USAID
FROM THE AMERICAN PEOPLE

DHS WORKING PAPERS

Women's Empowerment, Modern Energy, and Demand for Maternal Health Services in Benin

Alastaire Sèna Alinsato
Calixe Bidossessi Alakonon
Nassibou Bassongui

2022 No. 185

DEMOGRAPHIC AND HEALTH SURVEYS

September 2022

DHS Working Paper No. 185

Women's Empowerment, Modern Energy, and Demand for Maternal Health Services in Benin

Alastaire Sèna Alinsato[1]
Calixe Bidossessi Alakonon[1]
Nassibou Bassongui[1]

ICF
Rockville, Maryland, USA

September 2022

[1] *Laboratory of Public Economics, University of Abomey-Calavi, Benin.*

Corresponding author: Alastaire Sèna Alinsato, Laboratory of Public Economics, University of Abomey-Calavi, Benin; email: alastaires@yahoo.fr

Acknowledgments: The authors wish to thank USAID for funding the research project through the DHS Fellows Program, implemented by ICF in 2022, and the Laboratory of Public Economics of the University of Abomey-Calavi for supporting the DHS training and allowing time for us to participate in the DHS training. Some individuals deserve special mention. We are grateful to Drs. Kerry MacQuarrie, Shireen Assaf, Sara Riese, and Bienvenu Salim Camara for their thorough review of the paper's scientific content. We also appreciate the capacity building that we received through the training. Our appreciation also goes to 2022 DHS fellows for their constructive critique, which was instrumental in shaping this scientific endeavor.

Editor: Diane Stoy
Document Production: Joan Wardell and Chris Gramer

This study was conducted with support from the United States Agency for International Development (USAID) through The DHS Program (#720-OAA-18C-00083). The views expressed are those of the authors and do not necessarily reflect the views of USAID or the United States Government.

The DHS Program assists countries worldwide in the collection and use of data to monitor and evaluate population, health, and nutrition programs. For additional information about The DHS Program, contact: DHS Program, ICF, 530 Gaither Road, Suite 500, Rockville, MD 20850, USA; phone: +01 301-572-0950; fax: +01 301-572-0999; fax: +01 301-407-6501; email: reports@dhsprogram.com; internet: www.dhsprogram.com.

Recommended citation:

Alinsato, Alastaire, Calixe Alakonon, and Nassibou Bassongui. 2022. *Women's Empowerment, Modern Energy, and Demand for Maternal Health Services in Benin*. DHS Working Paper No. 185. Rockville, Maryland, USA: ICF.

CONTENTS

TABLES ..... **v**
FIGURES ..... **vii**
ABSTRACT ..... **ix**

1 INTRODUCTION **1**
1.1 Research Questions 5
1.2 Conceptual Framework 5

2 DATA AND METHODS **7**
2.1 Data 7
2.2 Variables 7
2.2.1 Interest variables 7
2.2.2 Control variables 8
2.3 Statistical Analysis 9

3 RESULTS **13**
3.1 Women's Characteristics 13
3.2 Distribution of Modern Energy Access 15
3.3 Features of Women's Empowerment 15
3.4 Features of Maternal Health Services 16
3.5 Multiple Regression 17

4 DISCUSSION **23**

5 CONCLUSION **25**

REFERENCES **27**

APPENDICES **33**

TABLES

Table 1	Socioeconomic and demographic characteristics of women	13
Table 2	Women's empowerment index	14
Table 3	Distribution of modern energy access by women's characteristics	15
Table 4	Distribution of women's empowerment by women's characteristics	16
Table 5	Distribution of maternal health services by women's characteristics	17
Table 6	Trivariate recursive probit estimates: Social independence model	18
Table 7	Trivariate recursive probit estimates: Decision-making model	20
Table 8	Marginal effects of the demand for maternal health services models	22
Appendix Table A1	Pairwise correlations: Modern energy equation	33
Appendix Table A2	Pairwise correlations: Women's empowerment	33
Appendix Table A3	Pairwise correlations: Maternal health	33
Appendix Table A4	Variance inflation factor: Maternal health	33

FIGURES

Figure 1 Conceptual framework 6

ABSTRACT

Globally, 152 mothers per 100,000 live births die each year from lack of access to universal health care services. Most of these deaths occur in sub-Saharan African countries, especially in the Middle, Eastern and Western African countries, where the prevalence is greater than 500 deaths per 100,000 live births. Despite significant progress during the last decade, this issue remains a considerable challenge for sub-Saharan African countries. This study analyzed how women's empowerment may improve the demand for maternal health services in Benin.

The study used secondary data from the 2017 Benin Demographic Health Survey. The methodology included two steps. First, we focused on the measurement of the variables of main interest. A composite index of women's empowerment was constructed with the principal component analysis method. This composite index was based on the social independence and decision-making pillars. Demand for maternal health services was measured through the completeness of antenatal care visits. Second, univariate (percentages), bivariate (chi-squared test of independence), and multiple regression (trivariate recursive probit model) analyses were used to determine the levels of access to modern energy, women's empowerment, and the demand for maternal health services, and the association between the demand for maternal health services and women's empowerment.

Our results revealed that women's empowerment in the sample was low, as indicated by a rate of 53.4% and 46.4% of unempowered women, respectively, for the social independence and the decision-making pillars. We reported a low level of demand for maternal health services in the sample, as found by the 47.5% of women who did not complete antenatal care visits during their last pregnancy. We also found that the demand for maternal health services was significantly and positively associated with women's empowerment. Being an empowered woman increases the chance of completing antenatal care visits by 7.0% and 8.0%, respectively, for the social independence and decision-making dimensions, compared with unempowered woman *ceteris paribus*, where all other variables are kept equal. We further highlighted the importance of women's wealth in accessing maternal health services.

To address maternal mortality in sub-Saharan African countries, policymakers should improve women's social independence by promoting women's education and access to information through the diffusion of information communication and technologies. Such policies should also focus on improving economic living conditions in households.

Key Words: gender, household and respondent characteristics, maternal health

1 INTRODUCTION

One of the major concerns for developing countries is improving the use of health services by the general population, and in particular, maternal and child health services. This concern reflects the Sustainable Development Goals 3 (SDG3), which aim to ensure the health and well-being of all by improving reproductive health, and especially maternal and child health. Thus, many government measures focus on the most relevant factors in maternal and child health services in order to limit maternal and child death.

Health service is considered as a private good in the economic literature, within the neoclassical demand and supply framework. In general, the demand for health care services can be defined as the level of actual consumption by an individual or household in order to prevent or treat an illness or injury. From a microeconomic perspective, the demand for health care services refers to the level of use at which the perceived marginal health benefits of care equal the marginal cost of accessing care (Santana et al. 2021). This emphasizes that the demand-side factors are as important as supply factors in the market of good "health care." In this study, we focus on the effective demand that refers to the willingness and ability of consumers to purchase a good or service under the framework of a price taker. In contrast, the notional or latent demand is the one that is constrained by the inability to afford a good or service, or by lack of knowledge.

The traditional analysis of the determinants of health services demand has included the controversy that within the theory of consumption, price is the most relevant factor in the demand for a good. For some, the demand for health services decreases as the price of services increases (Akin and Hutchinson 1999; Koch 2012; Mariko 2003). In contrast, other authors have shown that the demand for health services is price inelastic (Mariko 2003). Beyond the framework that focuses on the price of goods or services, Andersen (1995) developed a behavioral framework in which the demand for health care services is determined by demographic characteristics, the social structure, health beliefs, and other enabling variables.

Many empirical studies have integrated socioeconomic, political, demographic, religious, and cultural factors into the explanation of the general demand for health services, and in particular, the demand for maternal and child health services (Arisukwu et al. 2021; Nkoumou and Brice 2021). Recent works have highlighted the role of women's empowerment in the demand for maternal and child health services (Abreha and Zereyesus 2021; Rahman et al. 2021). These studies showed that women's empowerment positively affects maternal and child health outcomes by increasing the demand for health services. Other works have focused on the relationship between energy use within households and maternal and child health, and have found that modern energy can contribute to improving women empowerment (Wang et al. 2019; Polansky and Laldjebaev 2021). Modern energy is energy with higher content and heating value than traditional biomass energy, such as electricity, liquefied petroleum gas (LPG), and biogas. It can be argued that modern energy and the improvement of women's empowerment can be considered essential factors in economic policies that are designed to improve maternal and child health in developing countries (Duflo 2012).

Like its peers of sub-Saharan Africa countries, Benin has a high prevalence of maternal mortality. According to Benin's 2017 Demographic and Health Survey (BDHS), the maternal mortality rate is 391 deaths per 100,000 live births, which is far from the target of 70 deaths per 1,000 live births, with the target 3.1 of the

SDG3 goal by 2030 (INSAE and ICF 2019). These statistics show that Benin is one of the most vulnerable countries for maternal and child health.

It is necessary to identify the factors associated with the demand for maternal health services in order to guide more effective policy measures that will accelerate the reduction of maternal and child mortality. In recent years, policies were adopted in Benin to improve the level of women's empowerment (Aminou and Monwanou 2022; Atozou et al. 2017) and the use of modern energies (Beaurain and Amoussou 2016; Dedjinou 2022; Odilon and Lokonon 2020). These policies led to a slight increase in women's involvement in decision making at the household level. In this context, it is critical to provide policymakers with more information on factors that can increase the demand for maternal health services in Benin in order to decrease the prevalence of maternal mortality. More importantly, it is worth noting that despite the potential of the existing literature on the determinants that affect the demand for maternal health services, no study has investigated how women can be empowered to increase the demand for maternal health services. This study attempts to answer this question by assuming that improving the access to modern energy could empower women and, in turn, raise the demand for maternal health services.

Energy and women's empowerment

According to Duflo (2012), empowered women can fuel the achievement of desired development goals, including maternal and child health, especially in low-income countries. With Kabeer's (2005) definition, women's empowerment encompasses three interrelated pillars: agency, which is related to the individual choices, access to resources, and achievements. Given this definition, at least two direct channels of access to modern energy may affect maternal and child health in low-income countries. The first mechanism is the labor market participation channel. By reducing time spent on housework, modern energy improves women's disposable time that can be devoted to paid activities and leisure. Unpaid domestic work, such as firewood collection, cooking, and house cleaning, is mostly done by women and girls in low-income countries (Burke and Dundas 2015; Hanna and Oliva 2015; Schultz and Tansel 1997). Consequently, modern energy improves women's economic power.

