Environment and Development Economics (2024), **29**, 499–517
doi:10.1017/S1355770X24000226

RESEARCH ARTICLE

Adoption of clean energy cooking technologies in rural households: the role of women

Rossana Tornel-Vázquez,[1*] Eva Iglesias,[1,2] and Maria Loureiro[3]

[1]Department of Agricultural Economics, Statistics and Business, Universidad Politécnica de Madrid, Madrid, Spain; [2]Research Centre for the Management of Agricultural and Environmental Risks (CEIGRAM), Madrid, Spain and [3]Department of Economic Foundations, ECOBAS – University of Santiago de Compostela (USC), Santiago de Compostela, Spain
*Corresponding author: Rossana Tornel-Vázquez; Email: rossana.tornel.vazquez@alumnos.upm.es

(Submitted 12 February 2023; revised 19 February 2024; accepted 26 May 2024; first published online 28 October 2024)

Abstract
Ensuring energy access for rural households is crucial for global sustainable development. Technologies like liquefied petroleum gas, biogas, and efficient cookers are touted as solutions, yet their adoption remains limited despite their potential health, economic, and environmental benefits. We conducted a meta-analysis of 50 studies in developing countries, integrating contextual factors to explore gender and other determinants impacting rural energy transition. Our findings underscore socioeconomic status, social capital, environmental concerns, and gender dynamics as pivotal factors. Notably, women's involvement boosts adoption rates by 7.90 per cent, yet cultural barriers often sideline them from these processes. Thus, our recommendations stress addressing women's roles as energy technology users to foster inclusive energy transitions.

Keywords: clean energy; female empowerment; gender issues; social capital; technology adoption

JEL classification: J16; O13; O18; O31; O32; O33; O57

1. Introduction

Populations in developing countries, particularly in rural areas, heavily rely on biomass for cooking (Malla and Timilsina, 2014). The lack of access to clean cooking solutions results in significant social and environmental health costs. The negative impact is disproportionate in terms of health, education, employment, and welfare, with women and girls being the most affected, reinforcing gender stereotypes and poverty (Clean Cooking Alliance, 2023). This is largely because women and girls are primarily responsible for collecting solid fuels and performing related tasks (Ho *et al.*, 2021; UNFCCC, 2022). According to UN Women (2018), women and girls spend up to 18 h per week collecting fuel. The depletion of natural resources forces women and girls to walk longer distances in search of water or fuel for cooking, leading to increased time poverty (UNFCCC, 2022; Deininger *et al*., 2023).

In 2021, 2.3 billion people worldwide will remain without access to clean cooking, mainly in sub-Saharan Africa and Asia (IEA *et al*., 2023). The provision of clean energy for cooking is a key objective of the Sustainable Development Goals (SDGs), and specifically SDG 7, which aims to ensure 'access to affordable, reliable, sustainable, and modern energy for all' (United Nations Organization, 2015). Access, adoption and sustained use of clean cooking energy[1] could prevent indoor air pollution in millions of rural households, thus avoiding serious health effects such as respiratory diseases, cardiovascular diseases and cancer (World Health Organization, 2014). According to a WHO report, household air pollution caused 3.2 million deaths in 2020 (World Health Organization, n.d.).

Numerous international agencies, governments, and non-governmental organizations have developed programs to implement various technologies in rural areas. One prominent organization in clean cooking is the Clean Cooking Alliance (CCA), founded in 2010 to promote universal access to clean cookstoves. The CCA supports the development, sale, distribution, and consistent use of clean cooking solutions, mobilizing investments to create scalable businesses that offer affordable, high-quality products while protecting the environment. The ultimate goal is to improve population well-being.

However, as reflected in the literature, there is no standard for measuring the efficiency or scope of clean cooking technology implementation programs. Various indicators measure technology adoption and its determinants, resulting in diverse experiences even when implementing the same technology. This heterogeneity in adoption studies complicates the identification of common assessment elements.

Attempts to synthesize the literature on the adoption of clean energy for cooking are scarce. Furthermore, very few studies analyse the role of gender in promoting a successful and more sustainable energy transition. This study presents a meta-analytic review of the literature on the adoption of clean energy technologies for cooking, paying special attention to the role of gender issues in adoption, as it is one of the main activities carried out by women. Our work contributes to the existing literature by integrating contextual variables, which allows us to address the lack of information in the studies and enriches our analysis with a broader gender perspective.

A quantitative analysis was conducted on 50 scientific studies published between 2003 and 2022 in Africa, Asia, and Latin America. The study identified drivers and barriers that encourage the adoption of technology by rural households, taking into account the relationship between social capital and gender. Focusing on biogas, liquefied petroleum gas (LPG) and improved cookstoves (ICS) adoption, gender differences were found to play an important role in cleaner technology adoption. Similarly, factors such as the head of the household's age, household size, income, and environmental conditions affect the adoption of clean cooking stoves. In our analysis, variables such as education, region and study age (years since study) showed no significance.

[1] According to UNDP Climate (2022), 'clean cooking refers to sustainable fuels and modern cooking technologies that enable people to cook and heat their home in a way that is not harmful to their health and limits the immediate impacts on their environment'.

2. Background

In many parts of the world, firewood is freely available, and using it only generates the opportunity cost related to the effort of the people who collect it, but not a direct monetary cost to the household. Unfortunately, when resources are freely accessible, there is a tendency toward overexploitation and scarcity. This is the 'tragedy of the commons' coined by Garret Hardin (1968). In the case of firewood, overexploitation causes deforestation, meaning that it will become more expensive due to increasing scarcity. 'Where fuel is not free, the cost of firewood and charcoal can consume more than 30 per cent of a household's monthly income' (Lindgren, 2020: 1).

Subedi *et al.* (2014) establish a significant correlation between wood demand from forests and deforestation in Africa, particularly when countries with low GDPs are considered. They find that 70 per cent of deforestation in many African countries can be attributed to the demand for firewood and predict that, assuming current patterns of energy use and expected population growth, deforestation may increase by 83 per cent by 2030. The adoption of biogas, ICS and LPG seeks to substitute or reduce firewood use and mitigate related problems, such as indoor pollution by wood smoke and deforestation.

2.1 Technology: drivers and barriers to adoption in rural households

For the purposes of this study, technology is defined as new means, knowledge, or artefacts that facilitate or improve current conditions to carry out a task or process. So, adopting technology refers to implementing new practices or knowledge in carrying out a specific activity and place. This work focuses on the adoption of clean energy technology to cook in rural households, particularly biogas, LPG and ICS.

Technology adoption is a complex process that spans many areas inside and outside the household. Adoption can include a trial stage, early/late adoption, partial adoption, and disadoption (Ruzzante *et al.*, 2021). Candidates to adopt must not only be familiar with it but also recognize the shortcomings of their current tools. They need to evaluate the new technology's attributes and be convinced of its superiority. Once the desire to adopt the technology is established, they may encounter barriers such as economic constraints, external factors, and other underlying issues that influence their decision to acquire the technology. Based on their experience, they will then decide whether to continue using it or abandon it.

