# Essays on household energy poverty, energy transition, and women bargaining power in South Africa

By

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# Declaration

I declare that this thesis, which I hereby submit for the degree of PhD in Economics at the University of The Witwatersrand, is entirely my work and has not been submitted anywhere else for the award of a degree or otherwise.

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2025

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# Dedication

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# Abstract

This thesis examined the shift of South African homes to various energy sources, emphasizing the relationship between income levels, women's roles in decision-making, social grants, and energy selection. Herein, data from the National Income Dynamics Study (2008–2017) were examined to elucidate the impacts of socioeconomic factors on clean energy uptake and the transition from conventional fuels.

The initial study examined the influence of income levels on sustainable energy adoption using a dynamic panel threshold model, considering the notable disparities between urban and rural households. In urban homes, electricity expenditure markedly rises when income exceeds R417 ($22) per month. Conversely, there is no effect for rural households electricity expenditure above the threshold of R372 ($20) per month. Herein, numerous households found it challenging to purchase clean energy, suggesting that their resources are frequently allocated to other vital necessities.

The second study used multinomial logit analysis to investigate the impacts of women's decision-making authority on energy choices. It determined that enhanced bargaining power elevated the probability of selecting electricity for cooking by 6.8% and heating by 4.6%, relative to conventional fuels. In addition, no significant impacts were observed for lighting preferences. Moreover, a negative link exists between women's negotiating power and the utilization of gas and paraffin stoves, suggesting a preference for electric alternatives.

The third study evaluated the effects of the old-age pension on energy poverty using a regression discontinuity approach. Pension eligibility decreases energy poverty by

approximately four percentage points, with varying impacts according to location. Urban regions experienced a considerable decline of 10 percentage points, whereas the rural areas demonstrated no substantial variations, which were determined via multiple statistical techniques.

This research substantially improves our understanding of household energy transitions and provide essential academic and policy discourse insights. Moreover, it elucidates that income intricately and context-specifically affects energy decisions, accentuates women's negotiating power in clean energy adoption, and indicates that social grants can significantly alleviate energy poverty. The results highlight the necessity for customized energy policies that account for urban-rural disparities, enhance women's decision-making authority, and utilize social transfers in conjunction with infrastructure advancements, stressing the significance of geographic and demographic elements in formulating effective energy transition strategies for developing nations.

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## List Of Abbreviations

| | |
|---|---|
| ATE | Average Treatment Effect |
| DOE | Department of Energy |
| FBE | Free Basic Electricity |
| GMM | General Method of Moments |
| IEA | International Energy Agency |
| LPG | Liquefied Petroleum Gas |
| MEPI | Multidimensional Energy Poverty Index |
| NIDS | National Income Dynamics Study |
| OAP | Old-Age Pensions |
| RDD | Regression Discontinuity Design |
| RUT | Random Utility Theory |
| SDG | Sustainable Development Goals |

# Chapter 1 : Extended Introduction

## 1.1. Background

Energy access is central to socioeconomic development, serving as a foundation for improving health outcomes, education, and economic productivity. In addition, achieving the United Nations' Sustainable Development Goals (SDGs), particularly SDG 7, is critical to ensure universal access to affordable, reliable, and sustainable energy by 2030. However, significant disparities in energy access globally persist. In Sub-Saharan Africa, over 560 million people lack electricity. Moreover, approximately three billion people globally still rely on traditional biomass fuels, such as wood, charcoal, and dung, for cooking and heating (IEA, 2021). These reliance patterns highlight the persistence of energy poverty, a multifaceted issue encompassing the affordability, reliability, and sustainability of energy services.

South Africa is a compelling case study for exploring energy poverty. Since 1994, the country has achieved significant progress in expanding access to electricity, with over 90% of households now connected to the national grid (Statistics South Africa (Stats SA), 2023). Policies such as Free Basic Electricity (FBE), which provides 50 kWh of electricity per month at no cost to low-income households, have played a pivotal role in improving access for marginalized communities. However, the challenges associated with energy poverty remain pervasive. Many households, particularly in rural areas, still rely on firewood and traditional biomass fuels for cooking and heating owing to the high cost of electricity, unreliable supply caused by frequent load shedding, and entrenched cultural practices. For instance, in Limpopo and Mpumalanga provinces, fuelwood use accounted for 31 and 18 percent respectively in 2023. This dual reliance on traditional and modern energy sources, referred to as energy stacking, underscores the nuanced nature of energy poverty in South Africa (Bohlmann and Inglesi-Lotz, 2018; Stats SA, 2023).

