effects are easier to interpret since they indicate the percentage-point change in the probability of ANC utilization.

Table 4: Marginal Effects Estimates

	Antenatal Care Use (from Doctor)	dy/dx	Std.Err.	z	P>z	[95%Conf. Interval]
MEP Status	ME Non-Poor (RC)					
	ME Poor	-0.053	0.014	-3.66	0	-0.081 -0.025
Mother's Education	No Education (RC)					
	Primary	0.117	0.017	6.76	0	0.083 0.15
	Middle	0.176	0.017	10.47	0	0.143 0.209
	Secondary	0.179	0.017	10.84	0	0.147 0.212
	Higher	0.202	0.016	12.51	0	0.17 0.233
Use of Internet	Never Used (RC)					
	Using Internet	0.12	0.023	5.32	0	0.076 0.164
Region of the Residence	Punjab or Islamabad (RC)					
	Other	-0.042	0.013	-3.12	0.002	-0.068 -0.016

Area of Residence	Rural (RC)						
	Urban	0.058	0.014	4.24	0	0.031	0.084
No of Children ≤ 5	1 (RC)						
	2	-0.042	0.015	-2.84	0.004	-0.07	-0.013
	≥ 3	-0.053	0.015	-3.64	0	-0.082	-0.025
Hygiene (Disposal of Child Feces)	Unsafe (RC)						
	Safe	0.002	0.013	0.13	0.895	-0.023	0.027

The effect of energy poverty on ANC utilization is negative and statistically significant. The likelihood of women in households facing energy poverty to get ANC by a physician is lower by 5.3 percentage points than that of women in non-poverty households ($dy/dx = -.053$, $p < 0.001$). This finding supports the fact that energy poverty is a structural deprivation that weakens the use of maternal healthcare, presumably due to limited resources, lack of infrastructures and reduced access to healthcare services.

The education level of mother has a positive and strong correlation with ANC utilization. In comparison to women who have not received any formal education, women who have received primary education have a greater probability of seeking ANC with a physician by 11.7 percentage points ($p < 0.001$). This is more likely with increased educational levels: women with middle-level education are 17.6 percentage points more likely, women with secondary education are 17.9 percentage points more likely and women with tertiary education are 20.2 percentage points more likely to receive ANC by a physician. The findings highlight the central role of education as a human-capital channel that increases the level of awareness, decision-making ability and the willingness to seek professional maternal care.

The use of internet also boosts the probability of ANC utilization tremendously. Women who use internet have a 12 percentage points higher likelihood of getting ANC through a physician as compared to women who have never used the internet ($dy/dx = 0.12$, $p < 0.001$). This finding implies that digital connectivity enhances the spread of health information and awareness of maternal healthcare services, which supports the informational access channel.

The marginal effect results are still characterized by regional disparities. Out of the women who do not live in the Punjab or Islamabad provinces, 4.2 percentage points fewer are more likely to use ANC with a physician than women living in Punjab or Islamabad ($dy/dx = -.042$, $p = .002$). This shows that there still exist geographic inequities in healthcare access and infrastructure.

Living in urban areas significantly increases the maternal healthcare utilization. Females living in urban areas have a higher likelihood of ANC delivered by a physician by 5.8 percentage points higher than their rural counterparts ($dy/dx = 0.058$, $p < 0.001$). This observation indicates better healthcare infrastructure, an increase in service ability, and better transportation and informational networks in urban areas.

The household size of the young children has a negative impact on ANC utilization. Females who have two children below the age of five years are 4.2 percentage points less likely to receive ANC by a physician than those with one young child ($dy/dx = -0.042$, $p = 0.004$). Equally, women who have three or more young children are 5.3 percentage points less likely to receive ANC at the hands

of a physician ($dy/dx = -0.053$, $p < 0.001$). This implies that increased childcare demands can limit time and resources that can be used to access maternal healthcare services.