Second, modern energy may improve women's decision-making power through the education channel. Modern energy reduces time spent in unpaid domestic work, and provides more disposable time for girls to devote to their education. Moreover, modern energy improves women's knowledge directly by increasing their exposure to information through radio, television, and social media. It is also worth noting that women's empowerment may affect the use of modern energy. One of the most demand-side determinants of modern energy is household income and educational level. Using DHS data from a sample of 32 African countries, Wodon et al. (2009) showed that lack of income explains more than half of households' constraints in accessing electricity. Moreover, Blimpo et al. (2020) revealed that 30% to 80% of factors that explain the poor access to modern energy in sub-Saharan African countries were related to demand-side constraints, such as the household's income and educational level. The authors indicated that Central and Southern Africa regions experienced the highest level of demand constraints.

Other studies showed that women's empowerment can also improve the access to modern energies, especially those used for cooking (Akter and Pratap 2022; Cabiyo et al. 2021; Choudhuri and Desai 2020; Gould and Urpelainen 2020). Gould and Urpelainen (2020) showed that households with empowered women were more likely to adopt LPG for cooking in India, compared to those in which women were less empowered. The authors explained their findings through the decision-making power channel. The study

of Choudhuri and Desai (2020) also found that the adoption of LPG in India was positively associated with the economic status of women. They indicated that women who participated in the labor force market were more likely to adopt LPG as the main source of cooking energy. The recent study of Akter and Pratap (2022), which also used a conceptual framework, argued that women's empowerment can increase the use of modern energies. Their hypothesis was confirmed using data from India's households. Thus, we hypothesize that women's empowerment can improve the use of modern energies because the opportunity cost of using traditional energies is higher among empowered women.

Women's empowerment and health

In theory, women's empowerment affects the demand for health services by at least three channels. First, empowered women receive economic and financial resources for their achievement, and this will increase the demand for health care services, especially that of women and children *ceteris paribus* (Duflo 2012). Grossman (1972) argued that health is both a consumption and capital good. Hence, based on the neoclassical economic theory of rational consumer, it is expected that the demand for health services will increase with women's income. The importance of income in consumer choice is well recognized in the economic literature through the income elasticity of goods.

Second, the neoclassical utility theory of consumerism states that the demand for a good is based on the expected utility that depends on the value of that good. Thus, the bargaining and collective of households' decision-making model (Bateman and Munro 2009; Browning and Chiappori 1998) argues that the value of a good derived from a collective decision-making process is greater than that from a unitary decision-making model (Becker 1974; Hegtvedt and Turner 1989). Based on the bargaining and collective of the household decision-making model, Cockerill et al. (2007) and Dickie and Messman (2004) showed that households confer a greater value to good "health" than the unitary decision-making model. Recently, studies reported that the demand for health services within households depends on the decision-making autonomy of women (Chol et al. 2019; Osamor and Grady 2016; Woldemicael 2010). Hence, based on this literature, we can assume that the more decisions of health care services that are made together by men and women within households, the greater will be the demand for health care services.

Finally, through the channel of knowledge, it is argued that empowered women are more likely to take care of children's hygiene, nutrition, vaccination program, and antenatal care services (Astutik et al. 2020; Ford et al. 2018; Singh et al. 2021; Sohn and Jung 2020; Tadesse et al. 2013; Yaya et al. 2018). Moreover, Mandal et al. (2017) used the theory of change to shed light on the main pathways through which women's empowerment influences health outcomes. Through a literature review in developing countries, they showed that women's decision-making power, economic capabilities, and ownership of assets play an important role in maternal health and family planning.

Overview of the empirical literature

There is overwhelming literature on the effect of women's empowerment on maternal and child health in developing countries during the past two decades. Women's empowerment is one of the primary factors that has received a great deal of attention in empirical studies that focused on the determinants of the demand for maternal health services. This literature aims to assess if the status of women within households can be an effective tool to stimulate demand for health services in developing countries.

Sado et al. (2014) examined the effect of women's empowerment within the household, including decision-making power and attitudes towards domestic violence, on the use of prenatal and postnatal care in Albania. Using bivariate and multivariate analyses on a sample of 1,303 married women age 15 to 49, the study results showed that decision-making power and attitudes towards women's domestic violence positively influence the demand for maternal health services. In the same direction, Pandey et al. (2012) evaluated the effect of women's empowerment in Nepal on the demand for maternal health services using logistic regression on a sample of 7,878 women. Their results showed that three of the five empowerment indicators, including the age of women at the birth of their first child, their education, and their knowledge of sexually transmitted diseases, positively influence the demand for health services, and especially for prenatal and delivery services. However, women's empowerment, in terms of women's opinions on violence against women and their participation in financial decisions within the household, did not have a significant effect on the demand for maternal health services. Furthermore, with a sample of 44 low-income countries, Lan and Tavrow (2017) found that the gender equity index and the social institutions and gender index are significantly correlated with the rate of maternal mortality in all 44 countries.

In addition, Sebayang et al. (2019) simultaneously examined the relationship between women's empowerment and the demand for maternal health services in five Asian countries. With a focus on antenatal care services, the results, which are based on logistic regression, revealed that the four composite indicators of women's empowerment (active participation in the population; disagreement with the woman's reasons for beating; decision-making power over household problems; and level of knowledge) did not have the same effect on the number of antenatal visits completed and the period of the first antenatal visit in the five countries. There was a significant positive effect of labor force participation on the number of prenatal visits in Cambodia, the Philippines, and Timor-Leste. In contrast, empowerment indicators, such as disagreement with the reasons for beating one's wife and the level of knowledge of women, did not affect the number of antenatal care visits in Cambodia, Indonesia, and Myanmar. Furthermore, the results showed that women's decision-making power was associated with the number of antenatal care visits in Cambodia and Indonesia.

In Africa, some studies have explored the effect of women's empowerment on maternal and child health. Review of work by Abreha and Zereyesus (2021) shows that female empowerment at the household level was positively and statistically associated with better child health outcomes in sub-Saharan African countries. Ahuru (2021) used a sample of 8,006 women, drawn from data from the 2013 Nigeria Demographic and Health Survey, to assess the effect of women's empowerment on maternal and childcare utilization in Nigeria. The study used three indicators as measures of maternal and childcare utilization: prevalence of antenatal care, place of delivery, and completeness of child immunization. The findings confirmed that women's empowerment had a significant association with maternal and childcare utilization in Nigeria. Yaya et al. (2018) also investigated the effect of female empowerment on contraceptive use in sub-Saharan Africa. Their analysis was based on DHS data across a large sample of 32 sub-Saharan African countries, which represented 474,622 women age 15-49. Using multilevel logistic regression, the authors concluded that female empowerment had significant effects on contraceptive use.

Similarly, Ndaimani et al. (2018) studied the influence of women's empowerment on the use of child health services in Zimbabwe. This included a woman taking control over her income or the income of her partner, ownership of assets, and participation in decision making about their health as indicators of women's empowerment in households. The results of the multivariate logistic regression on a sample of 5,145

married women with children under age 5 indicated that women's empowerment measured through the mother's decision-making power and ownership of assets had no significant effect on the demand for diarrhea treatment services. However, the authors found a positive and significant association between women's empowerment and the use of immunization services.

This literature shows that the effect of women's empowerment on the demand for maternal and child health services is inconsistent, depending on the location of the studies. Thus, the effect of women's empowerment on the demand for maternal health services may be affected by other socioeconomic and environmental household factors. Yet, it is worth noting that despite the potential of the existent literature, no study has investigated how women can be empowered to leverage the demand for maternal health services. This study attempts to answer this question by assuming that improving the access to modern energy could empower women and, in turn, raise the demand for maternal health services.

1.1 Research Questions

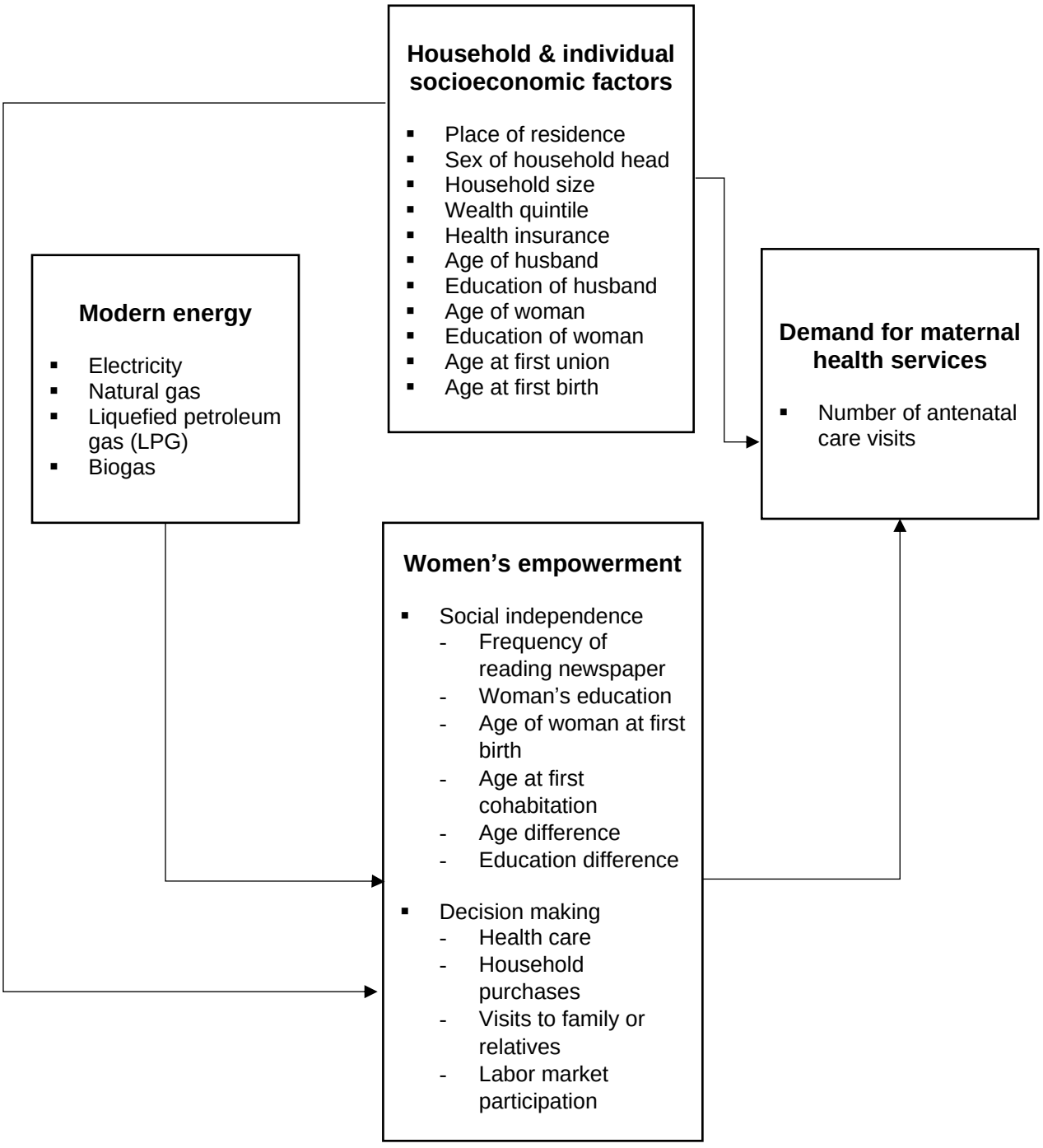
The main research question is, how do women's empowerment, modern energy, and demand for maternal health services interact in Benin? More specifically:

- What is the level of access to modern energy and current status of women's empowerment in Benin?
- What is the current status of women's empowerment in Benin?
- What is the effect of access to modern energies on women's empowerment in Benin? And
- What is the effect of women's empowerment on the demand for maternal health services?