The consequences of energy poverty are far reaching and multidimensional. Reliance on traditional fuels results in environmental degradation, deforestation, and increased carbon emissions, exacerbating global climate challenges. In addition, health impacts are severe; indoor air pollution owing to burning solid fuels is the leading cause of respiratory illnesses, cardiovascular diseases, and premature deaths, disproportionately affecting women and children (World Health Organization, 2024). Beyond these immediate impacts, energy poverty perpetuates socioeconomic inequalities by limiting educational opportunities, curtailing economic productivity, and reinforcing gender disparities (Raman et al., 2025; Sanchez et al., 2020; Pueyo and Maestre, 2019).

### 1.2. Research Problems

The relationship between income and energy transitions has long been a subject of academic and policy interest. Herein, the energy ladder hypothesis provides a widely used framework to understand these transitions, positing a linear progression in which households transition from traditional to modern energy sources as their income increased. According to this model, traditional fuels, such as wood and charcoal, occupy the lowest rung of the ladder, followed by transitional fuels such as kerosene. Finally, modern energy sources, such as electricity and gas, occupy the highest rung. However, empirical evidence increasingly challenges the validity of this framework. Many households, particularly those in low- and middle-income contexts, do not entirely abandon traditional fuels as their incomes increased. Instead, they adopted a combination of energy sources, a behavior termed energy stacking (Tinta, 2024). This phenomenon highlights the limitations of the energy ladder hypothesis and underscores the need for more nuanced frameworks that account for nonlinear dynamics and contextual variations.

Income alone does not determine the energy transition of households. A range of socioeconomic, cultural, and institutional factors influence energy decisions, often interacting in complex ways. One critical but underexplored factor is intrahousehold bargaining power. Women, who are typically the primary users of household energy, often lack the decision-making authority owing to entrenched gender norms and inequalities. This exclusion diminishes their ability to advocate for adopting clean energy, thereby perpetuating energy poverty and reinforcing broader gender disparities (Clancy et al., 2019). Although some studies emphasize the role of women's empowerment in promoting sustainable energy use, they often rely on proxies, such as education or income, which fail to capture the complexity of bargaining dynamics within households.

The role of elderly individuals reliant on fixed incomes, such as old-age pensions (OAPs), adds another layer of complexity. In South Africa, social grants such as OAP are a significant source of stipend for low-income households; however, their impact on energy transitions remains underexplored. Existing studies have primarily focused on the welfare impacts of these grants without examining their potential to alleviate energy poverty or promote clean energy adoption (Lloyd-Sherlock et al., 2012). This gap is particularly relevant in rural areas, where traditional fuel use persists despite access to additional income sources. These limitations in existing frameworks and research underscore the need for integrated analyses that account for income thresholds, intrahousehold dynamics, and the role of social transfers in shaping energy transitions.

## 1.3. Research Questions

This study aimed to address three interconnected research questions to broaden the understanding of household energy transitions in South Africa:

1. At what income threshold do households transition to clean energy sources, and how do these thresholds differ across urban and rural contexts?
2. How does women's bargaining power influence the adoption of clean energy within households, particularly in relation to cultural and socioeconomic factors?
3. What is the causal impact of OAPs on energy poverty, and how does this impact vary between urban and rural households?

## 1.4. Motivation and Literature Gap

Although the literature on household energy transitions has made substantial contributions to our understanding of the energy use determinants, significant gaps remain. Studies such as those by Li et al. (2020) and Chen et al. (2022) highlighted the importance of income thresholds to determine energy transitions, indicating a nonlinear relationship between income and energy consumption. However, these studies often generalize findings across diverse socioeconomic and geographic contexts, failing to account for the acute challenges faced by households in South Africa. Unlike other developing countries, South Africa's energy poverty stemmed from an engineered apartheid regime that isolated some population groups, excluding them from receiving basic services like electricity. The grid infrastructure has since relatively advanced, addressing access issues by electrifying over 90% households. However, people still use alternative fuels because of the unstable electricity supply, perpetuating energy poverty. Moreover, the cost of electricity has risen because of the additional capacity required to electrify the rest of the population (Essex and Groot, 2019). In a nutshell, factors such as frequent load shedding, high energy cost, limited rural electrification, and cultural reliance on traditional fuels distinguish the South African context from other developing countries and necessitate localized analyses.