Lastly, the hygiene factor that is the safe disposal of child feces is not significant. The marginal effect is small ($dy/dx = 0.002$, $p = 0.895$), which means that sanitary practices do not significantly change the likelihood of getting ANC in a physician in this model. It means that the effect of micro-level household environmental conditions on child health outcomes can be more significant as compared to the influence on maternal healthcare-seeking behavior. Overall, the marginal-effect analysis highlights that structural and socioeconomic factors, especially energy poverty, maternal education, access to digital devices and spatial inequalities are major determinants of ANC utilization, and household hygiene conditions seem to have a minor impact on maternal healthcare usage in this case.

Model Diagnostics

The regression results based on the Pakistan Demographic and Health Survey (PDHS) 2017–18 show that the model was estimated using 4,050 observations. The mean value of the dependent variable is 0.821 with a standard deviation of 0.383, indicating that approximately 82.1% of the respondents experienced the outcome of interest, while there is moderate variation in the responses. The overall model is statistically significant, as indicated by the likelihood ratio Chi-square value of 569.496 with a p-value of 0.000, meaning that the explanatory variables jointly have a significant effect on the dependent variable. The pseudo R-squared value of 0.15 suggests that the model explains about 15% of the variation in the probability of the outcome, which is considered a reasonable explanatory power for models based on cross-sectional demographic survey data. Furthermore, the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values are 3257.586 and 3333.263 respectively, which can be used to compare this model with alternative specifications, with lower values indicating a better model fit. The significance levels reported in the table (***) $p < 0.01$, ** $p < 0.05$, * $p < 0.1$) indicate the degree of statistical significance of the estimated coefficients.

Table 5: Model Diagnostics

Mean dependent var	0.821	SD dependent var	0.383
Pseudo r-squared	0.15	Number of obs	4050
Chi-square	569.496	Prob> chi2	0
Akaike crit. (AIC)	3257.586	Bayesian crit. (BIC)	3333.263
*** $p < .01$, ** $p < .05$, * $p < .1$			

Discussion

In this study, the relationship between multidimensional energy poverty, socioeconomic determinants, and the use of antenatal care (ANC) services in the Pakistani context was examined. The results show that maternal healthcare use is influenced by structural deprivation, household environmental conditions, and socioeconomic characteristics. The study explains the combined effects of energy access, information availability, and household conditions on the probability that women receive ANC from a medical professional, using the multidimensional energy poverty framework and maternal health determinants.

The analysis reveals a negative relationship between multidimensional energy poverty and ANC utilisation. Women living in households with a low energy supply are significantly less likely to use ANC services than those living in households with sufficient energy. This trend is consistent

with the current studies, which associate energy deprivation with negative health effects and limited access to medical services (Abbas, Xie, et al., 2021; Abbas, Xu, et al., 2021). Energy poverty reduces the wellbeing of a household in various ways, such as having limited access to lighting, communication, and clean cooking energy, and thus may become an obstacle to women accessing timely maternal healthcare. The negative impact of energy poverty on physical and mental health outcomes has also been reported previously, extending beyond its effect on overall health disparities (Brown and Vera-Toscano, 2021; Churchill and Smyth, 2021). These findings have been replicated in other developing economies, which show that poor access to modern energy services and their subsequent impacts negatively affect household welfare and health status (Ajayi, 2023; Phoumin and Kimura, 2019). The current research therefore supports the broader literature highlighting the health and wellbeing consequences of multidimensional energy deprivation.

The other salient finding is a strong positive association between maternal education and ANC utilisation. Women who are more educated are more likely to use ANC services than those who are not educated. The latter aligns with previous studies that have highlighted the role of education in increasing health awareness, decision-making skills, and access to information (Bintabara and Mwampagatwa, 2023; Khanal et al., 2023). Pakistan and other similar developing environments also have empirical evidence indicating that educated women are more likely to appreciate the value of prenatal monitoring and therefore seek professional medical services during pregnancy (Noh et al., 2019; Midhet et al., 2023). Recent studies also demonstrate that women's educational level and access to information significantly lower the mother's health risks and enhance service outcomes (Moga Rogoz et al., 2025). These findings support the established literature on the relationship between female education and improved maternal health service use.