An extensive set of reasons motivates the household to adopt new technologies. These reasons cover environmental, economic, technical, and social aspects (Kabir *et al.*, 2013). Most literature generally focuses on the first three aspects, leaving the social aspects somewhat aside. The inclusion of social capital and gender in the factors that influence technology adoption has rarely been addressed. Some related elements can be found in several studies, although not explicitly. Comparing the studies and accumulating the main findings regarding these topics is difficult.

In terms of socioeconomic aspects, there is a broad consensus that wealth and liquidity constraints are significant barriers to investment in developing countries, with direct implications for the adoption of technology in rural households (Karlan *et al.*, 2014). Rural households are supposed to be more willing to adopt the technology in the presence of loans, subsidies, or free technology delivery because improvements or positive changes are expected. In particular, 60 per cent of respondents in the work by Kabir *et al.* (2013) mentioned that a subsidy is a crucial reason for deciding to adopt a biogas plant.

Nevertheless, when financial barriers are removed for low-income households through grants, donations or funding models, adoption rates for ICS do not always

https://doi.org/10.1017/S1355770X24000226 Published online by Cambridge University Press

appear to increase (Lindgren, 2020). Many other factors act as a barrier to adoption, such as the learning effect of using new technology, opportunity cost, and information on how to cook, among others (Agurto Adrianzen, 2009; Puzzolo *et al.*, 2016; Troncoso *et al.*, 2019).

2.2 Gender

The opportunities to which women have access are often more limited: they must work harder to achieve the same conditions as men. This situation occurs worldwide, but women in developing countries, rural women, black women, and indigenous women have a double or triple burden. However, women are often the family's caretakers. They are in charge of childcare, food, education, and health and often have to support the household financially (Kisekka, 1986; Hart and Smith, 2013; UN Women, 2018; IEA *et al.*, 2020).

There is evidence that the inclusion of women in development processes increases the well-being of the general population. For example, Molinas (1998) finds that increasing the effective participation of women in local peasant organisations increases the performance of these organisations and increases the communities' prospects for alleviating poverty. However, this socio-cultural context surrounding gender issues is generally neglected in planning strategies for implementing new technologies. Studies of technological adoption in rural households are typically limited to differentiating the effect of the characteristics of the head of the household without delving into more detail on the constraints women face.

Ragasa (2012) conducts a review of empirical studies in various countries to identify the limitations and opportunities of the adoption and impact of technological innovations. Her analyses reveal significant methodological gaps related to gender that must be addressed to ensure the effective targeting of interventions.

Miller and Mobarak (2013) explore household decision-making dynamics in technology adoption, focusing on gender differences in preferences. Their results suggest that women's preferences and bargaining constraints within households inhibit technology adoption, despite awareness of health benefits. Troncoso *et al.* (2019) study LPG adoption in Chiapas, Mexico, and find that 30 per cent of women report the household head (typically the man) is who decides on the cooking energy source. These findings underscore the importance of analysing women's roles in household decision-making to develop effective technology adoption strategies.

2.3 Social capital

Social capital is understood as social networks, trust, and formal and informal rules that are shared to solve collective action problems (Ostrom and Ahn, 2003). Under certain circumstances, social capital can facilitate a higher degree of group innovation and adaptation (Fukuyama, 2000). Social capital is also helpful in addressing vulnerability by leveraging the shared lifestyle aspects of religion-based social networks, length of residence in the area, and neighbourhood norms, among other factors (Mguni *et al.*, 2020).

Some authors explore the role of social capital in the adoption of technology and sustainable practices. Alló *et al.* (2015) find that social factors such as social trust significantly influence farmers' decisions and encourage sustainable agricultural practices.

Satama and Iglesias (2020) highlight the critical role of local knowledge, social capital, and collective action in adopting sustainable agricultural practices in Ecuador. Van Rijn *et al.* (2012) present mixed evidence: structural social capital (connections beyond the village) is linked to broader innovation adoption, while cognitive social capital (shared norms and trust within the local community) can limit agricultural innovation by diverting time and resources. Finally, Nato *et al.* (2016) identify group participation and social support as key components of social capital that significantly influence the adoption of agricultural production technologies.

Social capital is intangible and, therefore, difficult to measure, although its effects can be observed. Some authors have identified various aspects of social capital and how it can be measured (see Liverpool-Tasie *et al.*, 2011: 32). Based on the previous literature, we considered proxies to measure social capital among the community's members.

2.4 Previous syntheses of adoption research

Previous efforts to synthesise the literature on the adoption of clean cooking technologies have explored a variety of factors that influence the uptake and use of these innovations. Lewis and Pattanayak (2012) examine the adoption of cleaner cooking technologies in Asian, African and Latin American countries. The study found a positive association between adoption and factors such as income, education, and urban location. However, variables such as fuel availability, prices, gender of household head and household size do not show a clear effect. They highlight the lack of consideration of important factors such as credit, supply chain strengthening and social marketing. On the other hand, van der Kroon *et al.* (2013) propose a conceptual framework for analysing household energy decisions and apply this in a meta-analysis exploring energy switching behaviour in urban and rural areas of developing countries. They highlight that the current literature focuses on socioeconomic characteristics, with little attention to the context of decisions and external factors such as access to capital, market conditions, and governmental aspects. The authors conclude that fuel switching is influenced by geographic location and climate, with urbanisation driving substitution. In rural areas, changes are slower, and the energy transition is best characterised by multiple fuel use. The work of Puzzolo *et al.* (2016) examine the factors that influence the adoption and sustained use of clean fuels in low- and middle-income countries in Africa, Asia, and Latin America. They find a wide range of elements that affect this process, such as household characteristics, knowledge, financial aspects, regulations, and specific characteristics of fuels and technologies. They highlight the limited evidence on solar fuels and insufficient understanding of gender roles in decision-making on clean cooking options.

Lindgren (2020) and Furszyfer Del Rio *et al.* (2020) highlight the importance of promoting behavioural change in adopting clean cookstoves. Lindgren emphasises the need to involve all household members in cookstove programmes, while Furszyfer Del Rio *et al.* (2020) identify shaping knowledge, rewards, threats, and social support as the most commonly used drivers. Both studies conclude that, in addition to the functionality of the technology, structural and regulatory aspects are critical to the sustained adoption of cookstoves. They suggest that the design of interventions should consider technical, financial, socio-environmental, and behavioural dimensions. On the other hand, Lindgren (2021) highlights the need to involve youth in cookstove implementation initiatives, pointing to collaboration with local educational institutions as an effective strategy to achieve greater adoption of efficient cooking technologies. He points out that waiting for cookstove users to become involved until they are adults is ineffective.

Gill-Wiehl *et al.* (2021*a*) focus on cooker performance and find that the most valued cooker characteristics are versatility, ease of use, perceived usefulness, social influence, durability, smokelessness, and cleanliness. They also highlight the importance of household dynamics and specific cooking needs in cooker choice and suggest that cooker programmes should offer a variety of models to meet the needs of all households. In another study, Gill-Wiehl *et al.* (2021*b*) discuss affordability as a barrier to the adoption of clean cookstoves and fuels in low-income households. The authors suggest that strategies aimed at improving affordability should consider gender gaps, rural-urban differences, and household spending and saving dynamics.