Intrahousehold dynamics, particularly bargaining power, have been identified as key determinants of household energy decisions in gender-focused studies. These studies underscore the centrality of women in driving clean energy adoption given their role as primary users of household energy. However, existing analyses often rely on limited proxies, such as women's education or income, which inadequately capture the multidimensional nature of bargaining power. This oversight is especially pronounced in patriarchal societies, where women's decision-making authority is often constrained by sociocultural norms. Therefore, by developing a comprehensive bargaining power index, this study aimed to address these limitations and provide a more nuanced understanding of how gendered dynamics influence energy transitions.

Social transfers, such as OAP, are critical but underexplored areas in energy poverty research. Although cash transfers are widely acknowledged as effective tools for poverty alleviation, their specific impacts on household energy behaviors remain ambiguous. Existing research, such as that of Lloyd-Sherlock et al. (2012), focused on the broad welfare impacts of pensions without examining their role in facilitating transitions to modern energy sources. This oversight is particularly significant in South Africa, where social grants constitute a substantial share of income for many low-income households. Studies like Gelo et al., (2023) investigated the OAP on energy transitions in South Africa. We contribute to the literature by building on Gelo et al., (2023)'s study, focusing on energy poverty instead, using the multimenstional energy poverty index to assess OAP's impact on reducing energy poverty. Moreover, we also assess this impact on the urban and rural household in isolation, which was not done in the Gelo et al.,

(2023) study. The need to investigate social grants impact on energy poverty reduction is necessary, since social grants are an important source of income for many households. Previous studies have shown their positive impact on household nutrition and childrens education outcomes (Ko, 2019); adding the energy transitions layer will provide a comprehensive impact that social grants has on households. By integrating income thresholds, intrahousehold bargaining power, and social transfer effects into a unified framework, this study aimed to address these critical gaps and provide academically and policy-relevant insights.

### 1.5. Data Description

This study utilized data from the National Income Dynamics Study (NIDS), South Africa's nationally representative longitudinal survey. NIDS provides a rich panel dataset spanning five waves (2008–2017), offering detailed information on household demographics, income sources, energy usage patterns, and access to social grants, such as OAP. The dataset captures urban and rural households across South Africa's nine provinces, prompting a robust analysis of geographic and socioeconomic disparities.

The dataset is not without shortcomings; it excludes energy-specific household decision-making questions that are required to construct the bargaining power index. However, we used all five household decision-making questions available in the survey, such as the purchasing of household appliances (e.g., electricity appliances) to capture women's bargaining power. Moreover, household energy price data were lacking in the survey; therefore, we used the energy expenditure data instead to analyze energy poverty.

The sampling strategy for NIDS follows a stratified, multistage cluster design to ensure national representativeness. Each wave includes approximately 28,000 individuals, tracked over time to provide insights into changes in income, energy behavior, and household dynamics. The longitudinal nature of the dataset utilized advanced econometric techniques, such as dynamic panel threshold models to examine income effects, multinomial logit regressions to analyze energy choices, and regression discontinuity designs (RDD) to evaluate the impact of OAP on energy poverty.

### 1.6. Summary of the Findings

This study produced several important findings. First, it identified income thresholds for clean energy adoption, with higher thresholds observed in urban areas than in rural ones. This discrepancy reflects the influence of better infrastructure and higher average incomes in urban settings, facilitating transitions to modern energy sources. In rural areas, cultural norms, affordability constraints, and unreliable electricity supply contribute to the continued reliance on traditional fuels, even as incomes increased.

Second, the findings indicate the critical role of women's bargaining power in influencing household energy decisions. Households wherein women have great decision-making authority are more likely to adopt clean energy technologies, emphasizing the importance of addressing structural gender inequalities to promote sustainable energy transitions. Finally, the analysis indicates that OAP reduced energy poverty by increasing household expenditure on modern energy. However, the effects are more pronounced in urban than in rural households because the infrastructures promote better utilization of additional income.

### 1.7. Contribution to the Literature

This research contributes to the literature by challenging the linear assumptions of the energy ladder hypothesis. This demonstrates that nonlinear and regime-specific dynamics shape energy transitions and that they are influenced by socioeconomic, geographic, and cultural factors. By identifying income thresholds for clean energy adoption, this study provides a more nuanced understanding of household energy behaviors of developing countries.

Developing a comprehensive bargaining power index is a methodological innovation, offering a robust framework for analyzing how gendered power dynamics influence energy transitions. Several previous studies used qualitative approaches to measure women empowerment or bargaining power. In South Africa, Listo (2020) used a feminist methodological approach looking at the role of energy in women's empowerment. Ngarava et al. (2022) analysed the gender aspect of energy poverty in South Africa. Outside South Africa, Chandrasekaran et al., (2023) quantitatively measured empowerment using principal component analysis (PCA). They used various socioeconomic indicators in the compilation of the empowerment index that are not specifically related to household decision making. We contribute to the literature by extending the previous PCA methodology, using intrahousehold decision making questions in our index to elicit women bargaining power. This approach moves beyond traditional proxies, capturing the multidimensional nature of bargaining power in patriarchal societies. In addition, the analysis of the impacts of OAPs on energy poverty fills a critical gap in the literature, providing insights into how social transfers can alleviate financial barriers to clean energy adoption.