1.2 Conceptual Framework

The demand for maternal health services is conceptualized as an outcome that depends directly on women's empowerment and the households' socioeconomic and demographic characteristics, and indirectly by the access to modern energies. Equally, women's empowerment is determined by modern energy access and the households' socioeconomic and demographic characteristics. Having greater knowledge of women's empowerment and access to modern energy could allow for a better prediction of the demand for maternal health services.

Figure 1 Conceptual framework



2 DATA AND METHODS

2.1 Data

This study used secondary data for testing the research hypotheses. We used the seventh edition (2018) of Benin's Demographic Health Survey data. This survey is based on a national representative sample of 14,156 households, including 6,364 urban residents and 7,792 rural residents. The sample is selected through a two-step sampling method based on 555 clusters. The sampling frame is based on the 2013 Benin national census of one million households. This study used the IR file data that focused on women age 15–49. The study sample included 8,331 women who are currently in union or living with a man and who had at least one child born in the previous 5 years.

2.2 Variables

2.2.1 Interest variables

The main variables of interest were the demand for maternal health services, women's empowerment, and access to modern energy. We measured the demand for maternal health services through the number of antenatal care visits during pregnancy. According to the World Health Organization (WHO), at least four antenatal care (ANC) visits are recommended during pregnancy. Consequently, the variable "number of antenatal care visits" was a dummy variable that takes the value 1 if a woman reached the threshold of 4 ANC visits during pregnancy and 0 otherwise.

The second variable of interest is women's empowerment. Women's empowerment is a complex concept, which justifies the difficulty and diversity of indicators used for its measurement. Despite this multidimensionality, there is a consensus among scholars that women's empowerment encompasses many components, and that any indicator that aims to measure women's empowerment should consider this multidimensionality. In this study, we used the Survey-based Women's emPowERment index (SWPER) approach (Ewerling et al. 2017) to construct composite indicators of women's empowerment. The SWPER is a set of composite indicators grouped into three pillars of women's empowerment: attitude to violence, social independence, and decision making. The main advantage of this indicator is the correction of the weight biases assigned subjectively in previous works (Msuya, et al. 2014; Tadesse et al. 2013; Upadhyay and Karasek 2012). Second, the SWPER index is women-focused, since it used data chiefly based on women. Third, the SWPER is an individual-based index, as opposed to most of the women's empowerment indices that were country-level based, such as the Women Empowerment Index of United Nations Women and the Women Economic Empowerment Index (Cingranelli and Richards 2010).

The SWPER index includes 15 items such as (i) woman's frequency of reading newspapers or magazines, woman's education in completed years of schooling, age of the woman at first birth, age at first cohabitation, and the age difference between the woman and her husband; (ii) education differences between a woman and her husband, who usually decides on respondent's health care, who usually decides on large household purchases, who usually decide on visits to family or relatives, and woman's work status in past 12 months; and (iii) beating not justified if the wife goes out without telling husband, beating not justified if wife neglects the children, beating not justified if wife argues with husband, beating not justified if the wife

refuses to have sex with husband, and beating not justified if wife burns the food. The SWPER index was then categorized into three dimensions: social independence, decision making, and attitude to violence.

In this study, we used the social independence and decision-making dimensions because they are more closely related to access to modern energy and the demand for maternal health services. The third dimension of the SWPER index, "attitude to violence," is captured through five indicators: (i) beating not justified if wife goes out without telling husband, (ii) beating not justified if wife neglects the children, (iii) beating not justified if wife argues with husband, (iv) beating not justified if wife refuses to have sex with husband, and (v) beating not justified if wife burns the food. Thus, we assume that there is less likelihood of access to modern energy being associated with beating in Benin's context. The social independence dimension was mainly correlated to group (i) of the 15 items, while the decision-making dimension was more closely related to the second group (ii). Each of the two women's empowerment indices was computed by weighting all the items with the principal component analysis method as follows (Ewerling et al. 2017):

$$SCI_{id} = \frac{\left[-\left(\sum_{k=1}^{15} \lambda_{kd}\, \bar{x}\right) + \sum_{k=1}^{15}\left(\lambda_{kd}\, \bar{x}_{ki}\right)\right]}{\sigma_d} \qquad (1)$$

Where SCI_{id} is the women's empowerment standardized composite index for women *i* in the dimension *d* *with d=1,...,3,* λ_{kd} is the weight given to each of the *k* items used in each dimension *d,* $\bar{x}_{ki}$ are the mean of individual values for x_1-x_{15} items included in the PCA analyses, and σ_d are the standard deviations of the predicted scores of each dimension *d*.

We assumed that a woman is empowered if her score was greater than the sample mean. Therefore, a dummy variable was created for each of these indices that took the value 1 if women's score was greater than the sample mean and 0 otherwise.

The last interest variable was access to modern energy. This was defined as the accessibility to energy or domestic purposes—cooking, lighting, entertainment. This information is accessible on the DHS household file. Consequently, energy sources used by households were categorized into two groups: modern energy sources (gas, liquefied petroleum gas, electricity, and biogas), also designated as clean energies; and non-modern energies, called polluting energies, such as biomass fuels (firewood, charcoal, dung, and fossil fuels). Thus, "access to modern energy" was a dummy variable taking the value 1 if households depend on the use of one of the modern energy sources and 0 otherwise.

2.2.2 Control variables

Two groups of control variables were used for the analyses—individual women's characteristics and household characteristics. The latter included the age and education of husbands (no education, primary, secondary, and higher education), wealth index (very poor, poor, middle income, rich, and very rich), place of residence (rural and urban area), gender of the head of household (male and female), access to health insurance, and household size. Individual women's characteristics included age (adolescent, adult, old), education, age at first union, age at first birth, and number of children.

2.3 Statistical Analysis

Three types of statistical analyses were used to determine the relationship between women's empowerment, modern energy, and the demand for maternal health services. First, weighted descriptive analyses were used through percentages for all study variables. Weighted bivariate analysis was used to measure the association between our interest variables and women's socioeconomic and demographic characteristics with the chi-squared test. The statistics of this test was defined as:

$$\chi^2(\mathrm{df}) = \sum \frac{\left(observed - \exp ected\right)^2}{\exp ected} \qquad (2)$$

Where *df* refers to the degrees of freedom.

The null hypothesis of the chi-squared test was H_o: there is no significant association between the two variables of interest.

Before running our multiple regressions, pairwise correlations and multicollinearity tests were conducted to avoid spurious regressions. The variance inflation factors test was used for predictors with a pairwise correlation value above 0.5. Results reported in Table A1 to A4 in the appendix confirmed that there was no problem of multicollinearity in the three equations.

Lastly, econometric analysis was used through the estimation of a recursive trivariate probit model. Thus, based on existing literature on the determinants of access to modern energy in developing countries (Odilon and Lokonon 2020; World Bank 2021a; Verma and Imelda 2019; Odo et al. 2021), the modern energy access model was specified as:

$$ME^* = \alpha_1 + \alpha_2 X_1 + \alpha_3 WE + \varepsilon_1 \qquad (3)$$

Where ME^* is a latent dependent variable measuring the probability of access to modern energy and ME is a dichotomous variable that is defined as: $ME = \begin{cases} 1 \text{ if } \mathrm{ME}^* \succ 0 \\ 0 \text{ otherwise} \end{cases}$

In equation 3, WE refers to women's empowerment, X_1 is a vector of control variables, including household wealth, residence. α_1 is the constant and α_2 and α_3 are parameters to be estimated. ε_1 is the error term that is assumed to be independent and identically distributed with zero mean and variance equal to σ_ε^2.

One of the objectives of this study was to analyze the effect of access to modern energy on women's empowerment. Based on Sen's (1983) capability theory, we assumed that modern energy can empower women through the mechanism of access to information, education, and labor market participation. Consequently, following Bakehe (2021), Polansky and Laldjebaev (2021), and Burke and Dundas (2015), the women's empowerment equation was specified as:

$$WE^* = \beta_1 + \beta_2 X_2 + \beta_3 ME + \varepsilon_2 \qquad (4)$$

Where WE^* is a latent dependent variable measuring the probability of being empowered and WE is a dichotomous variable that is defined as: $WE = \begin{cases} 1 \text{ if } \mathrm{WE}^* \succ 0 \\ 0 \text{ otherwise} \end{cases}$

ME is modern energy access, X_2 is a vector of control variables, including individual women's and households' characteristics. β_1 is the constant term and β_2 et β_3 are parameters to be estimated. ε_2 is the error term that is assumed to be independent and identically distributed with zero mean and variance equal to σ_ε^2.

The last objective of this study was to investigate the effect of women's empowerment on the demand for maternal health services in Benin. Based on Duflo (2012) women's empowerment and economic development theory and following recent empirical works in developing countries (Ahuru 2021; Cornish et al. 2021; Kareem et al. 2021; Polansky and Laldjebaev 2021; Singh et al. 2021; Yaya et al. 2021), we specified the demand for maternal health services as:

$$MH^* = \eta_1 + \eta_2 X_3 + \eta_3 ME + \eta_4 WE + \varepsilon_3 \qquad (5)$$

Where MH^* is a latent dependent variable measuring the probability of access to maternal health services and MH is a dichotomous variable that is defined as: $MH = \begin{cases} 1 \text{ if } \mathrm{MH}^* \succ 0 \\ 0 \text{ otherwise} \end{cases}$

In equation 5, ME and WE refer respectively to access to modern energy and women's empowerment, X_3 is a vector of household characteristics. η_i are model parameters to be estimated, including the constant term, and ε_3 is the error term that is assumed to be independent and identically distributed with zero mean and variance equal to σ_ε^2.