In summary, previous efforts to synthesise the literature show that studies focus mainly on the socioeconomic characteristics of households. Income, education, and residence in urban areas are identified as positively influencing the adoption of new technologies and fuels. However, it is highlighted that the existing information is limited concerning the context of decisions and the external environment of households.

Therefore, this article aims to contextualise the impact of gender gaps and other determinants that help to understand what facilitates or hinders the energy transition of rural households in developing countries. Despite the limitations imposed by the variables used in the analysed articles, we address the issue of gender and social capital through the information contained in each study and variables from external sources that enrich the analysis. This allows us to carry out a quantitative analysis of the literature in order to summarise the findings present in the literature in relation to the energy transition of rural households and gender.

3. Material and methods

The methodology used in this work is a meta-regression which consists of a quantitative analysis of a set of studies on a specific topic. According to Becker (2000: 499), meta-analysis is a term coined by Glass in 1976 to refer to 'analysis of analysis'. This research synthesis provides a way to examine results accumulated from a series of related studies through statistical analyses of those results.

Meta-regression analysis is a statistical technique used in meta-analysis, which involves synthesizing data from multiple studies to provide a comprehensive summary of research findings on a particular topic. By employing meta-regression analysis, we aim to identify key determinants and barriers to technology adoption, facilitating more informed decision-making and policy development in promoting technology uptake in developing regions. Our main hypothesis is that both social capital and gender influence the adoption of clean cooking technologies.

A crucial point in the meta-analysis lies in the systematic literature review and selection of primary studies to form the dataset. Following a rigorous review process, we compile a comprehensive dataset comprising studies that meet predetermined inclusion criteria. This dataset encompasses a range of research studies exploring factors influencing the adoption of clean cooking technologies in rural households, ensuring a diverse representation of findings across various contexts. Our research focuses on examining the adoption of biogas, LPG and ICS. Although our literature review encompassed other technologies, such as solar sources and ethanol, no studies meeting the inclusion criteria were identified for these alternatives.

With the dataset in place, we synthesized results of selected studies identifying relevant characteristics of the study, the characteristics of the potential beneficiaries, and program characteristics. We then fit a meta-regression approach to identify barriers and drivers and their effect on the adoption rate of clean cooking technologies in rural households of developing regions. Following Barrio and Loureiro (2010), we also include contextual variables of the region where the studies are conducted to complement the information contained within the selected studies. These variables have been used to account for the socio-cultural context where women's rights are embedded, which may affect the adoption process. The external variables in this study include the indicator of deaths attributable to household air pollution from the Social Progress Index (SPI),[2] the Social Institutions and Gender Index (SIGI)[3] from the Organization for Economic Co-operation and Development (OECD), and the forest area of each country from the World Bank database. From the latter source, we also extracted the 'Inflation, consumer prices (%)' and the official exchange rate (constant local currency (LCU) per US$) to standardise the currency in which each household's income is reported. These indices are available at the country level and have been used as contextual variables that may also have an impact on the adoption process.

3.1 Dataset construction, search strategy and inclusion criteria

Guidelines for literature search, empirical assessment, and reporting of the obtained results follow those by Stanley *et al.* (2013). An exhaustive literature search was conducted to compile studies investigating determinants or factors influencing the adoption of clean cooking technologies (biogas, LPG, ICS, solar energy, ethanol) in rural areas. The search was carried out through Web of Science, Scopus, Science Direct, and Google Scholar, using relevant keywords referring to clean cooking technology, adoption, gender, and social capital (see table 1). Studies published between the years 2000 and 2023 were considered. Although the introduction of biogas technology in rural households began in the 1970s, it was not until more recent decades that studies on the adoption of clean cooking technology emerged (Sesan, 2014; Afrane *et al.*, 2022). To avoid the risk of publication bias, no restrictions were set on the type of article, therefore, journals, working papers, and conference articles were included.

Following a comprehensive search using the keywords, 2,644 potential articles were identified. To manage this large repertoire of literature and ensure the integrity of the process, an approach based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (Page *et al.*, 2021) was followed (see figure 1).

During the screening phase, four inclusion and exclusion criteria were applied to identify relevant studies for analysis: (1) research should address specific technologies for food preparation, (2) studies should provide data on the adoption rate of the technology under analysis, or provide sufficient information to calculate this rate, (3) inclusion was restricted to studies focusing on rural areas, given the particular focus of this meta-analysis, and (4) The geographical scope was limited to certain regions, namely developing countries in Africa, Asia and Latin America. This was done to ensure

[2]For more information, see https://www.socialprogress.org/2024-social-progress-index/.

[3]The SIGI measures discrimination against women in social institutions across countries. Considering laws, social norms and practices that restrict women's and girls' rights and access to empowerment opportunities and resources, it captures underlying drivers of gender inequality. See https://www.oecd.org/stories/gender/social-norms-and-gender-discrimination/sigi/dashboard.

Table 1. Keywords and search string

Term type	Search term
Type of energy for cooking	'improved cookstoves' OR 'smokeless stoves' OR 'clean cook-stoves' 'biogas' OR 'Biogas cooking' OR 'Biodigester' 'LPG' OR 'Liquefied petroleum gas' 'solar cooking' OR 'solar cooker' OR 'solar stove' 'ethanol' OR 'ethanol for cooking' 'sustainable cooking solutions' OR 'clean cooking technologies'
AND	
Adoption	'adoption factors' OR 'technology adoption' OR 'adoption determinants' OR 'barriers to adoption' OR 'facilitators of adoption' OR 'adoption drivers' OR 'uptake'
AND	
Gender	'gender' OR 'women's participation' OR 'gender roles' OR 'woman and clean energy' OR 'gender and cooking technology'
AND	
Social Capital	'social capital' OR 'community networks' OR 'social connections' OR 'trust in community' OR 'community engagement' OR 'social cohesion'

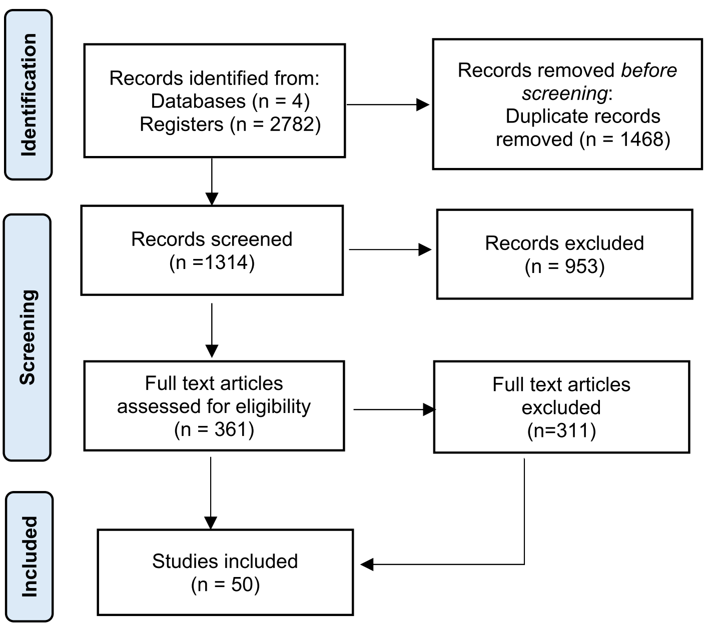

Figure 1. Study selection process through PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis).

https://doi.org/10.1017/S1355770X24000226 Published online by Cambridge University Press

comparability of findings within regions with similarly low levels of access to clean cooking energy. The United Nations classification of developing countries (United Nations, 2023) was used to identify countries with energy poverty, particularly in rural areas (World Health Organization, n.d.).