### 1.8. Structure of the Thesis

The remainder of this thesis is organized into four chapters. Chapter 2 presents an investigation of the income thresholds for electricity consumption using a dynamic panel threshold model. The chapter provides insights into the nonlinear and regime-dependent effects of income on energy transitions, particularly emphasizing the disparities between urban and rural regions. This approach elucidates the impacts of money on energy decisions, contesting the perception that energy changes linearly occur. By identifying the precise income thresholds at which households modify their energy consumption behaviors, valuable insights that might guide focused policy initiatives can be garnered. Chapter 3 discusses the role of women's bargaining power in household energy decisions, employing a multinomial logit model to analyze fuel choices and adoption of clean energy. Chapter 4 presents the causal impacts of OAPs on energy poverty using an RDD, focusing on urban–rural disparities. Chapter 5 synthesizes the findings, discusses their policy implications, and outlines directions for future research.

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# Chapter 2 :Threshold Effects of Income on Household Energy Transitions: Evidence from South Africa

**Abstract**

This study investigated the relationship between per capita income and household electricity expenditures in South Africa by employing a dynamic panel threshold model that allows for asymmetric effects depending on whether income is above or below a threshold. The findings indicate distinct regime-specific effects. For urban households, electricity expenditure significantly increases when per capita income exceeds the estimated threshold of R417 ($22) per month. This is consistent with the origin of the energy ladder hypothesis, while taking into account energy stacking behavious from the energy stacking theory, which is more relevant in developing countries. By contrast, there is no effect for rural households electricity expenditure above the threshold of R372 ($20) per month. Our results indicate the nuanced and asymmetric influence of income on household energy behavior. Policy implications emphasize the need for targeted interventions: below-threshold households require enhanced subsidies and infrastructure improvements to promote clean energy adoption, whereas above-threshold households, particularly in rural areas, would benefit from incentives to overcome persistent barriers to electricity use. This study contributes to the literature by illustrating the importance of accounting for regime-specific effects when analyzing household energy transitions in developing countries.

**Keywords:** energy, income, threshold, transition, policy, dynamics

**JEL CODES:** Q42, Q41, Q48, R22, D12, 013

## 2.1. Introduction

Energy access is a cornerstone of modern life, playing a crucial role in socioeconomic development, improving the quality of life, and reducing inequalities. Despite its importance, billions of people globally lack the access to modern energy services. Over one billion people do not have electricity, and nearly three billion rely on traditional biomass fuels, such as wood, charcoal, and dung, for cooking and heating (Abbas et al., 2021). This reliance on solid fuels significantly contributes to deforestation, global carbon emissions, and environmental degradation. In addition, exposure to indoor air pollution caused by burning biomass is linked to respiratory illnesses and premature deaths, disproportionately affecting women and children in low-income households (Adane et al., 2021).

South Africa illustrates the global duality of progress and persistent challenges in energy transition. Electrification rates increased from 56% in 1994 to over 90% by 2023, mainly owing to government initiatives such as the FBE policy. This program provides low-income households with up to 50 kWh of free electricity per month to address energy poverty and promote social equity (Chidembo et al., 2022). However, these gains are tempered by ongoing issues, such as frequent load shedding, high electricity cost, and significant reliance on solid fuels, particularly in rural areas (van der Walt et al., 2024). In 2023, nearly 7.8% and 11% of South African households used wood for cooking and heating, respectively, despite having electricity access (Acheampong, 2023).

This duality highlights the complexities of achieving universal energy access. The interplay among affordability, reliability, cultural preferences, and infrastructural constraints underscores the importance of understanding the nuanced drivers of household energy transitions. Addressing these challenges requires examining the economic, social, and geographic factors that influence energy choices in diverse contexts.

Traditional theories of energy transitions, particularly the energy ladder hypothesis, have posited a linear progression in household energy use as incomes increased. This framework assumes that as households become wealthy, they shift from traditional fuels to modern energy sources such as electricity (Taghizadeh-Hesary et al., 2021). However, this theory often oversimplifies the complexities of energy transitions in developing countries. In South Africa, many households engage in “energy stacking,” simultaneously using multiple energy sources instead of entirely transitioning to modern energy. This behavior is influenced by various factors, such as affordability constraints, unreliability of electricity, and cultural attachment to traditional fuels (Choumert-Nkolo et al., 2019).