Digital connectivity is another important determinant of ANC utilisation. More women who reported internet use seek ANC with a doctor than women who have never used the internet. This observation indicates the broadening of the digital platform for accessing health-related information and services. Past research indicates that internet use is one factor that enables women to access information about pregnancy, communicate with medical professionals, and increase their awareness of maternal health care (Al-Dahshan et al., 2021). Additionally, recent literature highlights the growing role of digital technologies and telehealth in maternal care and in enhancing health outcomes (Mohamed et al., 2025; Weinstein et al., 2025). In this way, the results support the assumption that digital inclusion can be a beneficial factor in increasing maternal healthcare usage, particularly when traditional information channels are scarce.

ANC utilisation in Pakistan seems to be influenced by regional disparities. Women living beyond Punjab or Islamabad have lower chances of using ANC services, implying that geographic disparities in healthcare facilities and services are still significant hindrances to access to maternal health. This trend is consistent with previous research reporting disparities in maternal healthcare access across regions of developing nations (Awoke et al., 2024; Khanal et al., 2023). Pakistan-based evidence also shows an unequal distribution of maternal healthcare services across geographical areas, reflecting differences in health infrastructure, service quality, and accessibility (Ihsan et al., 2023). These spatial inequalities highlight the need for targeted policy interventions to reduce regional disparities in maternal healthcare provision.

The statistics also indicate that women in urban settings are more likely to use ANC services than their counterparts in rural settings. Rural-urban differences in the utilisation of maternal healthcare are well documented and often explained by differences in healthcare facilities, transport infrastructure, and socioeconomic status (Langa & Bhatta, 2020; Towongo et al., 2023). Rural

families generally face greater barriers to accessing healthcare institutions due to distance, limited transport, and a shortage of qualified professionals. The same trends have been observed in Pakistan, where maternal healthcare use is significantly lower in rural areas than in urban areas (Aziz Ali et al., 2020; Rahaman et al., 2024). These findings therefore support current evidence that rural residence is a significant structural factor in limiting access to maternal healthcare.

Another important aspect is the burden of household childcare. Women having two or more children aged below five years are less likely to use ANC services. This fact indicates that women can be limited by the childcare and time availability to access prenatal health checkups. Similar results have emerged in research papers investigating the utilisation of maternal healthcare in developing environments, where women with many children often face competing household demands that limit their capacity to access healthcare services (Sakib et al., 2025; Towongo et al., 2023). This underscores the need to include household issues and care giving pressures in policy formulations aimed at expanding access to maternal healthcare.

Even though hygiene practices, namely safe disposal of child faeces, were also covered to capture household environmental conditions, the empirical findings show that they are not statistically significant for ANC utilisation. Although the importance of sanitation and hygiene has been well-established as important determinants of maternal and child health outcomes (Geere & Hunter, 2020; Parikh et al., 2021), the lack of significance herein may indicate that hygiene practices have a more direct impact on health outcomes due to disease exposure instead of healthcare utilisation behaviour. However, environmental health conditions are still considered part of maternal and child health systems and may interact with other structural determinants, including access to energy and household living conditions.

All the results together emphasise the complex nature of maternal healthcare utilisation, including structural deprivation, access to information, and socioeconomic factors. The negative correlation between multidimensional energy poverty and ANC utilisation highlights the need to address energy deprivation as part of the general population health policy. The focus of previous research has been on the severe health consequences of energy poverty, especially in developing nations where modern energy services are still not evenly distributed (Crentsil et al., 2019; Nyame-Baafi et al., 2025; Mousavinik et al., 2025). In that regard, the findings support the hypothesis that increasing access to contemporary energy services, alongside education, digital connectivity, and healthcare infrastructure, can significantly improve maternal healthcare use and reduce maternal health disparities.

As a whole, this study contributes to the growing body of literature on energy poverty and its health effects, showing that multidimensional energy poverty can also affect maternal healthcare-seeking behaviour. By combining structural, socioeconomic, and environmental determinants within a single empirical framework, the research provides new evidence on the mechanisms by which energy poverty can influence maternal health service utilisation in Pakistan.