Estimate equations 3, 4, and 5, could be estimated using ordinary least squares (OLS) methods. However, that is not the case, because of the endogeneity issues. Indeed, the error terms of all three models are correlated, so estimating these equations separately will lead to biased estimates. To handle this issue, we estimated these equations simultaneously within a framework a system of three equations through the recursive model as follows:

$$\begin{cases} ME^* = \alpha_1 + \alpha_2 X_1 + \alpha_3 WE + \varepsilon_1 \\ WE^* = \beta_1 + \beta_2 X_2 + \beta_3 ME + \varepsilon_2 \\ MH^* = \eta_1 + \eta_2 X_3 + \eta_3 ME + \eta_4 WE + \varepsilon_3 \end{cases} \qquad (6)$$

Where the stochastic error terms $(\varepsilon_1, \varepsilon_2, \varepsilon_3)$ were assumed to be jointly normally distributed with zero mean and covariance matrix as follows:

$$\sum = \begin{pmatrix} 1 & \rho_{12} & \rho_{13} \\ \rho_{12} & 1 & \rho_{23} \\ \rho_{13} & \rho_{23} & 1 \end{pmatrix} \quad (7)$$

In equation 7, the off-diagonal elements represent the unobservable relation between the stochastic terms $(\varepsilon_1, \varepsilon_2, \varepsilon_3)$.

It is worth noting that equation 6 cannot be estimated simultaneously directly because the system is not identified, and some exclusion restrictions should be set for this purpose (Greene 2005). Thus, since our objective is not to analyze the effect of women's empowerment on access to modern energy, we exclude the women's empowerment variable from the modern energy access equation and the identified system to be estimated is specified as follows:

$$\begin{cases} ME_i^* = \alpha_1 + \alpha_2 X_{i1} + \varepsilon_{i1} \\ WE_i^* = \beta_1 + \beta_2 X_{i2} + \beta_3 ME_i + \varepsilon_{i2} \\ MH_i^* = \eta_1 + \eta_2 X_{i3} + \eta_3 WE_i + \varepsilon_{i3} \end{cases} \quad (8)$$

Where *i* is the woman subscript. Equation 8 was estimated using the maximum simulated likelihood method (Ahuru 2021; Cappellari and Jenkins 2003). The test of exogeneity under the null hypothesis of $\rho = 0$ was run (Greene 2012; Knapp and Seaks 1998). Failing to reject the null hypothesis implies that the three models in equation 6 can be estimated separately.

All statistical analyses were performed using STATA statistical software program, version 17.0.

3 RESULTS

3.1 Women's Characteristics

Table 1 presents women's characteristics through individual and household-level indicators. Results showed that most women were rural residents (59%), and 40% of women live either in poor or the poorest households. Individual characteristics indicate that 64% of women were younger than age 35. Most of the women in the sample were not educated (82%), and only 1% had achieved a higher educational level. These results are consistent with the majority of sub-Saharan African countries, which are characterized by a low level of human capital. It is worth noting that 41% of women in the sample entered into union before reaching age 18, and 51% were in union when they were between 19–34. Our results revealed that most women (64%) had their first birth between age 18 to 25. Our results also showed that 66% of women do not have access to modern energy. Indeed, this region experiences the lowest rate of access to modern energy worldwide, which is about 46% for electricity. In comparison, other developing countries recorded a rate of 98% in Latin America, Asia, and North Africa (World Bank 2021b; IEA 2021). We also found that 48% of women did not complete their ANC visits during the last pregnancy, which is recommended by the World Health Organization.

The results on women's empowerment revealed that 53% and 46% of the women were not empowered when considering the social independence and decision-making dimensions, respectively. More importantly, results in Table 2 indicated that the average woman's empowerment was low in the sample for both the social independence and decision-making dimensions. The sample means were 0.31 and 0.42, respectively, for the social independence and decision-making dimensions that were below 0.5. Our results also highlighted that only 1% of women were covered by health insurance.

Table 1 Socioeconomic and demographic characteristics of women

			95% CI	
Characteristics	**Frequency**	**Percentage**	**Lower**	**Upper**
Women's age				
15–24	1,322	22.9	21.8	24.4
25–34	2,400	41.6	40.4	43.3
35–49	2,042	35.4	33.7	36.5
Women's education				
No education	9,203	82.4	81.5	84.0
Primary and secondary	1,809	16.2	14.9	17.1
Higher	158	1.4	1.0	1.6
Total children ever born				
No child	624	5.6	5.0	6.0
1–3	5,119	45.8	44.8	47.1
4–6	3,803	34.1	32.9	35.0
More than 6	1,624	14.5	13.7	15.5
Age at first cohabitation				
10–17	4,610	41.3	39.9	42.6
19–25	5,691	51.0	49.7	52.2
26–34	780	7.0	6.4	7.6
35–47	89	0.8	0.7	1.0

Continued…

Table 1—*Continued*

Characteristics	Frequency	Percentage	95% CI Lower	95% CI Upper
Age at first birth				
11–17	2,979	28.3	26.8	29.0
18–25	6,716	63.7	63.3	65.4
26–34	822	7.8	6.9	8.1
35–40	29	0.3	0.2	0.4
Husband's age				
15–24	641	5.8	5.3	6.3
25–34	3,697	33.3	32.3	34.8
35–59	6,337	56.6	55.4	57.8
60–95	495	4.3	3.8	4.9
Husband's education level				
No education	5,755	54.3	52.1	56.1
Primary	2,130	20.1	19.6	22.0
Secondary	2,063	19.5	18.2	20.6
Higher	656	6.2	5.1	6.5
Sex of household head				
Male	9,447	84.6	83.4	85.8
Female	1,723	15.4	14.3	16.4
Place of residence				
Urban	4,609	41.3	37.3	42.1
Rural	6,561	58.7	57.9	62.7
Wealth quintiles				
Poorest	2,261	20.2	17.3	21.7
Poorer	2,204	19.7	18.5	21.3
Middle	2,158	19.3	18.6	21.4
Richer	2,241	20.1	19.4	22.5
Richest	2,306	20.6	18.1	21.8
Household size				
1–6	6,085	54.5	53.0	56.8
7–12	3,774	33.8	32.1	34.7
Over 12	1,311	11.7	10.1	13.7
Health insurance				
No	11,040	98.8	98.7	99.2
Yes	130	1.2	0.9	1.3
Access to modern energy				
No access modern energy	7,349	65.8	63.5	68.2
Access modern energy	3,821	34.2	31.8	36.6
Number of antenatal care visits				
No antenatal visits 0–3	3,861	47.5	44.8	48.7
Antenatal visits 4 and more	4,260	52.5	51.3	55.2
Women empowerment: social independence				
Not empowered	5,962	53.4	51.9	54.7
Empowered	5,208	46.6	45.3	48.1
Women empowerment: decision making				
Not empowered	5,185	46.4	44.7	48.2
Empowered	5,985	53.6	51.9	55.3

Table 2 Women's empowerment index

Variable	Obs	Mean	Std. Dev.	Min	Max
Social independence score	10,604	0.305	0.123	0	1
Decision-making score	10,604	0.418	0.209	0	1

3.2 Distribution of Modern Energy Access

Table 3 presents the distribution of modern energy access by women's characteristics. Results show that modern energy access had significant associations with women's individual characteristics (age and education), and households characteristics (place of residence, wealth quintile, household size, and husband's education level). The largest proportion of women who did not have access to modern energy had no education (72%), while only 6% of women with higher education levels did not have access to modern energy. Our results also revealed a statistical association between access to modern energy and household wealth. Women in rich households were more likely to access modern energy (90%) than the poorest women (2%).

Table 3 Distribution of modern energy access by women's characteristics

	Modern energy access		Chi-square
Characteristics	**No**	**Yes**	***p* value**
Women's age			.004
15–24	69.4	30.6	
25–34	63.6	36.4	
35–49	63.6	36.4	
Women's education			
No education	72.1	27.9	
Primary and secondary	39.0	61.0	
Higher	6.3	93.7	
Place of residence			.000
Urban	47.0	53.0	
Rural	79.0	21.0	
Wealth quintiles			.000
Lowest	98.1	1.9	
Second	94.1	5.9	
Middle	81.3	18.7	
Fourth	48.3	51.7	
Highest	9.6	90.4	
Husband's education level			.000
No education	79.7	20.3	
Primary	63.2	36.9	
Secondary	47.0	53.0	
Higher	22.0	78.1	

3.3 Features of Women's Empowerment

Table 4 presents the distribution of women's empowerment by women's characteristics. The results indicated a positive and significant association between women's empowerment and women's wealth quintile. Thus, wealth played a major role in empowering women. Our results revealed that 69.6% of the poorest women were not empowered on the social independence dimension and 59.5% on the decision-making dimension, compared to 30.3% and 31.6% respectively for women in the richest wealth quintile. We also reported that women's empowerment was negatively associated with household size. Further, 59.7% of women who did not have access to modern energy were not empowered on the social independence dimension, while 49.2% of those women with no access were empowered on the decision-making dimension, compared to 58.9% of women who had access to modern energy were empowered for social independence and 62.2% on the decision-making dimension.