Moreover, the relationship between income and energy use is nonlinear, with specific income thresholds marking significant changes in energy behavior. Households below these thresholds often prioritize subsistence needs over energy consumption. Above the thresholds, increased income may promote shifts toward modern energy sources, although these shifts differ based on geographic and socioeconomic contexts. Existing studies (Paudel et al., 2023; Waleed and Mirza, 2023; Koch et al., 2024) have rarely addressed these nonlinearities or the asymmetric effects of income on energy transitions. In addition, the literature inadequately explores the heterogeneities between urban and rural households, leaving important questions about the structural and cultural factors that shape energy choices unanswered (Li et al., 2020). Moreover, the role of grant income, a significant source of livelihood for many low-income households in South Africa, is underexplored in the context of energy transition. In this chapter, we also look at all the sources of grant income available to households to assess their role in energy transitions. Contrary to Chapter 4, that only looks at old age pensions.

This chapter addressed two key questions: What is the income threshold at which South African households transition from traditional to modern energy sources, and how do these thresholds differ between urban and rural households? By examining these questions, this study seeks to uncover nonlinear and regime-dependent effects of income on energy transition and provide insights into the barriers to and facilitators of clean energy adoption.

This study was motivated by several critical gaps in the existing literature on household energy transitions. Although income is widely recognized as a key determinant of energy consumption, most studies assume a linear relationship. For instance, Kumar et al. (2023) and Zheng et al. (2024) documented a positive relationship between household income and energy expenditures in high-income and industrialized countries. However, studies like these rarely addressed the complexities of energy transition in low-income settings, wherein affordability, cultural norms, and infrastructure constraints shape energy use patterns.

Recent research has explored the effects of nonlinear income. Li et al. (2020) identified income thresholds in Chinese households, indicating that energy transitions occur only after a household surpasses specific income levels. These findings underscore the importance of examining threshold effects but lack relevance for African contexts, where structural and cultural factors play significant roles. South African households face complex challenges, such as unreliable electricity supply, high costs, and the availability of alternative fuels such as wood and paraffin, which influence energy decisions (Acheampong, 2023). These challenges also stem from the legacy of apartheid, where the electricity infrastructure was only available to a selected few (Essex & de Groot, 2019).

Energy stacking further complicates the narrative of energy transitions. As Grimsby et al., (2024) noted, households often diversify their energy portfolios to address the challenges of cost and reliability. This behavior is particularly evident in rural households, where traditional fuels are affordable and deeply ingrained in cultural practices (Elasu et al., 2023). By contrast, urban households benefit from better access to modern energy infrastructure but face higher costs and frequent outages, limiting their ability to fully transition to electricity.

Another significant gap lies in the understanding of the role of grant income. In South Africa, social transfers such as child support and OAPs constitute a substantial share of household earnings, particularly among low-income households. Although grant income can alleviate financial constraints, its impact on energy use remains unclear. In the grant analysis, we isolate grant incomes as reported in the survey, since grant recipient may also receive other income like wages and transfers. This enables discovering the specific grant impact on energy transitions. Existing studies have either overlooked grant income or failed to analyze its potential to drive clean energy adoption (van der Walt et al., 2024). Therefore, addressing this gap is crucial to understand how social protection programs influence household energy behavior.

This study filled these gaps by employing a dynamic panel threshold model to analyze income thresholds and their asymmetric effects on electricity expenditure. By disaggregating the results for urban and rural households and incorporating grant income into the analysis, this study provides a comprehensive understanding of household energy transitions in South Africa.

This study hypothesized that income has asymmetric effects on electricity expenditure, depending on whether households fall below or above a specific income threshold. Below the threshold, income has insubstantial impacts on electricity use owing to affordability constraints, reliance on traditional fuels, and restricted access to modern infrastructure. Above the threshold, hypothetically, income has substantial positive effects on electricity use, particularly in urban households with better infrastructure and more appliances. However, in rural households, persistent reliance on traditional fuels, cultural preferences, and limited electricity reliability may moderate the impacts of high income.

This research makes several contributions to related literature. First, it advanced the empirical understanding of energy transitions by modeling nonlinear income effects and identifying distinct income thresholds that mark significant shifts in energy behavior. Second, it provided a nuanced analysis of urban and rural households, highlighting the socioeconomic and geographic heterogeneities that influence energy transitions. Third, it incorporated grant income into the analysis, addressing a critical gap in understanding the role of social transfers in shaping energy behavior. Finally, the findings offer insights for policymakers, emphasizing the need for tailored interventions that address the specific challenges of urban and rural households.