Conclusion

The current paper examined the relationships among multidimensional energy poverty, domestic environmental conditions, and the use of maternal healthcare services in Pakistan, using data from the country representative Pakistan Demographic and Health Survey (PDHS). The empirical results show that women living in families with multidimensional energy deficiency have a statistically significant decrease in the probability of using a qualified physician for antenatal care. This observation highlights the imperative role played by structural deprivation in the maternal healthcare-seeking behaviour. Moreover, the discussion shows that increased maternal education

and internet availability significantly increase the likelihood of using antenatal care services, underscoring the critical roles of human capital and information availability in improving maternal health outcomes. On the other hand, negative relationships exist between antenatal care use and regional differences, and between residence in rural areas and increased childcare duties, as manifestations of long-term spatial and intra-household limitations on the accrual of healthcare services.

The findings, in general, suggest that maternal healthcare use is not solely determined by access to healthcare services, but also by broader structural and socioeconomic factors, such as access to energy and environmental conditions at home. Reducing multidimensional energy poverty, promoting women's educational achievement and online access, and curbing regional differences in healthcare facilities are thus essential to enhancing maternal healthcare use. These results support the need for integrated policy interventions that can narrowly address energy access, socioeconomic equity, and systemic healthcare barriers to enhance maternal health outcomes in developing settings, including Pakistan.

Practical Implications

The results have several policy implications that can be used to enhance maternal healthcare use. First, the negative correlation of multidimensional energy poverty with the use of antenatal care is observed, which may indicate that the expansion of the access to modern energy services, including electricity and clean cooking fuels, may indirectly improve the maternal health through the reduction of structural deprivation and improvement of the living conditions (Abbas, Xie, et al., 2021; Churchill & Smyth, 2021; Brown & Vera-Toscano, 2021). Second, the positive and significant contribution of maternal education implies that investments in female education will significantly increase maternal healthcare use by improving health awareness and decision-making ability (Bintabara & Mwampagatwa, 2023; Midhet et al., 2023).

Third, internet use has a positive impact, underscoring the significance of digital connectivity for disseminating maternal health information and promoting healthcare-seeking behaviour. Increasing access to the internet and online health programs might thus enhance maternal health awareness (Al-Dahshan et al., 2021; Mohamed et al., 2025; Weinstein et al., 2025). Fourth, in the use of antenatal care, there are regional and rural-urban inequalities, which indicate the need to invest specifically in healthcare infrastructure and service accessibility in underserved areas and regions (Awoke et al., 2024; Ihsan et al., 2023; Langa & Bhatta, 2020). Lastly, the adverse impact of childcare load indicates that household restrictions affect healthcare use, underscoring the need for community-based maternal health services and outreach initiatives (Sakib et al., 2025; Towongo et al., 2023).

Future Research Directions and Limitations of the Study

The research has several limitations. Firstly, the data are cross-sectional, so causal inference is not possible; the results should be viewed as associations. Longitudinal or quasi-experimental studies can be used in future research to enhance causal relationships. Second, the multidimensional energy poverty index captures some important dimensions of energy deprivation but fails to adequately capture energy reliability or affordability. More specific energy access indicators could be included in future research (Nussbaumer et al., 2012; Crentsil et al., 2019). Third, the research focuses on antenatal care and does not examine the full spectrum of maternity care. The research can be further developed in future research to include postnatal care and general maternal health outcomes (Rahaman et al., 2024). Lastly, the effects of the interaction between energy poverty and

other socioeconomic variables, such as education and access to digital devices, would be an appropriate future research topic to gain a clearer understanding of the processes linking structural deprivation and maternal healthcare use.