Based on the established criteria, a review was conducted on the titles and abstracts of 1,314 identified studies. A thorough analysis of the full text of 361 selected studies was then performed. The studies were included based on the following criteria: (i) the dependent variable must be the adoption of clean cooking technologies; (ii) excluded from the study were studies that focused on explaining health effects, technical aspects of the technology, literature reviews, or public policy analyses; (iii) adoption analysis should be conducted at the household level; and (iv) studies should provide at least information on age, household size, education level, and household income. If any of these four information criteria is missing, the study must provide the name of the study area so that the missing data can be obtained from national statistics or the UN database.

During the comprehensive review of the text, the main reasons for not including the studies were that they: (a) focused on urban areas, (b) were literature reviews, (c) focused on performance of the technologies, (d) were not available as full articles, (e) focused on willingness to pay, or (f) focused on health impacts. In the end, 54 studies were included in the bibliographic database for analysis. The search was conducted during October and November of the year 2023. The list of included articles can be seen in the online appendix, table A1.

4. Conceptual framework and empirical strategy

The conceptual framework of our analysis relies on random utility theory which postulates that individuals make choices that maximise their utility. Such utilities are a function of observable and non-observable characteristics. Hence, rational agents will aim to make decisions that carry the best possible outcomes when measured in terms of utility.

For the sake of simplicity, we will motivate the theoretical underpinnings of our model with the development of discrete choice models as the basic model for choice between two alternatives (adoption and non-adoption). We formulate this in a random utility framework with utility derived from two choices:

$$U_{i,1} = x_{i,1}\beta' + z_i' y + \varepsilon_{i,1}, \tag{1}$$

$$U_{i,0} = x_{i,0}'\beta + z_i' y + \varepsilon_{i,0}, \tag{2}$$

where 1 = adoption and 0 = non-adoption.

Utility is a function of characteristics (x_i) and attributes (z_i) while the random terms, $\varepsilon_{i,1}$ and $\varepsilon_{i,0}$ represent respectively unmeasured influences on utility. To take into account the fact that the analyst observes the individual's most preferred choice, that is, the one with the greatest utility, we can assume that choice 1 is the preferred choice. Thereby, the observed outcome reveals that

$$\begin{aligned} U_{i,1} > U_{i,0} \; or \; x_{i,1}'\beta + z_i' y + \varepsilon_{i,1} > x_{i,0}'\beta + z_i' y + \varepsilon_{i,0} \\ \text{or } (x_{i,1}'\beta - x_{i,0}'\beta) + (z_i' y - z_i' y) > (\varepsilon_{i,0} - \varepsilon_{i,1}). \end{aligned} \tag{3}$$

Given that the utility variable depicted in (1) is a non-observable variable, and based on the fact that researchers only observe behaviour, we model the probability of adoption

https://doi.org/10.1017/S1355770X24000226 Published online by Cambridge University Press

of the new technologies, assuming rational behaviour by the individuals. In other words, the derived utility from adopting the technology is greater than the utility derived from not adopting it.

The dependent variable in this meta-regression equation is the adoption rate, which is a continuous variable between 0 and 100, labelled as *Adoption*. The explanatory variables are grouped into six different categories: (1) economic variables, (2) sociodemographic variables, (3) environmental variables, (4) social capital variables, (5) gender variables, and (6) study characteristics. To facilitate the understanding of the variables included in each category and to be consistent with the classification, we have created subcategories, as suggested by Prokopy *et al.* (2008). Employing this theoretical background, our empirical strategy is as follows. The estimated regression corresponds to the following equation:

$$\begin{aligned} Adoption_i = \beta_0 &+ \beta_1\ Technology\ characteristics_i + \beta_2\ Socioeconomic\ variables_i \\ &+ \beta_3\ Environmental\ conditions_i + \beta_4\ Social\ captial_i + \beta_5\ Gender_i \\ &+ \beta_6\ Study\ characteristics_i + u_i, \end{aligned} \tag{4}$$

where β_0 is the constant term, βs are vectors that contain the coefficients associated with the explanatory variables in each category, and u_i is the disturbance error term that follows a normal distribution with mean 0 and variance σ^2. The baseline model applied is a robust ordinary least squares (OLS) regression. Given that the dependent variable is censored, we also propose using a fractional regression model to investigate the robustness of our results. Fractional response data may occur when the outcome of interest is measured as a fraction, like in this case, with values of 0–100.

5. Results

5.1 Description of included studies

A total of 50 studies met the inclusion criteria, with 53 observations recorded in total. The number of observations is higher than the number of studies since, in some documents, the adoption rate is reported for two different groups (i.e., two different communities). The average adoption rate is 52.71 per cent (24.88 standard deviations).

Out of the 53 observations, 30 were related to biogas, 12 to ICS, and 11 to LPG. The literature search also covered solar cookstoves or solar energy cookstoves, but no studies were found that met the inclusion criteria. The majority of studies on this technology have concentrated on the characteristics of stoves, rather than adoption rates, which is consistent with the limited evidence on solar fuels noted by Puzzolo *et al.* (2016). Half of the studies (27) were conducted in Asia, 22 in Africa, and 4 in Latin America. Regarding the type of adoption, 7 observations correspond to hypothetical adoption. These are exploratory studies where the adoption rate is the willingness to adopt the technology. The remaining 46 correspond to actual adoption, where households own a clean cooking technology. For a description of the variables used in the study, refer to table 2.

Table 3 provides a summary of the main elements included in the selected articles on gender and the transition to clean cooking energy. The majority of studies that incorporate gender in their analysis focused on adoption rates in households headed by women as compared to those headed by men. The importance of women's inclusion in decision-making on household fuel choice is recurrently mentioned, although very few studies elaborate on this.

Table 2. Statistical description of the selected studies

Category	Variable	Definition	N	Mean	SD
Dependent variable	Adoption	Percentage of adoption in each study	53	52.71	24.88
Technology characteristics	Biogas	1 if the technology is biogas; 0 otherwise	30		
	Improved cookstove	1 if the technology is Improved cookstove 0 otherwise	12		
	LPG	1 if the technology is LPG; 0 otherwise	11		
Socioeconomic	Africa	1 if the region is Africa; 0 otherwise	22		
	Asia	1 if the region is Asia; 0 otherwise	27		
	Latin America	1 if the region is L.A; 0 otherwise	4		
	Size	Average of inhabitants in the household	53	5.86	1.74
	Age	The average age of household head	53	44.53	4.86
	Education	Years of education of the household head	53	7.00	2.75
	Income	Average household income per year in USD 2018	53	1947.18	1,510.9
Social Capital	Execution	1 if the government participates in the execution of the project, 0 otherwise	53	0.47	0.50
	Information	1 if the beneficiaries receive complete information about the technology implementation, 0 otherwise.	53	0.50	0.51
Gender	SIGI[a]	Social Institutions and Gender Index which measures discrimination against women in social institutions.	53	30.12	13.68
	Woman enrollment	1 if the woman was interviewed or participated in workshops, 0 otherwise.	53	0.30	0.46
Environment	Air_poll[a]	Household air pollution attributable deaths (deaths/100,000)	53	53.52	23.12
	ForestArea[a]	Forest area as a proportion of total land area (%) from the World Bank	53	20.71	15.30
Study characteristics	Actual adoption	1 if is ex-post adoption, 0 if it is ex-ante hypothetical.	53	0.87	0.34
	Year	Year the study was published.	53	2017	3.92
	Study_age	Years since the study was conducted	53	9.64	4.22

[a]Information obtained from external sources. SD: standard deviation.