The remainder of this chapter is organized as follows. The next section provides an overview of the South African household energy landscape, highlighting progress and persistent challenges in achieving universal energy access. The subsequent section briefly reviews the literature on income effects, energy stacking, and urban–rural disparities in the energy transition. The methodology section describes the dynamic panel threshold model and the data sources used for the analysis. The results section presents the key findings, such as the income thresholds for electricity expenditure and the urban–rural differences. This chapter concludes with a discussion and conclusions section that discusses policy implications, limitations, and directions for future research.

## 2.2. Study Context

### 2.2.1. The South African Household Energy Scene

At the start of 2000, South Africa embarked on an electrification program, providing electricity to households to achieve universal electricity access by 2025. However, this initiative was disrupted by the load shedding in 2008. While adding more customers to the national electricity grid, no new investments were made to accommodate the new customers, resulting in electricity shortages. Nonetheless, almost 16 million households were provided with electricity by 2017, taking electricity access from 56% in 1994 to 86% in 2017 (Bohlmann and Inglesi-Lotz, 2018). Even though Eskom[1] continued to battle with supply constraints even after 2020, considerable progress has been made in the electrification rates. According to Stats SA (2023), 90% of households are connected to the national grid.

Significant progress can be attributed to the policies drafted after the apartheid era in the 1990s. The guidelines aimed at universal electricity access and affordable energy for all households. On that basis, an FBE was introduced wherein poor households were eligible to get 50 kWh of free electricity to cater to the most basic electricity needs (Bohlmann and Inglesi-Lotz, 2018). However, notwithstanding the progress made with electrification and the provision of free electricity for people experiencing poverty, about 10% of households still does not have electricity. Therefore, they do not benefit from the FBE program. They most likely use solid fuels for their energy needs, harming their health.

[1]Eskom is a South African state-owned entity that supplies electricity.

Recently, wood has been the most preferred item for cooking among South African households (7.8%) owing to its abundance in some areas of the country. Rural areas often have solid fuels in abundance, the result of this may be increased reliance on solid fuels use given their availability and the fact that household may not even have to pay for them. These solid fuels are used as a shield owing to power outages and high electricity costs (Stats SA, 2023). Although some low-income households use wood out of necessity, Walt et al. (2024) found that other middle- and high-income households in South Africa burn wood for cooking and heating their fireplaces by choice, for comfort and ambiance. Using wood in the household is more detrimental than smoking indoors owing to its high wood particulate matter concentrations. In addition, Stats SA (2023) also stated candles as another preferred solid fuel option. The risks associated with burning candles for lighting in the house are eye problems and household fires, which can cause injuries (Abbas et al., 2021).

Although the load-shedding situation in South Africa has been alleviated as of 2024, concerns remain regarding the aging energy infrastructure. Old power stations may break down without notice and require regular maintenance. Often, power outages caused by aging infrastructure breakdowns are prolonged. This means that although excess power supply in 2024 brought back some confidence in the national energy producer of the country, households are not entirely off the hook from power outages. Moreover, slow progress with renewable energy transitions remains, which continues to make the country reliant on coal for power generation (90% of the electricity is from coal). However, it is important to note that electricity use for households is a step towards the right direction, e.i. moving away from traditional energy use, hence in the study we categorise electricity as clean, because it is not combusted at a household level, affecting household health. Unlike traditional solid fuels that are burnt in the household resulting to diseases.

### 2.2.2. Income Inequality and the Rise of the Middle-Income Households

Similar to the energy issue of many households not provided with electricity in the apartheid era before the 1990s, many South African households were excluded from participating in the economic activity of the country. The economic benefits were intended for the privileged few, thus increasing inequality. The new democratic government introduced changes in 1994 through various policies such as the Reconstruction and Development Programme; Growth, Employment, and Redistribution; Accelerated and Shared Growth Initiative for South Africa; and the National Development Plan, which were aimed at addressing pressing social issues and increasing economic growth (Mdingi and Ho, 2023). The previously excluded racial groups were allowed access to education and employment opportunities, which improved their lives and introduced them to the middle-income bracket. Even though the middle-income population has grown, inequality persists, especially among racial groups, such as Black South Africans, owing to high unemployment, sluggish growth, and other structural bottlenecks.