References

- Abbas, K., Xie, X., Xu, D., & Butt, K. M. (2021). Assessing an empirical relationship between energy poverty and domestic health issues: A multidimensional approach. *Energy*, 221, 119774. <https://doi.org/10.1016/j.energy.2021.119774>
- Abbas, K., Xu, D., Li, S., & Baz, K. (2021). Health implications of household multidimensional energy poverty for women: A structural equation modeling technique. *Energy and Buildings*, 234, 110661. <https://doi.org/10.1016/j.enbuild.2020.110661>
- Ajayi, P. I. (2023). Energy poverty and household wellbeing in Nigeria. *Ife Social Sciences Review*, 31(1), 1-14.
- Al-Dahshan, A., Chehab, M., Mohamed, A., Al-Kubaisi, N., & Selim, N. (2021). Pattern of internet use for pregnancy-related information and its predictors among women visiting primary healthcare in Qatar: a cross-sectional study. *BMC Pregnancy and Childbirth*, 21(1), 747. <https://doi.org/10.1186/s12884-021-04227-0>
- Awoke, N., Ababulgu, S. A., Hanfore, L. K., Gebeyehu, E. G., & Wake, S. K. (2024). Regional disparities in antenatal care utilization among pregnant women and its determinants in Ethiopia. *Frontiers in Global Women's Health*, 5, 1230975. <https://doi.org/10.3389/fgwh.2024.1230975>
- Aziz Ali, S., Aziz Ali, S., Feroz, A., Saleem, S., Fatmai, Z., & Kadir, M. M. (2020). Factors affecting the utilization of antenatal care among married women of reproductive age in the rural Thatta, Pakistan: findings from a community-based case-control study. *BMC Pregnancy and Childbirth*, 20(1), 355. <https://doi.org/10.1186/s12884-020-03009-4>
- Bahi, D. S., & Paavola, J. (2024). *Liquefied petroleum gas access and consumption expenditure: measuring energy poverty through wellbeing and gender equality in India*. mdpi.com.
- Bentley, R., Daniel, L., Li, Y., Baker, E., & Li, A. (2023). The effect of energy poverty on mental health, cardiovascular disease and respiratory health: a longitudinal analysis. *The Lancet Regional Health - Western Pacific*, 35, 100734. <https://doi.org/10.1016/j.lanwpc.2023.100734>
- Bintabara, D., & Mwampagatwa, I. (2023). Socioeconomic inequalities in maternal healthcare utilization: An analysis of the interaction between wealth status and education, a population-based surveys in Tanzania. *PLOS Global Public Health*, 3(6), e0002006. <https://doi.org/10.1371/journal.pgph.0002006>
- Brown, H., & Vera-Toscano, E. (2021). Energy poverty and its relationship with health: empirical evidence on the dynamics of energy poverty and poor health in Australia. *SN Business & Economics*, 1(10), 139. <https://doi.org/https://doi.org/10.1007/s43546-021-00149-3>
- Chatata, A. G., & Chirwa, G. C. (2025). The impact of multidimensional poverty on antenatal care service utilization in Malawi. *Health Economics Review*, 15(1), 1. <https://doi.org/10.1186/s13561-024-00581-9>
- Churchill, S. A., & Smyth, R. (2021). Energy poverty and health: Panel data evidence from Australia. *Energy Economics*, 97, 105219.
- Crentsil, A. O., Asuman, D., & Fenny, A. P. (2019). Assessing the determinants and drivers of multidimensional energy poverty in Ghana. *Energy policy*, 133, 110884. <https://doi.org/https://doi.org/10.1016/j.enpol.2019.110884>
- Geere, J.-A. L., & Hunter, P. R. (2020). The association of water carriage, water supply and sanitation usage with maternal and child health. A combined analysis of 49 Multiple Indicator Cluster Surveys from 41 countries. *International Journal of Hygiene and Environmental Health*, 223(1), 238-247. <https://doi.org/https://doi.org/10.1016/j.ijheh.2019.08.007>