5.2 Model results

The Rstudio software was used to estimate the empirical models. The results of the robust linear regression analysis are presented in table 4 with six different model specifications. The models show a consistent fit as all six specifications have an adjusted coefficient of determination (adjusted R-squared) of 0.60–0.61. Model 1 is used as a reference for commenting on the results. Table A2 in the online appendix shows the results of the fractional logit model, which are consistent with the OLS regression model.

https://doi.org/10.1017/S1355770X24000226 Published online by Cambridge University Press

Table 3. Gender and the adoption of clean cooking technologies (CCT)

Topic	References	
Household head sex	Abbas *et al.* (2017), Kabir *et al.* (2013), Kelebe *et al.* (2017)	CCT are more likely to be adopted in female-headed households.
	Agurto Adrianzen (2009), Kulindwa *et al.* (2018)	Households with at least one adult female member are more likely to adopt the clean cooker.
	Kabyanga *et al.* (2018), Karanja and Gasparatos (2020), Zeng *et al.* (2019)	Female heads of households have a lower adoption rate of CCT. This is often associated with their lack of income, education, and information. It is important to note that this statement is based on objective evidence and not on subjective evaluations.
Decision making	Ahmad and Jabeen (2023), Gould and Urpelainen (2020), Mengistu *et al.* (2016), Miller and Mobarak (2013), Shallo *et al.* (2020), Walekhwa *et al.* (2009)	Decision-making within the household is predominantly controlled by men. These studies indicate that women's participation in the household decision-making process positively influences the adoption of CCT
Female education	El Tayeb Muneer and Mukhtar Mohamed (2003), Miller and Mobarak (2013), Pine *et al.* (2011)	Women's educational level positively influences levels of adoption of CCT, in addition to exposure to information about the technology.
Time burden	Ahmad and Jabeen (2023), Khanwilkar *et al.* (2021), Kulindwa *et al.* (2018), Troncoso *et al.* (2019)	The adoption of CCT has a positive impact on reducing the time spent collecting fuelwood or other solid fuels.

The results reveal significant relationships between predictor variables and the adoption of clean cooking technology. Notably, the type of adoption (actual) has a significant negative effect on clean technology adoption (the estimated coefficient is −44.82, $p < 0.001$), indicating that the willingness to adopt is higher than actual adoption. Although households may recognize the benefits of the technology, economic and other barriers often prevent them from acquiring it. Our findings highlight significant obstacles to actual adoption, and the subsequent discussion will explore the nature of these barriers.

5.2.1 Sociodemographic characteristics

Regarding the role of sociodemographic characteristics of the household, it was found that the *age* of the household head had a significant negative effect on the adoption of clean cooking technology (the coefficient estimate is −1.19, $p < 0.05$). This may be due to lower receptiveness to technological change or higher adherence to traditional cooking practices. The relationship between the age of the household head and the level of adoption is inverse, which is consistent with previous studies (Walekhwa *et al.*, 2009; Abbas *et al.*, 2017; Sarker *et al.*, 2020). However, the impact of age on adoption is not entirely clear, as some studies suggest the opposite (Qu *et al.*, 2013; Kelebe *et al.*, 2017; Yasmin and Grundmann, 2019). Kabyanga *et al.* (2018) found that the age structure has an inverse U-shaped effect on adoption, meaning that the likelihood of building a digester increases with the age of the head of the household, but decreases after the age of 45.

https://doi.org/10.1017/S1355770X24000226 Published online by Cambridge University Press

Table 4. Robust OLS regression

	Adoption					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Publishing	−0.55 (0.51)	−0.55 (0.53)	−0.52 (0.55)	−0.66 (0.53)	−0.53 (0.52)	−0.54 (0.53)
Type adoption (actual)	−44.82 (6.08)	−44.81 (5.90)	−44.39 (5.73)	−44.53 (6.08)	−44.74 (5.90)	−44.75 (6.29)
Log(Income)	9.04 (2.46)	8.95 (3.08)	9.65 (2.93)	8.70 (2.73)	9.19 (2.73)	8.85 (2.52)
Size	3.53 (1.73)	3.52 (1.68)	3.63 (1.80)	3.08 (2.13)	3.53 (1.77)	3.52 (1.81)
Age	−1.19 (0.55)	−1.19 (0.54)	−1.21 (0.52)	−1.14 (0.63)	−1.19 (0.55)	−1.20 (0.55)
Education	–	–	–	–	–	0.14 (0.91)
Information	15.93 (4.78)	15.91 (4.80)	16.14 (4.77)	14.92 (4.73)	16.02 (4.88)	15.83 (4.81)
Exc_government	–	–	–	−4.35 (5.38)	–	–
Woman enrollment	7.90 (4.09)	7.87 (3.98)	7.80 (4.04)	8.78 (4.36)	7.88 (3.96)	8.05 (4.17)
SIGI	−0.36 (0.19)	−0.36 (0.21)	−0.35 (0.20)	−0.36 (0.19)	−0.37 (0.21)	−0.37 (0.19)
Forest area	0.51 (0.20)	0.51 (0.20)	0.53 (0.19)	0.47 (0.20)	0.51 (0.20)	0.51 (0.20)
Air_poll	–	−0.01 (0.10)	–	–	–	–
Africa	–	–	2.50 (4.97)	–	–	–
LPG	–	–	–	–	0.80 (5.38)	–
Constant	53.04 (23.50)	53.88 (29.23)	46.24 (31.62)	59.56 (24.09)	51.79 (22.93)	54.02 (22.38)
Observations	53	53	53	53	53	53
R_2	0.68	0.68	0.68	0.68	0.68	0.68
Adjusted R^2	0.61	0.60	0.60	0.61	0.60	0.60
Residual Std. Error	14.73	15.26	15.18	14.24	15.21	14.67

Note: Standard errors are in parentheses.

Clean technology adoption is positively influenced by household size (the coefficient estimate is 3.53, $p < 0.05$), indicating that larger households are more inclined to adopt these technologies. This can be attributed to two main factors: (1) increased expenditure on cooking fuel in larger households makes fuel-saving technologies attractive, and (2) the presence of more household members facilitates the maintenance of biogas systems (Walekhwa *et al*., 2009; Kabyanga *et al*., 2018). This also reflects that with more

https://doi.org/10.1017/S1355770X24000226 Published online by Cambridge University Press

members there may be a greater capacity for investment or access to shared resources within the household. However, other studies show that the impact of household size on technology adoption may vary depending on the specific technology. For instance, Agurto Adrianzen (2009) found opposite results. This study assesses the adoption of ICS and finds that households with more adults are less likely to adopt due to the greater availability of labour for collecting firewood which results in a lower opportunity cost when using traditional fuelwood.