Table 4 Distribution of women's empowerment by women's characteristics

Characteristics	Women's empowerment *(Social independence)*		Chi-square *p* value	Women's empowerment *(Decision making)*		Chi-square *p* value
	No	Yes		No	Yes	
Sex of household head			.000			.000
Male	54.9	45.1		49.0	51.0	
Female	45.0	55.0		32.1	67.9	
Type of place of residence			.000			
Urban	43.9	56.1		40.6	59.4	.000
Rural	60.0	40.0		50.2	49.8	
Wealth quintiles			.000			.000
Lowest	69.6	30.4		59.5	40.5	
Second	63.4	36.6		53.4	46.6	
Middle	57.0	43.0		46.6	53.4	
Fourth	47.3	52.7		41.4	58.6	
Highest	30.3	69.7		31.6	68.4	
Household size			.000			.000
1–6	47.3	52.8		42.3	57.7	
7–12	59.2	40.8		48.6	51.4	
Over 12	65.1	34.9		59.4	40.6	
Modern energy access			.000			.000
Not access	59.7	40.3		50.8	49.2	
Access	41.1	58.9		37.8	62.2	

3.4 Features of Maternal Health Services

Table 5 reports the association between the demand for maternal health services and women's socioeconomic and demographic characteristics. The demand for maternal health services was positively and significantly associated with the sex of household head, place of residence, wealth index, health insurance coverage, and women's empowerment. In contrast, the demand for maternal health services was negatively associated with household size—53.2% of unempowered women on the social independence dimension did not have access to maternal health services, compared with 39.2% of the empowered women. A total of 60.8% of the empowered women on the social dimension scale had access to such services. On the decision-making dimension, 54.9% of unempowered women did not have access to maternal health services, while 38.9% of the empowered women did not have access, compared with those who did have access (61.1%). More importantly, 69.1% of the poorest women did not have access to maternal health services, while only 18.9% of women in the richest wealth quintile did not have access to such services.

Table 5 Distribution of maternal health services by women's characteristics

Characteristics	Maternal health services		Chi-square *p* value
	No	Yes	
Place of residence			.000
Urban	38.3	61.7	
Rural	51.6	48.4	
Wealth quintiles			.000
Lowest	69.1	30.9	
Second	54.4	45.6	
Middle	48.1	51.9	
Fourth	38.2	61.8	
Highest	18.9	81.1	
Household size			.000
1–6	38.8	61.2	
7–12	52.5	47.5	
Over 12	61.3	38.7	
Health insurance			
No	46.7	53.4	
Yes	14.1	86.0	
Women empowerment *(social independence)*			.000
Not empowered	53.2	46.8	
Empowered	39.2	60.8	
Women empowerment *(decision making)*			.000
Not empowered	54.9	45.1	
Empowered	38.9	61.1	

3.5 Multiple Regression

This section presents the results of the trivariate recursive probit model estimated with the maximum simulated likelihood method. Results presented in Tables 6 and 7 confirmed the validity of our structural estimation as indicated by the significance of the Wald statistics—at 1% level in each of the two models. Results of the Likelihood Ratio (LR) test also rejected the null hypothesis of the nullity of rho, as indicated by the p value = .000. This implied that the trivariate recursive probit models were less biased than estimating the three equations separately.

The results of the model using the social independence construct to represent women's empowerment are presented in Table 6 and the results of the model using the decision-making construct to represent women's empowerment are shown in Table 7. Within each table, the equation for access to modern energy is shown first, then the equation for women's empowerment, and finally the equation for maternal health services. In the first equation of the two models (Table 6 and 7), the results showed that most explanatory variables had significant coefficients, which implied that modern energy access was significantly associated with the wealth quintile, gender of the household head, and educational level and age of women, as well as age at first union and birth. Access to modern energy was positively associated with the wealth quintile, educational level and age of women, age at first union, and age at first birth. In contrast, being in a household headed by a woman was negatively associated with access to modern energy.

Results of equation 2 in Table 6 indicated that access to modern energy and households headed by women were positively and significantly associated with women's empowerment, while the size of household and living in rural areas were negatively associated with women's empowerment in the social independence model. In the decision-making model shown in Table 7, our results indicated that access to modern energy does not have a significant effect on women's empowerment, while the wealth quintile was positively associated with women's empowerment.

Finally, the results of equation 3 in both models showed that women's empowerment, gender of household head, wealth quintile, and household size were significantly associated with the demand for maternal health services.

Table 6 Trivariate recursive probit estimates: Social independence model

Variables	Coefficient	Adjusted Standard error	*p* value	95% CI Lower	95% CI Upper
Equation 1: Modern energy					
Place of residence (reference=Urban)					
Rural	0.006	0.093	.944	-0.175	0.187
Sex of household head (reference=Male)					
Female	-0.259	0.082	.002	-0.420	-0.099
Wealth quintiles (reference=Lowest)					
Second	0.582	0.183	.001	0.223	0.940
Middle	0.981	0.173	.000	0.642	1.319
Fourth	1.755	0.184	.000	1.394	2.116
Wealth	2.613	0.218	.000	2.184	3.041
Husband's education (reference=No educ)					
Primary	-0.075	0.072	.300	-0.216	0.066
Secondary	-0.047	0.079	.554	-0.204	0.109
Higher	-0.301	0.110	.007	-0.518	-0.083
Women's age (reference=15–24)					
25–34	0.114	0.068	.093	-0.019	0.248
35–49	0.346	0.095	.000	0.159	0.533
Women's education (reference=No education)					
Primary and secondary	0.618	0.080	.000	0.460	0.776
Higher	0.707	0.253	.005	0.209	1.203
Number of children born (reference=0–3)					
4–6	0.162	0.105	.124	-0.044	0.369
More than 6	0.060	0.088	.494	-0.112	0.233
Age at first union (reference=10–17)					
19–25	0.486	0.083	.000	0.322	0.650
26–34	0.739	0.146	.000	0.452	1.027
35–47	0.564	0.406	.165	-0.232	1.361
Age at first birth (reference=11-17)					
18–25	0.121	0.062	.051	-0.001	0.244
26–34	0.279	0.125	.026	0.033	0.525
35–40	0.225	0.331	.498	-0.425	0.875
Constant	-2.441	0.226	.000	-2.885	-1.996
Equation 2: Women's empowerment: social independence					
Modern energy (reference=No access)	1.261	0.107	.000	1.049	1.472
Place of residence (reference=Urban)					
Rural	-0.131	0.055	.017	-0.239	-0.233
Sex of household head (reference=Male)					
Female	0.172	0.059	.004	0.555	0.290
Wealth quintiles (reference=Lowest)					
Second	0.051	0.065	.442	-0.078	0.179
Middle	0.059	0.071	.410	-0.081	0.199
Fourth	-0.150	0.109	.169	-0.364	0.063
Wealthiest	-0.386	0.137	.005	-0.655	-0.116
Household size (reference=1–6)					
7–12	-0.106	0.042	.013	-0.190	-0.022
Over 12	-0.165	0.068	.015	-0.299	-0.322
Constant	-0.347	0.066	.000	-0.478	-0.217

Continued...

Table 6—*Continued*

Variables	Coefficient	Adjusted Standard error	*p* value	95% CI Lower	95% CI Upper
Equation 3: Maternal health services					
Social independence (reference=No)	0.180	0.091	.049	0.001	0.359
Place of residence (reference=Urban)					
Rural	0.013	0.071	.847	-0.125	0.153
Sex of household head (reference=Male)					
Female	0.152	0.068	.027	0.017	0.286
Wealth quintiles (reference=Lowest)					
Second	0.393	0.068	.000	0.258	0.528
Middle	0.557	0.077	.000	0.405	0.709
Fourth	0.803	0.082	.000	0.641	0.965
Highest	1.314	0.093	.333	1.132	1.496
Health insurance (reference=No)					
Yes	0.297	0.307	.000	-0.305	0.899
Household size (reference=1–6)					
7–12	-0.192	0.053	.000	-0.296	-0.088
Over 12	-0.347	0.095	.000	-0.534	-0.159
Constant	-0.478	0.087	.000	-0.650	-0.306
Number of Observations	4,027				
Wald test Chi2 (23) statistic	2221.30				
LR test Chi2(3) $H_o = \rho_{21} = \rho_{31} = \rho_{32} = 0$	95.674		.000		
ρ_{21}	-0.752		.000		
ρ_{31}	0.011		.760		
ρ_{32}	-0.024		.609		

Table 7 Trivariate recursive probit estimates: Decision-making model

Variables	Coeffi-cient	Adjusted standard error	*p* value	95% CI Lower	95% CI Upper
Equation 1: Modern energy					
Place of residence (reference=Urban)					
Rural	-0.075	0.101	.458	-0.275	0.123
Sex of household head (reference=Male)					
Female	-0.166	0.090	.067	-0.343	0.011
Wealth quintiles (reference=Lowest)					
Second	0.610	0.196	.002	0.224	0.996
Middle	1.147	0.189	.000	0.775	1.518
Fourth	2.099	0.190	.000	1.725	2.472
Highest	3.174	0.222	.000	2.738	3.609
Husband's education (reference=No educ)					
Primary	0.126	0.100	.208	-0.323	0.070
Secondary	0.054	0.102	.593	-0.146	0.256
Higher	-0.202	0.143	.160	-0.484	0.080
Women's age (reference=15–24)					
25–34	-0.033	0.088	.706	-0.206	0.139
35–49	0.090	0.121	.455	-0.146	0.327
Women's education (reference=No education)					
Primary and secondary	0.174	0.090	.053	-0.002	0.351
Higher	0.416	0.297	.161	-0.166	0.998
Number of children born (reference=0–3)					
4–6	-0.034	0.128	.789	-0.285	0.216
More than 6	-0.052	0.106	.626	-0.261	0.157
Age at first union (reference=10–17)					
19–25	-0.082	0.076	.279	-0.233	0.067
26–34	-0.115	0.140	.412	-0.390	0.159
35–47	-0.534	0.361	.139	-1.242	0.173
Age at first birth (reference=11-17)					
18–25	0.023	0.079	.764	-0.132	0.179
26–34	-0.027	0.148	.851	-0.319	0.264
35–40	0.006	0.374	.987	-0.728	0.740
Constant	-1.894	0.255	.000	-2.395	-1.393
Equation 2: Women's empowerment: Decision making					
Modern energy (reference=No access)	-0.024	0.164	.882	-0.346	0.297
Place of residence (reference=Urban)					
Rural	-0.059	0.065	.365	-0.186	0.068
Sex of household head (reference=Male)					
Female	0.282	0.072	.000	0.140	0.424
Wealth quintiles (reference=Lowest)					
Second	0.138	0.076	.071	-0.011	0.288
Middle	0.279	0.084	.001	0.114	0.445
Fourth	0.295	0.111	.008	0.076	0.514
Highest	0.591	0.169	.000	0.259	0.924
Household size (reference=1–6)					
7–12	-0.146	0.051	.005	-0.248	-0.045
Over 12	-0.349	0.072	.000	-0.491	-0.206
Constant	-0.174	0.076	.024	-0.324	-0.023

Continued...