- He, Z., Bishwajit, G., & Wu, F. (2025). Sociodemographic Determinants of Reproductive Healthcare Service Use Among Pregnant Women in Pakistan. *Healthcare*, 13(4), 440. <https://doi.org/10.3390/healthcare13040440>
- Hystad, P., Duong, M., Brauer, M., Larkin, A., Arku, R., Kurmi, O. P.,...investigators], o. b. o. P. U. a. R. E. P. S. (2019). Health Effects of Household Solid Fuel Use: Findings from 11 Countries within the Prospective Urban and Rural Epidemiology Study. *Environmental Health Perspectives*, 127(5), 057003. <https://doi.org/10.1289/EHP3915>
- Ihsan, A., Ali, F., Khan, Y., & Adil, S. (2023). A spatial analysis of maternal health care in Punjab, Pakistan. *Journal of Population Therapeutics and Clinical Pharmacology*, 31(4), 1424-1440.
- Khanal, V., Bista, S., Mishra, S. R., & Lee, A. H. (2023). Dissecting antenatal care inequalities in western Nepal: insights from a community-based cohort study. *BMC Pregnancy and Childbirth*, 23(1), 521. <https://doi.org/10.1186/s12884-023-05841-w>
- Langa, N., & Bhatta, T. (2020). *The rural-urban divide in Tanzania: Residential context and socioeconomic inequalities in maternal health care utilization*. journals.plos.org.
- Marcoje, B. M., Hallack, M., Schiavon, L. d. C., Machado, D. C., & Abreu, M. W. d. (2026). Energy poverty in Brazil: A look at access to energy services. *Development and Sustainability in Economics and Finance*, 9, 100103. <https://doi.org/https://doi.org/10.1016/j.dsef.2025.100103>
- Mehboob, H., Anwar, S., & Ashraf, M. (2023). Assessing the Relationship between Cultural Beliefs and Antenatal Care Accessibility in the Southern Punjab, Pakistan. *Pakistan Social Sciences Review*, 7(3), 738-744. [https://doi.org/https://doi.org/10.35484/pssr.2023\(7-III\)60](https://doi.org/https://doi.org/10.35484/pssr.2023(7-III)60)
- Midhet, F., Hanif, M., Khalid, S. N., Khan, R. S., Ahmad, I., & Khan, S. A. (2023). Factors associated with maternal health services utilization in Pakistan: Evidence from Pakistan maternal mortality survey, 2019. *PLOS ONE*, 18(11), e0294225. <https://doi.org/10.1371/journal.pone.0294225>
- Moga Rogoz, A. T., Sart, G., Bayar, Y., Danilina, M., & Gavriltea, M. D. (2025). Effect of Women's Education, Information and Communication Technologies, and Income on Maternal Mortality: Evidence from BRIICS Countries. *Healthcare*, 13(6), 602. <https://doi.org/10.3390/healthcare13060602>
- Mohamed, H., Ismail, A., Sutan, R., Rahman, R. A., & Juval, K. (2025). A scoping review of digital technologies in antenatal care: recent progress and applications of digital technologies. *BMC Pregnancy and Childbirth*, 25(1), 153. <https://doi.org/10.1186/s12884-025-07209-8>
- Mousavinik, S. H., Bagheri Pormehr, S., Askari, A., & Bayat, M. (2025). Studying the impact of energy poverty on Household's health status in Iran. *Economic Growth and Development Research*.
- Nadeem, M., Anwar, M., Ul Rehman, W., Malik, M. I., Ali, W., Al-Rawi, M. B. A., & Syed, W. (2025). Household fuel consumption, indoor air pollution, and respiratory health infections among children in Pakistan. *Humanities and Social Sciences Communications*, 12(1), 1323. <https://doi.org/10.1057/s41599-025-05070-w>
- Nie, P., Li, Q., & Sousa-Poza, A. (2021). Energy poverty and subjective well-being in China: New evidence from the China Family Panel Studies. *Energy Economics*, 103, 105548. <https://doi.org/10.1016/j.eneco.2021.105548>
- Nihal, S., & Shekhar, C. (2024). *An assessment of adequate quality antenatal care and its determinants in India*. Springer. <https://doi.org/10.1186/s12884-024-06806-3>
- Noh, J.-W., Kim, Y.-m., Lee, L. J., Akram, N., Shahid, F., Kwon, Y. D., & Stekelenburg, J. (2019). Factors associated with the use of antenatal care in Sindh province, Pakistan: A population-based study. *PLOS ONE*, 14(4), e0213987. <https://doi.org/10.1371/journal.pone.0213987>
- Nussbaumer, P., Bazilian, M., & Modi, V. (2012). Measuring energy poverty: Focusing on what matters. *Renewable and Sustainable Energy Reviews*, 16(1), 231-243. <https://doi.org/10.1016/j.rser.2011.07.150>
- Nyame-Baafi, K., Darmoe, J., Ohemeng, W., & ... (2025). *Assessing the effect of energy poverty on health outcomes: insights from Ghana*. Springer. <https://doi.org/10.1186/s12889-025-23602-6>