5.2.2 Economic variables

A significant positive association was found between *log (income)* and clean technology adoption (the coefficient estimate is 9.04, $p < 0.001$), suggesting that an increase in income is associated with a higher likelihood of adopting clean cooking technologies. Our findings align with previous studies, including those of Lewis and Pattanayak (2012), Puzzolo *et al.* (2016), and Gill-Wiehl *et al.* (2021*a*), which also identify income as a significant determinant. These studies suggest that income is even more crucial when it comes to technologies such as LPG or biogas. Although households have the willingness to spend a significant portion of their income, the initial investment may be considered excessive (Kabyanga *et al.*, 2018).

5.2.3 Environmental variables

The analysis demonstrated a significant positive effect of forest areas on the adoption of clean cooking technology (the coefficient estimate is 0.51, $p < 0.05$). This indicates that a higher proportion of forest area correlates with a greater likelihood of adopting new energy technologies. While abundant fuelwood may typically discourage the switch to clean technologies, this result may be due to heightened environmental awareness in these communities. Supporting this, Kabir *et al.* (2013) found that 62 per cent of respondents cited afforestation benefits as a motivation for adopting biogas. Similarly, Mengistu *et al.* (2016) and Shallo *et al.* (2020) reported a positive relationship between tree planting and clean technology adoption. In the studied Ethiopian area, planted trees are a vital income source for rural households, enhancing their financial capacity to install biogas systems.

5.2.4 Social capital

Social links and networks can provide benefits through extra-family and community connections. These connections can facilitate access to new means of communication, knowledge, and financing, increasing the possibility of households accessing these technologies (He *et al.*, 2022). Information can flow through different channels and will have different impacts depending on the characteristics of the population. In rural communities, word-of-mouth communication is often more accessible and influential in development programmes. Our analysis shows that the variable 'Information' has a significant positive effect on adoption (the estimated coefficient is 15.93, $p < 0.01$), indicating that access to relevant information promotes the adoption of clean technologies. Information should be disseminated through media that are compatible with those used in the community. According to Amir *et al.* (2019), the Dera Ismail Khan district in Pakistan disseminated project information effectively through village organizations. The intention was to reduce mistrust while providing accurate information. Recent studies, such as Rahman *et al.* (2021), suggest that the use of modern communication methods, such as the internet and mobile phones, promotes the widespread adoption of biogas, as well as knowledge and awareness of its uses.

5.2.5 Gender issues

In the adoption process, users and decision makers play crucial but distinct roles in the effective adoption of technology in the home. In the case of the technologies analysed here (biogas, ICS, and LPG), as they mainly serve as cooking fuel, both parties (users and decision-makers) must be aware of the economic, technical, and health benefits. These usage dynamics and decisions are crucial in guiding the project's implementation strategies.

The regression results indicate that the variable *woman enrolment*, which serves as a proxy for women's participation in adoption programmes, showed a significant trend (the coefficient estimate is 7.90, $p = 0.06$). This suggests that households involved in programs where women are interviewed or attend specific meetings to share their experiences with new technology are more likely to adopt clean technologies. El Tayeb Muneer and Mukhtar Mohamed (2003) find that the division of labour and gendered responsibilities in African societies were not fully recognised at the outset of clean energy dissemination programmes. As a result, training courses and outreach campaigns were mainly directed towards men. It was only after consulting with women and women's organisations that the programmes achieved better outcomes. However, women are frequently excluded from technology implementation processes, such as attending information meetings or training. This is often due to a lack of communication or the belief that their husbands will share the knowledge gained during the meetings with them. Additionally, women are sometimes not explicitly invited to participate. Moreover, the analysis revealed a significant negative effect of the SIGI on the adoption of clean technology (the coefficient estimate is -0.36, $p = 0.06$). This suggests that a higher degree of discrimination against women in social institutions is linked to a lower level of adoption of clean cooking technologies. This highlights the importance of addressing institutional and gender barriers by promoting inclusive policies and programmes that foster gender equality and empower women as agents of change in the energy transition.

6. Conclusions and implications

To advance the transition to clean cooking technologies in rural areas, we conducted a meta-analytic review of 50 studies meeting our inclusion criteria. Our research enriches the existing literature by incorporating contextual variables and offering a broader gender perspective, allowing for comparisons across diverse settings.

Our findings highlight significant barriers to adoption, including low participation of women in decision-making processes and social discrimination against women. Men often overlook the impacts of using solid fuels beyond the economic aspect. Despite the expectation that women, who are more adversely affected by traditional cooking methods, would adopt clean technologies at higher rates, the literature indicates no significant gender difference in adoption rates. In some cases, female-headed households show even lower adoption rates. To achieve SDG 7, it is crucial to consider factors such as access to education, purchasing power, unpaid work, and social dynamics that influence domestic energy decisions. By addressing these factors, we can develop effective strategies to overcome the barriers to clean technology adoption.

It is crucial to involve women in the adoption of new technologies, particularly in areas that directly impact them, such as the substitution of firewood. The effectiveness of technology adoption is dependent on the recognition of the central role of women as primary users. Therefore, it is essential to develop specific strategies that create opportunities for female participation in communities that have historically been restricted

https://doi.org/10.1017/S1355770X24000226 Published online by Cambridge University Press

for cultural reasons. Forming alliances with local women's groups and established organizations can facilitate the adaptation of implementation strategies to local practices and needs, thus promoting true inclusion of women. Furthermore, targeted grants and loans can empower women and reduce the gender gap, facilitating their participation in decision-making. In the context of SDG 5 (gender equality), it is crucial to ensure that women have a voice in the adoption of clean technologies, as this can improve household health and the economy, and contribute to environmental care. Significant change towards a more equitable and sustainable society can be promoted by involving women actively in the design, implementation, and evaluation of programs and policies related to domestic energy.

An important difference was found between hypothetical adoption and actual adoption. This gap provides evidence that despite the initial willingness to adopt new technology, there are important barriers that deserve special attention in the design of clean technology adoption programs.

As noted above, most studies focus on sociodemographic and economic characteristics and there is a limited number of studies analysing gender or social capital issues in technology adoption, which affects the scope of our sample. Despite the acknowledged significance of women's role in the adoption of clean cooking technologies, our analysis reveals a concerning gap in research inclusion, with only 30 per cent of the selected studies explicitly incorporating women. This discrepancy underscores the urgent need for greater gender-inclusive approaches in investigating and addressing clean cooking initiatives, ensuring that women's perspectives and contributions are fully recognized and integrated into the development and promotion of sustainable solutions. Efforts to bridge this divide are critical for fostering equitable advancements in clean cooking technology adoption and promoting socioeconomic empowerment among women worldwide.

Scaling up programs and future research should consider cultural and gender effects related to female empowerment in a more specific and detailed manner within their research agenda and action plan. It is important to acknowledge the Clean Cooking Alliance's efforts in developing a monitoring, evaluation, and learning framework that accelerates the transition to clean kitchens. Furthermore, when implementing new methodologies, such as randomized control trials, it is important to consider gender issues. This ensures reliable observational data and accurate identification of the role of gender. Otherwise, policy evaluation measures may be biased and adoption rates may be more limited than desired.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S1355770X24000226.