Table 7—*Continued*

Variables	Coeffi-cient	Adjusted standard error	*p* value	95% CI Lower	95% CI Upper
Equation 3: Maternal health services					
Decision making (reference=No)	0.157	0.141	.265	-0.119	0.433
Place of residence (reference=Urban)					
Rural	0.004	0.071	.956	-0.136	0.144
Sex of household head (reference=Male)					
Female	0.141	0.070	.044	0.003	0.279
Wealth quintiles (reference=Lowest)					
Second	0.398	0.069	.000	0.261	0.534
Middle	0.566	0.077	.000	0.414	0.718
Fourth	0.829	0.081	.000	0.670	0.988
Highest	1.337	0.094	.000	1.151	1.522
Health insurance (reference=No)					
Yes	0.332	0.307	.280	-0.270	0.935
Household size (reference=1–6)					
7–12	-0.191	0.052	.000	-0.295	-0.088
Over 12	-0.343	0.097	.000	-0.533	-0.152
Constant	-0.483	0.104	.000	-0.688	-0.278
Number of Observations	4,027				
Wald test Chi-squared (23) statistic	1341.88		.000		
LR test Chi2(3) $H_o = \rho_{21} = \rho_{31} = \rho_{32} = 0$	37.070		.000		
ρ_{21}	0.038		.623		
ρ_{31}	0.025		.471		
ρ_{32}	0.052		.511		

Table 8 presents the marginal effects that indicate how a change in independent variables affects the sum of the three probabilities with respect to access to modern energy, women's empowerment, and access to maternal health services. We only reported in this table the marginal effects of the demand for maternal health services model in which women's empowerment was measured by social independence (model 1) and decision making (model 2). Results from this table showed that being an empowered woman increases the chance of the demand for maternal health services by 7.0% and 8.0%, respectively for the social independence and decision-making dimension compared with unempowered woman *ceteris paribus.* Our results also revealed that women's wealth quintile increases the probability of the demand for maternal health services. Especially, being in the middle wealth quintile (richest wealth quintile) increases the probability of access to maternal health services by 13.1% (30.7%), compared to the poorest women's *ceteris paribus* for the social independence model.

Table 8 Marginal effects of the demand for maternal health services models

Variable	Mean	Standard deviation	Minimum	Maximum
Model 1/Equation 3: Demand for maternal health services				
Social independence (reference=No)	0.070	0.033	0.001	0.116
Place of residence (reference=Urban)				
Rural	0.005	0.003	0.000	0.009
Sex of household head (reference=Male)				
Female	0.035	0.017	0.001	0.059
Wealth quintiles (reference=Lowest)				
Second	0.093	0.044	0.002	0.154
Middle	0.131	0.062	0.002	0.217
Fourth	0.187	0.089	0.003	0.311
Highest	0.307	0.147	0.005	0.510
Health insurance (reference=No)				
Yes	0.072	0.035	0.001	0.120
Household size (reference=1–6)				
7–12	-0.045	0.021	-0.074	-0.001
Over 12	-0.082	0.039	-0.136	-0.001
Model 2/Equation 3: Demand for maternal health services				
Decision making (reference=No)	0.079	0.044	0.005	0.148
Place of residence (reference=Urban)				
Rural	0.002	0.001	0.000	0.003
Sex of household head (reference=Male)				
Female	0.025	0.014	0.002	0.047
Wealth quintiles (reference=Lowest)				
Second	0.082	0.045	0.006	0.154
Middle	0.116	0.064	0.008	0.217
Fourth	0.171	0.095	0.012	0.321
Highest	0.274	0.152	0.019	0.514
Health insurance (reference=No)				
Yes	0.073	0.041	0.005	0.138
Household size (reference=1–6)				
7–12	-0.038	0.021	-0.072	-0.003
Over 12	-0.067	0.037	-0.126	-0.005

4 DISCUSSION

This study investigated the association between modern energy access, women's empowerment, and the demand for maternal health services in Benin by using secondary data from the 2017 Demographic Health Survey of Benin. We first determined the levels of women's empowerment using a composite index. Using the SWPER index, we computed a composite index of women's empowerment through the social independence dimension by including 15 variables under the principal component analysis method. Second, the demand for maternal health services was measured through the number of antenatal care visits, while modern energy access was measured through dependence on the use of electricity and gas, or biogas as domestic fuels.

Our results revealed that women in the sample were characterized by low levels of empowerment, low levels of modern energy access, and low demand for maternal health services. Then, after controlling for the place of residence, the household size, wealth quintile, and the gender of the household head, we found that women's empowerment was significantly associated with modern energy access. This result agrees with our expectations. Access to modern energy can improve women's empowerment through many channels. First, with access to electricity, women are more likely to access information through television and social media, which will raise their educational attainment and social independence. Electricity and clean cooking fuels can also provide better conditions for women in upgrading their ongoing vocational training.

Second, previous studies confirmed the association between women's empowerment and modern energy. Using a large sample of 175 countries, Burke and Dundas (2015) concluded that a reduction in the use of biomass fuels increases female labor market participation. Bakehe (2021) used Cameroonian households' survey data and showed that the adoption of clean cooking fuels increases the probability of women's participation in the labor market. Dinkelelman (2011) found that access to electricity in South Africa's rural areas increases women's time spent in paid activities by 9.5%.

Third, we found that the demand for maternal health services was positively associated with women's empowerment. Women with social independence were more likely to complete antenatal care visits as a measure of maternal health services than women with no social independence. This finding aligns with Dufflo's (2012) theory that argued that empowered women could fuel the achievement of desired development goals, including maternal and child health, especially in low-income countries. Thus, the positive association between women's empowerment and the demand for maternal health services can be explained by the fact that empowered women were more educated, had more access to information, and were more exposed to newspapers and magazines. Consequently, empowered women were more likely to be informed on maternal health issues. Empowered women also have the advantage of delaying the age of their first cohabitation and their first birth, which implies that they are more established before starting motherhood.

Previous studies also reported that women's empowerment is positively associated with maternal and child health care services in developing countries (Ahuru 2021; Kabir et al. 2020; Singh et al. 2021; Sohn and Jung 2020). Based on Demographic and Health Surveys (DHS) data of five Southeast Asian Countries (Cambodia, Indonesia, Myanmar, Philippines, and Timor-Leste) and logistic regression, Sebayang et al.

(2019) analyzed the association between women's empowerment and the use of antenatal care services. Their results found a positive association between women's empowerment and the use of antenatal care services in the sample with some disparities among countries. Women's labor market participation, women's attitude toward violence, and women's decision making were the main channels through which women's empowerment was positively associated with antenatal care services in Southeast Asian Countries.

Recently, Ahuru (2021) used a sample of 8,006 women drawn from the 2013 Nigeria Demographic and Health Survey data to evaluate the effect of women's empowerment on maternal and childcare use in Nigeria. They used three indicators as measures of maternal and childcare: the prevalence of antenatal care visits, place of delivery, and completeness of child immunization. Women's empowerment was measured through women's autonomy. The results confirmed that women's empowerment had a significant association with the use of maternal and childcare in Nigeria. The Yaya et al. 2018 study also investigated the effect of women's empowerment on the use of contraceptives in sub-Saharan Africa. Their empirical analysis was based on DHS data with a large sample of 32 sub-Saharan African countries and 474,622 women age 15–49. Using multilevel logistic regression and measuring women's empowerment through decision making, participation in the labor market, and attitude to violence, the authors concluded that women's empowerment had significant effects on the use of contraceptives.

However, some previous studies found no association between women's empowerment and health care services in Africa. Ndaimani et al. (2018) analyzed the association between women's empowerment and the uptake of child health services in Zimbabwe. Using the 2015 Zimbabwe Demographic and Health Survey data, they applied logistic regression to assess the association between women's empowerment, measured through women's decision making and ownership of assets, and the uptake of child health services, as measured by two indicators: completeness of basic vaccinations and treatment of childhood diarrhea. They concluded that neither women's decision making nor ownership of assets is associated with the completeness of basic vaccinations or treatment of childhood diarrhea. The authors attributed their findings to some sociocultural factors of Zimbabwean women.

We found a significant association between the demand for maternal health services and women's sociodemographic and household characteristics, such as wealth quintile, the size of households, and the gender of the household head. Our results align with those of Ndaimani et al. (2018), who reported that women in the middle wealth quintile were more likely to complete basic child vaccinations than women in the poorest wealth quintile.

This study provides new evidence on the demand-side constraints of access to health care in a low-income country. More importantly, we highlighted the necessary conditions (access to modern energy) before women's empowerment could increase the demand for maternal health services. One of the limits of this study was the measurement of the demand for maternal health services that was limited to effective demand rather than latent demand.

5 CONCLUSION

This study investigated the extent to which women's empowerment was associated with the demand for maternal health services in Benin. A trivariate recursive probit model was used to test our research hypotheses using a sample of 11,170 married women drawn from the 2017 Benin DHS data. Our analyses led to three main findings. First, we showed that Benin's households were characterized by a low level of access to modern energy. This was determined by household's size and wealth quintile, woman's and head of household's education, the age at first union, and age at first birth. Second, through a composite index based on women's social independence and constructed by the principal component analysis method with the SWPER framework, we showed that the women in the sample were generally characterized by low levels of empowerment. We also revealed a low demand for maternal health services measured by the threshold number of antenatal care visits. Finally, we concluded that women's empowerment had a significant association with the demand for maternal health services.

Our findings have implications for policymakers in sub-Saharan African countries. First, to reach the third SDG that aims to reduce the maternal mortality rate to 70 per 100,000 live births by 2030, sub-Saharan African countries must address the issue of women's social independence by promoting women's education and improving household economic living conditions.