- Oliveras, L., Borrell, C., González-Pijuan, I., Gotsens, M., López, M. J., Palència, L.,...Marí-Dell'Olmo, M. (2021). The Association of Energy Poverty with Health and Wellbeing in Children in a Mediterranean City. *International Journal of Environmental Research and Public Health*, 18(11), 5961. <https://doi.org/10.3390/ijerph18115961>
- Pakistan 2019 Maternal Mortality Survey, P. *The DHS Program*. <https://www.dhsprogram.com/pubs/pdf/SR267/SR267.pdf>
- Parikh, P., Kwami, C. S., Khanna, R., Lall, M., Reddy, H., Benton, L.,...Lakhanpaul, M. (2021). Linkages between environmental factors (WASH and energy) and Infant and Young Child Feeding practices in rural India: implications for cross-sectoral interventions for child health. *Journal of Water, Sanitation and Hygiene for Development*, 11(6), 902-915. <https://doi.org/10.2166/washdev.2021.005>
- Phoumin, H., & Kimura, F. (2019). Cambodia's energy poverty and its effects on social wellbeing: Empirical evidence and policy implications. *Energy policy*, 132, 283-289. <https://doi.org/10.1016/j.enpol.2019.05.032>
- Qurat-ul-Ann, A.-R., & Mirza, F. M. (2021). Determinants of multidimensional energy poverty in Pakistan: a household level analysis. *Environment, Development and Sustainability*, 23(8), 12366-12410.
- Rahaman, M., Roy, A., Chouhan, P., Malik, N. I., Bashir, S., Ahmed, F., & Tang, K. (2024). Contextualizing the standard maternal continuum of care in Pakistan: an application of revised recommendation of the World Health Organization. *Frontiers in Public Health*, 11, 1261790. <https://doi.org/10.3389/fpubh.2023.1261790>
- Sakib, M. M. H., Alam, M. K., Yasmin, N., & Rois, R. (2025). Unveiling the sociodemographic and socioeconomic determinants of antenatal care utilization in Bangladesh: insights from the 2017–18 BDHS. *Journal of Health, Population and Nutrition*, 44(1), 159. <https://doi.org/10.1186/s41043-025-00839-w>
- Towongo, M. F., Ngome, E., Navaneetham, K., & Letamo, G. (2023). A secondary analysis of the factors associated with women's adequate utilization of antenatal care services during their last pregnancy in Uganda. *BMC Pregnancy and Childbirth*, 23(1), 692. <https://doi.org/10.1186/s12884-023-05994-8>
- Weinstein, J. M., Bozkurt, B., Aijaz, M., Cilenti, D., Khairat, S., Shea, C. M., & Planey, A. M. (2025). Community-Level Internet Connectivity and Utilization of Maternal Telehealth. *Telemedicine and e-Health*, 31(4), 405-411. <https://doi.org/10.1089/tmj.2023.0670>
- Zhang, Z., Linghu, Y., Meng, X., & Yi, H. (2022). Is there gender inequality in the impacts of energy poverty on health? *Frontiers in Public Health*, 10, 986548. <https://doi.org/10.3389/fpubh.2022.986548>