Competing interest. The authors declare no conflict of interest.

References

Abbas T, Ali G, Adil SA, Bashir MK and Kamran MA (2017) Economic analysis of biogas adoption technology by rural farmers: the case of Faisalabad District in Pakistan. *Renewable Energy* **107**, 431–439.

Afrane S, Ampah JD and Mensah EA (2022) Visualization and analysis of mapping knowledge domains for the global transition towards clean cooking: a bibliometric review of research output from 1990 to 2020. *Environmental Science and Pollution Research* **29**, 23041–23068.

Agurto Adrianzen M (2009) The role of social capital in the adoption of firewood efficient stoves in the Northern Peruvian Andes. MPRA Paper. University Library of Munich, Germany.

Ahmad M and Jabeen G (2023) Biogas technology adoption and household welfare perspectives for sustainable development. *Energy Policy* **181**, 113728.

Alló M, Loureiro ML and Iglesias E (2015) Farmers' preferences and social capital regarding agri-environmental schemes to protect birds. *Journal of Agricultural Economics* **66**, 672–689.

Amir SM, Liu Y, Shah AA, Khayyam U and Mahmood Z (2019) Empirical study on influencing factors of biogas technology adoption in Khyber Pakhtunkhwa, Pakistan. *Energy & Environment* **31**, 308–329.

Barrio M and Loureiro ML (2010) A meta-analysis of contingent valuation forest studies. *Ecological Economics* **69**, 1023–1030.

Becker BJ (2000) Multivariate meta-analysis. In Tinsley HEA and Brown SD (eds), *Handbook of Applied Multivariate Statistics and Mathematical Modeling*. San Diego: Academic Press, pp. 499–525.

Clean Cooking Alliance (2023) Gender and clean cooking. Available at https://cleancooking.org/wp-content/uploads/2023/07/Gender-and-Clean-Cooking.pdf

Deininger FH, Woodhouse AF, Kuriakose AT, Gren AI and Liaqat S (2023) Placing gender equality at the center of climate action (English). World Bank Group Gender Thematic Policy Notes Series. Washington, DC : World Bank Group.

El Tayeb Muneer S and Mukhtar Mohamed EW (2003) Adoption of biomass improved cookstoves in a patriarchal society: an example from Sudan. *Science of The Total Environment* **307**, 259–266.

Fukuyama F (2000) Social capital and civil Society. International Monetary Fund Working Paper WP/00/74.

Furszyfer Del Rio DD, Lambe F, Roe J, Matin N, Makuch KE and Osborne M (2020) Do we need better behaved cooks? Reviewing behavioural change strategies for improving the sustainability and effectiveness of cookstove programs. *Energy Research & Social Science* **70**, 101788.

Gill-Wiehl A, Ray I and Kammen D (2021*a*) Is clean cooking affordable? A review. *Renewable and Sustainable Energy Reviews* **151**, 111537.

Gill-Wiehl A, Price T and Kammen DM (2021*b*) What's in a stove? A review of the user preferences in improved stove designs. *Energy Research & Social Science* **81**, 102281.

Gould CF and Urpelainen J (2020) The gendered nature of liquefied petroleum gas stove adoption and use in rural India. *The Journal of Development Studies* **56**, 1309–1329.

Hardin G (1968) The tragedy of the commons. *Science (New York, N.Y.)* **162**, 1243–1248.

Hart C and Smith G (2013) *Scaling Adoption of Clean Cooking Solutions Through Women's Empowerment: A Resource Guide*. Washington, DC: Global Alliance for Clean Cookstoves.

He P, Lovo S and Veronesi M (2022) Social networks and renewable energy technology adoption: empirical evidence from biogas adoption in China. *Energy Economics* **106**, 105789.

Ho EW, Strohmeier-Breuning S, Rossanese M, Charron D, Pennise D and Graham JP (2021) Diverse health, gender and economic impacts from domestic transport of water and solid fuel: a systematic review. *International Journal of Environmental Research and Public Health* **18**, 10355.

IEA, IRENA, UNSD, World Bank, WHO (2020) *Tracking SDG7: The Energy Progress Report 2020*. Washington, DC: World Bank.

IEA, IRENA, UNSD, World Bank, WHO (2023) *Tracking SDG7: The Energy Progress Report 2023*. Washington, DC: World Bank.

Kabir H, Yegbemey RN and Bauer S (2013) Factors determinant of biogas adoption in Bangladesh. *Renewable and Sustainable Energy Reviews* **28**, 881–889.

Kabyanga M, Balana BB, Mugisha J, Walekhwa PN, Smith J and Glenk K (2018) Are smallholder farmers willing to pay for a flexible balloon biogas digester? Evidence from a case study in Uganda. *Energy for Sustainable Development* **43**, 123–129.

Karanja A and Gasparatos A (2020) Adoption of improved biomass stoves in Kenya: a transect-based approach in Kiambu and Muranga Counties. *Environmental Research Letters* **15**, 024020.

Karlan D, Osei R, Osei-Akoto I and Udry C (2014) Agricultural decisions after relaxing credit and risk constraints. *The Quarterly Journal of Economics* **129**, 597–652.

Kelebe HE, Ayimut KM, Berhe GH and Hintsa K (2017) Determinants for adoption decision of small scale biogas technology by rural households in Tigray, Ethiopia. *Energy Economics* **66**, 272–278.

Khanwilkar S, Gould CF, DeFries R, Habib B and Urpelainen J (2021) Firewood, forests, and fringe populations: exploring the inequitable socioeconomic dimensions of liquified petroleum gas (LPG) adoption in India. *Energy Research & Social Science* **75**, 102012.

Kisekka M (1986) El papel de la mujer en el desarrollo socioeconómico. El caso de Nigeria y de Uganda. *Estudios de Asia y Africa* **21**, 413–441 (in Spanish).

Kulindwa YJ, Lokina R and Ahlgren EO (2018) Driving forces for households' adoption of improved cooking stoves in rural Tanzania. *Energy Strategy Reviews* **20**, 102–112.

Lewis JJ and Pattanayak SK (2012) Who adopts improved fuels and cookstoves? A systematic review. *Environmental Health Perspectives* **120**, 637–645.

Lindgren SA (2020) Clean cooking for all? A critical review of behavior, stakeholder engagement, and adoption for the global diffusion of improved cookstoves. *Energy Research & Social Science* **68**, 101539.

Lindgren S (2021) Cookstove implementation and education for sustainable development: a review of the field and proposed research agenda. *Renewable and Sustainable Energy Reviews* **146**, 111184.

Liverpool-Tasie LS, Kuku O and Ajibola A (2011) A review of literature on agricultural productivity, social capital and food security in Nigeria. Nigeria Strategy Support Program (NSSP) working paper 21, International Food Policy Research Institute (IFPRI).

Malla S and Timilsina GR (2014) Household cooking fuel choice and adoption of improved cookstoves in developing countries: a review. Policy Research working paper, no. WPS 6903. Washington, DC: World Bank Group. Available at http://documents.worldbank.org/curated/en/542071468331032496/Household-cooking-fuel-choice-and-adoption-of-improved-cookstoves-in-developing-countries-a-review.