REFERENCES

Abreha, S. K., and Y. A. Zereyesus. 2021. “Women’s Empowerment and Infant and Child Health Status in Sub-Saharan Africa: A Systematic Review.” *Maternal and Child Health Journal* 25 (1): 95–106. https://doi.org/10.1007/s10995-020-03025-y

Afifi, M. 2009. “Women’s Empowerment and the Intention to Continue the Practice of Female Genital Cutting in Egypt.” *Archives of Iranian Medicine* 12 (2): 154–160. https://www.sid.ir/en/Journal/ViewPaper.aspx?ID=134136

Ahuru, R. R. 2021. “The Influence of Women Empowerment on Maternal and Childcare Use in Nigeria.” *International Journal of Healthcare Management* 14 (3): 1–10. https://doi.org/10.1080/20479700.2019.1688505

Akin, J. S., and P. Hutchinson. 1999. “Health-Care Facility Choice and the Phenomenon of Bypassing.” *Health Policy and Planning* 14 (2): 135–151. https://doi.org/10.1093/heapol/14.2.135

Akter, S., and C. Pratap. 2022. “Impact of Clean Cooking Fuel Adoption on Women’s Welfare in India: The Mediating Role of Women’s Autonomy.” *Sustainability Science* 17 (1): 243–57. https://doi.org/10.1007/s11625-021-01069-9

Aminou, F. A., and D. I. Monwanou. 2022. “The Effect of Women Decision Deprivation on Child Nutrition in Benin.” *Repères et Perspectives Economiques* 6 (1): 265–77. https://doi.org/10.34874/IMIST.PRSM/RPE/31796

Andersen, R. M. 1995. “Revisiting the Behavioral Model and Access to Medical Care: Does It Matter?” *Journal of Health and Social Behavior* 36 (1): 1–10. https://doi.org/10.2307/2137284

Arisukwu, O., S. Akinfenwa, and C. Igbolekwu. 2021. “Primary Healthcare Services and Maternal Mortality in Ugep.” *Annals of Medicine and Surgery* 68: 102691. https://doi.org/10.1016/j.amsu.2021.102691

Astutik, E., F. Efendi, S. K. Sebayang, S. Hadisuyatmana, E. M. M. Has, and H. Kuswanto. 2020. “Association between Women’s Empowerment and Diarrhea in Children under Two Years in Indonesia.” *Children and Youth Services Review* 113: 105004. https://doi.org/10.1016/j.childyouth.2020.105004

Atozou, B., R. Mayuto, and A. Abodohoui. 2017. “Review on Gender and Poverty, Gender Inequality in Land Tenure, Violence Against Woman and Women Empowerment Analysis: Evidence in Benin with Survey Data.” *Journal of Sustainable Development* 10 (6): 137. https://doi.org/10.5539/jsd.v10n6p137

Bakehe, N. P. 2021. “Energy Poverty: Consequences for Respiratory Health and Labour Force Participation in Cameroon.” *Journal of Environmental Economics and Policy* Online: 1–13. https://doi.org/10.1080/21606544.2021.1962412

Bateman, I. J., and A. Munro. 2009. “Household Versus Individual Valuation: What’s the Difference?” *Environmental and Resource Economics* 43 (1): 119–135. https://doi.org/10.1007/s10640-009-9268-6

Beaurain, C., and M. B. Amoussou. 2016. “Les Enjeux Du Développement de l’énergie Solaire Au Bénin. Quelques Pistes de Réflexion Pour Une Approche Territoriale.” *Mondes En Developpement* 176 (4): 59–76. https://doi.org/10.3917/med.176.0059

Becker, G. S. 1974. “A Theory of Social Interactions.” *Journal of Political Economy* 82 (6): 1063–1093. https://doi.org/10.1086/260265

Blimpo, M. P., A. Postepska, and Y. Xu. 2020. “Why Is Household Electricity Uptake Low in Sub-Saharan Africa?” *World Development* 133: 105002. https://doi.org/10.1016/j.worlddev.2020.105002

Browning, M., and P. A. Chiappori. 1998. “Efficient Intra-Household Allocations: A General Characterization and Empirical Tests.” *Econometrica* 66 (6): 1241–1278. https://doi.org/10.2307/2999616

Burke, P. J., and G. Dundas. 2015. “Female Labor Force Participation and Household Dependence on Biomass Energy: Evidence from National Longitudinal Data.” *World Development* 67(C): 424–437. https://doi.org/10.1016/j.worlddev.2014.10.034

Cabiyo, B, I. Ray, and D. I. Levine. 2021. “The Refill Gap: Clean Cooking Fuel Adoption in Rural India.” *Environmental Research Letters* 16 (1). https://doi.org/10.1088/1748-9326/abd133

Cappellari, L., and S. P. Jenkins. 2003. “Multivariate Probit Regression Using Simulated Maximum Likelihood.” *The Stata Journal: Promoting Communications on Statistics and Stata* 3 (3): 278–294. https://doi.org/10.1177/1536867x0300300305

Chol, C., J. Negin, K. E. Agho, and R. G. Cumming. 2019. “Women’s Autonomy and Utilisation of Maternal Healthcare Services in 31 Sub-Saharan African Countries: Results from the Demographic and Health Surveys, 2010–2016.” *BMJ Open* 9 (3). https://doi.org/10.1136/bmjopen-2018-023128

Choudhuri, P., and S. Desai. 2020. “Gender Inequalities and Household Fuel Choice in India.” *Journal of Cleaner Production* 265: 121487. https://doi.org/10.1016/j.jclepro.2020.121487

Cingranelli, D. L., and D. L. Richards. 2010. “The Cingranelli and Richards (CIRI) Human Rights Data Project.” *Human Rights Quarterly* 32 (2) 401–423, 465, 467. http://www.jstor.org/stable/40783984

Cockerill, C. A., S. M. Chilton, and W. G. Hutchinson. 2007. “Household Decision Making Models and The Value of Child Farm Safety.” Paper presented at The Agricultural Economics Society’s 81st Annual Conference, University of Reading, UK, April 2–4, 2007.

Cornish, H., H. Walls, R. Ndirangu, N. Ogbureke, O. M. Bah, J. F. Tom-Kargbo, M. Dimoh, and M. Ranganathan. 2021. “Women’s Economic Empowerment and Health Related Decision-Making in Rural Sierra Leone.” *Culture, Health and Sexuality* 23 (1): 19–36. https://doi.org/10.1080/13691058.2019.1683229

Dedjinou, S. V. F. 2022. “La Demande D’énergie Électrique Des Ménages Au Benin.” *Les Cahiers Du Cread* 38 (1): 61–103. https://doi.org/10.4314/cread.v38i1.3

Dickie, M., and V. L. Messman. 2004. “Parental Altruism and the Value of Avoiding Acute Illness: Are Kids Worth More than Parents?” *Journal of Environmental Economics and Management* 48 (3): 1146–1174. https://doi.org/10.1016/j.jeem.2003.12.005

Duflo, E. 2012. “Women Empowerment and Economic Development.” *Journal of Economic Literature* 50 (4): 1051–1079. https://doi.org/10.1257/jel.50.4.1051

Ewerling, F., J. W. Lynch, C. G. Victora, A. van Eerdewijk, M. Tyszler, and A. J. D. Barros. 2017. “The SWPER Index for Women’s Empowerment in Africa: Development and Validation of an Index Based on Survey Data.” *The Lancet Global Health* 5 (9): e915-e923. https://doi.org/10.1016/S2214-109X(17)30292-9

Ford, C., C. J. Chibwesha, J. Winston, C. Jacobs, M. K. Lubeya, P. Musonda, J. S. A. Stringer, and B. H. Chi. 2018. “Women’s Decision-Making and Uptake of Services to Prevent Mother-to-Child HIV Transmission in Zambia.” *AIDS Care - Psychological and Socio-Medical Aspects of AIDS/HIV* 30 (4): 426–434. https://doi.org/10.1080/09540121.2017.1381328

Gould, C. F., and J. Urpelainen. 2020. “The Gendered Nature of Liquefied Petroleum Gas Stove Adoption and Use in Rural India.” *Journal of Development Studies* 56 (7): 1309–1329. https://doi.org/10.1080/00220388.2019.1657571

Greene, W. 2005. “Fixed and Random Effects in Stochastic Frontier Models.” *Journal of Productivity Analysis* 23 (1): 7–32. https://doi.org/10.1007/s11123-004-8545-1

Greene, W. H. 2012. *Econometric Analysis* 7th Ed. Pearson. http://www.mysmu.edu/faculty/zlyang/ECON6002_21-Web/William_H_Greene-Econometric_Analysis-7th.pdf

Grossman, M. 1972. “On the Concept of Health Capital and the Demand for Health.” *Journal of Political Economy* 80 (2): 223–255. https://doi.org/10.1086/259880

Hanna, R., and P. Oliva. 2015. “The Effect of Pollution on Labor Supply: Evidence from a Natural Experiment in Mexico City.” *Journal of Public Economics* 122: 68–72. https://doi.org/10.1016/j.jpubeco.2014.10.004

Hegtvedt, K. A., and J. H. Turner. 1989. “A Theory of Social Interaction.” *Social Forces* 68 (2): 646. https://doi.org/10.2307/2579266

IEA. 2021. “Tracking SDG7: The Energy Progress Report 2021.” https://www.iea.org/reports/tracking-sdg7-the-energy-progress-report-2021

Institut National de la Statistique et de l’Analyse Economique (INSAE) et ICF. 2019. Enquête Démographique et de Santé au Bénin, 2017–2018. Cotonou, Bénin et Rockville, Maryland, USA: INSAE et ICF. https://dhsprogram.com/pubs/pdf/FR350/FR350.pdf

Kabeer, N. 2005. “Gender Equality and Women’s Empowerment: A Critical Analysis of the Third Millennium Development Goal.” *Gender and Development* 13 (1): 13–24. https://doi.org/10.1080/13552070512331332273

Kabir, A., M. M. Rashid, K. Hossain, A. Khan, S. S. Sikder, and H. F. Gidding. 2020. “Women’s Empowerment is Associated with Maternal Nutrition and Low Birth Weight: Evidence from Bangladesh Demographic Health Survey.” *BMC Women’s Health* 20 (1): 1–12. https://doi.org/10.1186/s12905-020-00952-4

Kareem, Y. O., I. O. Morhason-Bello, F. M. OlaOlorun, and S. Yaya. 2021. “Temporal Relationship between Women’s Empowerment and Utilization of Antenatal Care Services: Lessons from Four National Surveys in Sub-Saharan Africa.” *BMC Pregnancy and Childbirth* 21 (1): 198. https://doi.org/10.1186/s12884-021-03679-8

Knapp, L. G., and T. G. Seaks. 1998. “A Hausman Test for a Dummy Variable in Probit.” *Applied Economics Letters* 5 (5): 321–323. https://doi.org/10.1080/758524410

Koch, S. F. 2012. “The Abolition of User Fees and the Demand for Health Care: Re-Evaluating the Impact.” Working Papers 30, *Economic Research Southern Africa*.