Conversely, governments in developing countries have long used social grants to help people experiencing poverty. For instance, the South African government uses social grants for social justice and to assist in alleviating poverty. Social grants were among the policies that addressed social inequalities in the post-Apartheid period. In addition, child grant is one of the most extensive social grant programs, with 13 million beneficiaries. Because poor people also have children, the child grant helps meet the children's needs. Some studies have demonstrated the positive impacts of the grants. According to Coetzee (2011), the positive effects were increased school attendance, improved nutrition, and better health outcomes. Moreover, several other grants in the quest to alleviate poverty were determined, making the grant social system one of the critical systems in the country. Stats SA (2023) stated that grants are the second income source of South African households. Grant recipients increased from 13% in 2003 to 31% in 2019. Therefore, considering social grants in energy studies in countries such as South Africa is crucial.

### 2.3. Brief Literature Review

The income threshold hypothesis is entrenched in consumer behavior theory, which posits that increased income encouraged consumer spending, in turn increasing economic growth and improving social welfare (Akarsu, 2021). This relationship has often been assumed to be linear; however, income threshold theory states that increases in income do not automatically translate to improvements in welfare. A threshold may exist where socioeconomic outcomes switch from a positive to a negative trajectory because of increased incomes, proving the potential presence of nonlinearities in different contexts. The income threshold effects hypothesis has been proven in different sectors and contexts, such as economic growth, inequality, health, and development (Mistry et al., 2004; Lin et al., 2014; Ibrahim et al., 2020; Zamora et., 2021; Yiadom et al. 2023).

Meanwhile, random utility theory (RUT) was utilized to determine income complexity and its relationship to socioeconomic outcomes. According to RUT, consumers spend on goods that maximize their utility against a set of choices presented to them (Cazor et al., 2024). Studies such as that of Ashraf (2024) have revealed threshold effects wherein increased income motivates consumers to spend on nonessential items, which do not improve welfare. Consumers' decisions from Ashraf (2024)'s study confirm the RUT hypothesis; the nonessential goods are chosen because they maximize consumers' utility.

In a world where consumers are faced with a myriad of choices, the RUT is an important concept to be considered. For instance, in our study, households had different energy choices to choose from. The choices may be influenced by income, preferences, or both. This may also be the reason households stack energy fuels instead of moving up the ladder when income increases, as stated by the energy ladder hypothesis. They may use modern energy fuels because they are connected to the grid and can afford them; however, modern fuels may not maximize their utility; hence, they resort to using a suite of energy fuels.

Nonetheless, income is essential for consumption, and it is the main driving force or determinant of household energy consumption (Zheng et al., 2024; Kitole et al., 2023; Li et al., 2020). In South Africa, Davis (1998) suggested that income had a vast potential to drive rural households to transition from solid fuels to electricity. The former statement is supported by Chidembo et al. (2022), who also showed that income was a barrier to solar PV rooftop adoption in South Africa. The same is true in Kenya; Baek et al. (2020) and Ang'u et al. (2023) stated that income is essential when adopting modern energy technologies because such technologies are costly. The likelihood of clean energy adoption increased by 19% in Kenya as income increased. In Nigeria, Shari et al. (2022) observed an increased adoption of clean energy sources as a result of increased incomes in rural households.

In an experiment in rural Tanzania, Kulindwa et al. (2018) further showed that cash flows determined the adoption of improved cookstoves. The authors suggested that improved cookstove intake will likely increase during harvest time when there is increased cash flow for households involved in agricultural activities. Similarly, to investigate the determinants of cookstoves and fuel choices in India, Menghwani et al. (2019) conducted a randomized controlled trial and found income to be the main factor determining cookstove choices. Owing to increased income, Ishengoma and Igangula (2021) found higher odds of households stacking with liquefied petroleum gas (LPG) as their energy fuel. Gould and Urpelainen (2020) had the same findings: Increased income can prompt households to use LPG for cooking. Other studies (Acheampong, 2022) have viewed income from the credit access channel, stating that access to credit increased income and improved clean energy adoption. This indicates that only a small amount of energy transition was observed without income.

According to Elasu et al. (2023), affordability significantly determines switching to clean energy sources. Moreover, the available budget determines the type of energy that the household chooses. This may mean that when the budget is more generous, the likelihood of selecting clean fuels is great. Kowsari and Zerriffi (2011) stated that when income increased and households have access to all essential energy services, some of the additional income can be used for clean energy fuels. In addition, Zheng et al. (2024) found that income is positively correlated with household energy consumption in China. They stated that on the energy efficiency front, buying energy-efficient appliances mainly depends on income. This is because energy-efficient appliances are affordable with increased revenue.