Mengistu MG, Simane B, Eshete G and Workneh TS (2016) Factors affecting households' decisions in biogas technology adoption, the case of Ofla and Mecha Districts, northern Ethiopia. *Renewable Energy* **93**, 215–227.

Mguni P, van Vliet B, Spaargaren G, Nakirya D, Osuret J, Isunju JB, Ssekamatte T and Mugambe R (2020) What could go wrong with cooking? Exploring vulnerability at the water, energy and food nexus in Kampala through a social practices lens. *Global Environmental Change* **63**, 102086.

Miller G and Mobarak AM (2013) Gender differences in preferences, intra-household externalities, and low demand for improved cookstoves. NBER Working Paper 18964. National Bureau of Economic Research, Cambridge, MA.

Molinas JR (1998) The impact of inequality, gender, external assistance and social capital on local-level cooperation. *World Development* **26**, 413–431.

Nato GN, Halimu Shauri HS and Kadere TT (2016) Influence of social capital on adoption of agricultural production technologies among beneficiaries of African institute for capacity development training programmes in Kenya. *International Journal of Social Sciences and Technology* **1**, 1–21.

Ostrom E and Ahn TK (2003) Una perspectiva del capital social desde las ciencias sociales: capital social y acción colectiva. *Revista Mexicana de Sociología* **65**, 155–233 (in Spanish).

Page MJ, Mckenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R, Glanville J, Grimshaw JM, Hróbjartsson A, Lalu MM, Li T, Loder EW, Mayo-Wilson E, McDonald S, McGuinness LA, Stewart LA, Thomas J, Tricco AC, Welch VA, Whiting P and Moher D (2021) The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* **372**, n71.

Pine K, Edwards R, Masera O, Schilmann A, Marrón-Mares A and Riojas-Rodríguez H (2011) Adoption and use of improved biomass stoves in rural Mexico. *Energy for Sustainable Development* **15**, 176–183.

Prokopy LS, Floress K, Klotthor-Weinkauf D and Baumgart-Getz A (2008) Determinants of agricultural best management practice adoption: evidence from the literature. *Journal of Soil and Water Conservation* **63**, 300–311.

Puzzolo E, Pope D, Stanistreet D, Rehfuess EA and Bruce NG (2016) Clean fuels for resource-poor settings: a systematic review of barriers and enablers to adoption and sustained use. *Environmental Research* **146**, 218–234.

Qu W, Tu Q and Bluemling B (2013) Which factors are effective for farmers' biogas use?–Evidence from a large-scale survey in China. *Energy Policy* **63**, 26–33.

Ragasa C (2012) Gender and institutional dimensions of agricultural technology adoption: a review of literature and synthesis of 35 case studies. 2012 Conference of International Association of Agricultural Economists, 18–24 August 2012, Foz Do Iguacu, Brazil.

Rahman MS, Majumder MK and Sujan MHK (2021) Adoption determinants of biogas and its impact on poverty in Bangladesh. *Energy Reports* **7**, 5026–5033.

Ruzzante S, Labarta R and Bilton A (2021) Adoption of agricultural technology in the developing world: a meta-analysis of the empirical literature. *World Development* **146**, 105599.

Sarker SA, Shouyang W, Adnan KMM and Sattar MN (2020) Economic feasibility and determinants of biogas technology adoption: evidence from Bangladesh. *Renewable and Sustainable Energy Reviews* **123**, 109766.

Satama M and Iglesias E (2020) Fuzzy cognitive map clustering to assess local knowledge of ecosystem conservation in Ecuador. *Sustainability* **12**, 2550.

Sesan T (2014) Global imperatives, local contingencies: an analysis of divergent priorities and dominant perspectives in stove development from the 1970s to date. *Progress in Development Studies* **14**, 3–20.

Shallo L, Ayele M and Sime G (2020) Determinants of biogas technology adoption in southern Ethiopia. *Energy, Sustainability and Society* **10**, 1.

Stanley T, Doucouliagos C, Giles M, Heckemeyer J, Johnston R, Laroche P, Nelson J, Paldam M, Poot J, Pugh G, Rosenberger RS and Rost K (2013) Meta-analysis of economics research reporting guidelines. *Journal of Economic Surveys* **27**, 390–394.

Subedi M, Matthews RB, Pogson M, Abegaz A, Balana BB, Oyesiku-Blakemore J and Smith J (2014) Can biogas digesters help to reduce deforestation in Africa? *Biomass and Bioenergy* **70**, 87–98.

Troncoso K, Segurado P, Aguilar M and Soares da Silva A (2019) Adoption of LPG for cooking in two rural communities of Chiapas, Mexico. *Energy Policy* **133**, 110925.

UNDP Climate (2022) 5 things to know about clean cooking. Available at https://undp-climate.exposure.co/5-things-to-know-about-clean-cooking

UNFCCC (2022) Dimensions and examples of the gender differentiated impacts of climate change, the role of women as agents of change and opportunities for women. Synthesis Report by the Secretariat. Bonn Climate Change Conference, June 2022. Available at https://unfccc.int/sites/default/files/resource/sbi2022_07.pdf

United Nations (2023) *World Economic Situation and Prospects 2023*. New York: United Nations, DESA Publications.

United Nations Organization (2015) Energy. United Nations Sustainable Development; United Nations: Sustainable Development Goals. Available at https://www.un.org/sustainabledevelopment/energy/

UN Women (2018) *Turning Promises Into Action: Gender Equality in the 2030 Agenda for Sustainable Development*. UN Women.

van der Kroon B, Brouwer R and van Beukering PJH (2013) The energy ladder: theoretical myth or empirical truth? Results from a meta-analysis. *Renewable and Sustainable Energy Reviews* **20**, 504–513.

van Rijn F, Bulte E and Adekunle A (2012) Social capital and agricultural innovation in Sub-Saharan Africa. *Agricultural Systems* **108**, 112–122.

Walekhwa PN, Mugisha J and Drake L (2009) Biogas energy from family-sized digesters in Uganda: critical factors and policy implications. *Energy Policy* **37**, 2754–2762.

World Health Organization (2014) *WHO Guidelines for Indoor Air Quality: Household Fuel Combustion*. Available at https://www.who.int/publications/i/item/9789241548885

World Health Organization (n.d.) The Global Health Observatory. Available at https://www.who.int/data/gho/data/indicators/indicator-details/GHO/household-air-pollution-attributable-deaths

Yasmin N and Grundmann P (2019) Adoption and diffusion of renewable energy – the case of biogas as alternative fuel for cooking in Pakistan. *Renewable and Sustainable Energy Reviews* **101**, 255–264.

Zeng Y, Zhang J and He K (2019) Effects of conformity tendencies on households' willingness to adopt energy utilization of crop straw: evidence from biogas in rural China. *Renewable Energy* **138**, 573–584.

Cite this article: Tornel-Vázquez R, Iglesias E, Loureiro M (2024). Adoption of clean energy cooking technologies in rural households: the role of women. *Environment and Development Economics* **29**, 499–517. https://doi.org/10.1017/S1355770X24000226