Lan, C. W., and P. Tavrow. 2017. “Composite Measures of Women’s Empowerment and Their Association with Maternal Mortality in Low-Income Countries.” *BMC Pregnancy and Childbirth* 17 (Suppl. 2): 337. https://doi.org/10.1186/s12884-017-1492-4

Makonese, T., A. P. Ifegbesan, and I. T. Rampedi. 2017. “Household Cooking Fuel Use Patterns and Determinants across Southern Africa : Evidence from the Demographic and Health Survey Data.” 29 (1): 29–48. https://doi.org/10.1177/0958305X17739475

Mandal, M., A. Muralidharan, and S. Pappa. 2017. “A Review of Measures of Women’s Empowerment and Related Gender Constructs in Family Planning and Maternal Health Program Evaluations in Low- and Middle-Income Countries.” *BMC Pregnancy and Childbirth* 17 (Suppl. 2): 342. https://doi.org/10.1186/s12884-017-1500-8

Mariko, M. 2003. “Quality of Care and the Demand for Health Services in Bamako, Mali: The Specific Roles of Structural, Process, and Outcome Components.” *Social Science and Medicine* 56 (6): 1183–96. https://doi.org/10.1016/S0277-9536(02)00117-X

Msuya, S. E, J. Adinan, and N. Mosha. 2014. *Intimate Partner Violence and Empowerment among Women in Tanzania: Prevalence and Effect on Utilization of Reproductive and Maternal Health Services*. DHS Working Paper No. 106. Rockville, MD, USA: ICF International. https://dhsprogram.com/pubs/pdf/WP106/WP106.pdf

Ndaimani, A., M. Mhlanga, and V. Dube-Mawerewere. 2018. *The Association between Women’s Empowerment and Uptake of Child Health Services: A Demographic and Health Survey-Based Synthesis.* DHS Working Paper, No. 139. Rockville, MD, USA: ICF. https://www.dhsprogram.com/publications/publication-wp139-working-papers.cfm

Nkoumou, N. and G. Brice. 2021. “Gratuité Des Soins Et Utilisation Des Services De Santé Maternelle – Une Analyse D’impact Au Sénégal.” *L’Actualité Économique* 96 (2): 159–193. https://doi.org/10.7202/1076510ar

Odilon, B., and K. Lokonon. 2020. “Household Cooking Fuel Choice : Evidence from the Republic of Benin.” *African Development Review* 32 (4): 686–698. https://doi.org/10.1111/1467-8268.12471

Odo, D. B., I. A. Yang, D. Green, and L. D. Knibbs. 2021. “Women’s Empowerment and Household Fuel Use in 31 African Countries: A Cross-Sectional Analysis of Households in the Demographic and Health Survey.” *Environmental Research Letters* 16 (2021): 025012. https://doi.org/10.1088/1748-9326/abdd59

Osamor, P. E., and C. Grady. 2016. “Women’s Autonomy in Health Care Decision-Making in Developing Countries: A Synthesis of the Literature.” *International Journal of Women’s Health* 8: 191–202. https://doi.org/10.2147/IJWH.S105483

Pandey, S., G. Lama, and H. Lee. 2012. “Effect of Women’s Empowerment on Their Utilization of Health Services: A Case of Nepal.” *International Social Work* 55 (4): 554–573. https://doi.org/10.1177/0020872811408575

Polansky, J., and M. Laldjebaev. 2021. “Gendered Energy Relations at the Crossroads of Asia: Electrification, Empowerment, and Mixed Outcomes in Northeastern Afghanistan.” *Energy Research and Social Science* 73 (March 2021): 101928. https://doi.org/10.1016/j.erss.2021.101928

Rahman, R., M. Rahman, and S. E. Haque. 2021. “Empowerment Dimensions and Their Relationship with Continuum Care for Maternal Health in Bangladesh.” *Scientific Reports* 11 (1): 18760. https://doi.org/10.1038/s41598-021-98181-8

Sado, L., A. Spaho, and D. R. Hotchkiss. 2014. “The Influence of Women’s Empowerment on Maternal Health Care Utilization: Evidence from Albania.” *Social Science and Medicine* 114: 169–177. https://doi.org/10.1016/j.socscimed.2014.05.047

Santana, I. R., A. Mason, N. Gutacker, P. Kasteridis, R. Santos, and N. Rice. 2021. “Need, Demand, Supply in Health Care: Working Definitions, and Their Implications for Defining Access.” *Health Economics, Policy and Law* 1–13. https://doi.org/10.1017/S1744133121000293

Schultz, T. P., and A. Tansel. 1997. “Wage and Labor Supply Effects of Illness in Côte d’Ivoire and Ghana: Instrumental Variable Estimates for Days Disabled.” *Journal of Development Economics* 53 (2): 251–286. https://doi.org/10.1016/S0304-3878(97)00025-4

Sebayang, S. K., F. Efendi, and E. Astutik. 2019. “Women’s Empowerment and the Use of Antenatal Care Services: Analysis of Demographic Health Surveys in Five Southeast Asian Countries.” *Women and Health* 59 (10): 1155–1171. https://doi.org/10.1080/03630242.2019.1593282

Sen, A. 1983. “Poor, Relatively Speaking.” *Oxford Economic Papers* 35 (2): 153–189. https://doi.org/10.1093/oxfordjournals.oep.a041587

Singh, K., I. S. Speizer, R. E. Ijdi, and L. M. Calhoun. 2021. “The Association of Empowerment Measures with Maternal, Child and Family Planning Outcomes in Plateau State Nigeria by Urban-Rural Residence.” *BMC Pregnancy and Childbirth* 21 (1): 170. https://doi.org/10.1186/s12884-021-03659-y

Smith, K. R., and A. Pillarisetti. 2017. “Household Air Pollution from Solid Cookfuels and Its Effects on Health.” In *Disease Control Priorities, Third Edition (Volume 7): Injury Prevention and Environmental Health*, 133–52, World Bank. https://doi.org/10.1596/978-1-4648-0522-6_ch7

Sohn, M., and M. Jung. 2020. “Effects of Empowerment and Media Use by Women of Childbearing Age on Maternal Health Care Utilization in Developing Countries of Southeast Asia.” *International Journal of Health Services* 50 (1): 32–43. https://doi.org/10.1177/0020731419867532

Tadesse, M., H. Teklie, G. Yazew, and T. Gebreselassie. 2013. “Women’s Empowerment as a Determinant of Contraceptive Use in Ethiopia. Further Analysis of the 2011 Ethiopia Demographic and Health Survey.” *DHS Further Analysis Reports* No. 82. Calverton, Maryland, USA: ICF International. https://dhsprogram.com/publications/publication-fa82-further-analysis.cfm

Upadhyay, U. D., and D. Karasek. 2012. “Women’s Empowerment and Ideal Family Size: An Examination of DHS Empowerment Measures in Sub-Saharan Africa.” *International Perspectives on Sexual and Reproductive Health* 38 (2): 78-89. https://doi.org/10.1363/3807812

Verma, A. P. and I. Imelda. 2019. “Clean Energy Access : Gender Disparity, Health, and Labor Supply.” UC3M Working Papers (Economics). Universidad Carlos III de Madrid, Departamento de Economía. http://hdl.handle.net/10016/29397

Wang, Y., X. Chen, and S. Ren. 2019. “Clean Energy Adoption and Maternal Health: Evidence from China.” *Energy Economics* 84 (October 2019): 104517. https://doi.org/10.1016/j.eneco.2019.104517

Wodon, Q., S. G. Banerjee, A. Diallo, and V. Foster. 2009. “Is Low Coverage Of Modern Infrastructure Services in African Cities Due to Lack of Demand or Lack of Supply?” *Policy Research Working Papers*, no 4881. World Bank. https://www.researchgate.net/publication/228304408_Is_Low_Coverage_of_Modern_Infrastructure_Services_in_African_Cities_Due_to_Lack_of_Demand_or_Lack_of_Supply

Woldemicael, G. 2010. “Do Women with Higher Autonomy Seek More Maternal Health Care? Evidence from Eritrea and Ethiopia.” *Health Care for Women International* 31 (7): 599–620. https://doi.org/10.1080/07399331003599555

World Bank. 2021a. *Global Economic Prospects*. The World Bank. https://www.worldbank.org/en/publication/global-economic-prospects

World Bank. 2021b. “World Bank. 2021. World Bank Global Electrification Database.” https://databank.worldbank.org/source/world-development-indicators

Yaya, S. O., B. Zegeye, B. O. Ahinkorah, A. A. Seidu, E. K. Ameyaw, N. K. Adjei, and G. Shibre. 2021. “Predictors of Skilled Birth Attendance among Married Women in Cameroon: Further Analysis of 2018 Cameroon Demographic and Health Survey.” *Reproductive Health* 18 (1): 70. https://doi.org/10.1186/s12978-021-01124-9

Yaya, S., O. A. Uthman, M. Ekholuenetale, and G. Bishwajit. 2018. “Women Empowerment as an Enabling Factor of Contraceptive Use in Sub-Saharan Africa: A Multilevel Analysis of Cross-Sectional Surveys of 32 Countries.” *Reproductive Health* 15: 214. https://doi.org/10.1186/s12978-018-0658-5

APPENDICES

Appendix Table A1 Pairwise correlations: Modern energy equation

Variables	(1)	(2)	(3)	(4)	(5)
(1) Place of residence	1.000				
(2) Sex of household head	-0.013 (0.183)	1.000			
(3) Wealth quintile v190	-0.377 (0.000)	0.043 (0.000)	1.000		
(4) Household size	0.120 (0.000)	-0.153 (0.000)	-0.189 (0.000)	1.000	
(5) Husband/partner's education level	-0.247 (0.000)	0.067 (0.000)	0.488 (0.000)	-0.233 (0.000)	1.000

Appendix Table A2 Pairwise correlations: Women's empowerment

Variables	(1)	(2)	(3)
(1) Modern energy	1.000		
(2) Place of residence	-0.331 (0.000)	1.000	
(3) Sex of household head	-0.010 (0.310)	-0.013 (0.183)	1.000

Appendix Table A3 Pairwise correlations: Maternal health

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) Modern energy	1.000					
(2) Social independence	0.186 (0.000)	1.000				
(3) Place of residence	-0.331 (0.000)	-0.157 (0.000)	1.000			
(4) Sex of household head	-0.010 (0.310)	0.074 (0.000)	-0.013 (0.183)	1.000		
(5) Wealth quintile	0.671 (0.000)	0.270 (0.000)	-0.377 (0.000)	0.043 (0.000)	1.000	
(6) Covered by health insurance	0.114 (0.000)	0.082 (0.000)	-0.084 (0.000)	0.039 (0.000)	0.130 (0.000)	1.000

Appendix Table A4 Variance inflation factor: Maternal health

	VIF	1/VIF
Wealth quintile	1.945	0.517
Modern energy	1.798	0.556
Place of residence	1.181	0.847
Social independence	1.089	0.919
Covered by health insurance	1.024	0.977
Sex of household head	1.008	0.992
Mean VIF	1.339	NA