Umit et al. (2019) found a positive correlation between income and the likelihood of buying energy-efficient appliances in 22 European countries. Similarly, Kumar et al. (2023) found a positive correlation between income and energy efficiency in US households. In addition, Karlin et al. (2023) stated that an expectation that high-income households are likely to invest in more efficient appliances exists. Moreover, Auffhammer (2014) emphasized that not only income but also the shape of its distribution pushes households toward energy efficiency. However, a consensus must be reached on how energy efficiency changes as income increased.

Although a vast literature on income and its relationship to energy consumption at the macro and microlevels exists (Han et al., 2018; Ai et al., 2021; Shari et al., 2022; Chen et al., 2022), the relationship is inconsistent. Some macrostudies have found a positive relationship between income, energy transitions, and economic growth (Taghizadeh-Hesary et al., 2021; Shari et al., 2022; Menghwani et al., 2019). On the contrary, an inverted U-shaped relationship exists between income and energy consumption (Shabur and Ali, 2024; Feng et al., 2024). Similar to microstudies, the relationship is not straightforward. In some studies (Ma et al., 2019; Fentile et al., 2023; Ang'u et al., 2023), a positive relationship exists between income and energy transitions, which is supported by the energy ladder hypothesis. In other studies (Han et al., 2018; Ishengoma and Igangula, 2021; Ma et al., 2022), increased incomes result in energy stacking.

On a different note, Li et al. (2020) and Chen et al. (2022) found a threshold wherein the relationship between income and energy consumption changes in China. Li et al. (2020) investigated the income threshold on household appliance acquisition in an urban context. Chen et al. (2022) analyzed the income threshold as the rural household demand biomass to measure the relative energy poverty. We contribute to the literature by investigating the income threshold at which household electricity consumption increased in rural and urban contexts. Electricity is the most used energy source by South African households. Although the South African electricity is generated by coal, it is not combusted at the household level, affecting household health.

We approached this study through an expenditure lens. Chen et al. (2022) used consumption to measure the relative energy poverty line, and we used electricity expenditure in our analysis. These measures determine the effects of income on households. Using consumption may understate the results, especially in a country such as South Africa where some poor households receive a free 50 kWh of electricity from the government. Our analysis not only examined electricity but also other energy sources, providing a comprehensive picture of the income threshold effects of the whole population.

Moreover, because many South African households depend on social grants, we assessed the grant threshold at which households switch to electricity and other energy sources. Chakrabart and Handa (2021) studied the impacts of unconditional cash transfers on household energy choices in Malawi and Zambia. Their results indicate that cash transfers can prompt households to adjust their fuel use, thereby reducing solid fuel dependence. We are interested in determining whether South African cash transfers can affect household energy transitions.

## 2.4. Methodology

### 2.4.1. Econometric Model

We used a dynamic panel threshold model to investigate the income threshold at which households switch to clean energy use. A threshold model suits complex nonlinear relationships (Ochi et al., 2023). This occurs when the relationship between a dependent and an independent variable is inconsistent and changes because of different conditions, resulting in a specific threshold(s). A threshold model is relevant to our study because consumer choice and preferences changed as income changed. Moreover, household energy use may change as income changed, resulting in different thresholds.

The dynamic element of the model entails a lagged variable in the panel threshold model. This helps address the potential endogeneity in the model. Endogeneity can stem from simulteneity of income and electricity expenditure, where increased income influences electricty expenditure, while on the other side also decrease the expenditure of other essentials in the household especially if the cost of electricity keeps rising. Moreover, endegeneity may stem from unobserved preferences, the presence of the appliane index, and the biasness of self reported household incomes. The instrument is used to ensure the analysis is independent of previous other potential shocks. Furthermore, the lagged electricity expenditure also deals with human habits. Humans have long been associated with habits, i.e., previous habits can affect future habits. In household energy consumption studies, households may consume a similar quantity of electricity as they did in the past. The dynamic part of the model accounts for this. If previous consumption is not considered, the results may be biased. In addition, other unobserved factors that affect the consumption patterns may exist, which are addressed in the dynamic models.

We build on Kremer et al.'s (2013) model, which originates from Hansen's (1999) original static panel threshold model. The shortcomings of Hansen's model stem from the exogenous assumptions of the variables, that is, all explanatory variables must meet the exogenous hypothesis. Kremer et al. (2013) addressed this problem by considering the endogenous factors of the model and using instrumental variables to ease the exogeneity assumption. Our model is defined as follows:

$$y_{it} = \beta_1 x_{it} + u_i + \varepsilon_{it}\,(q_{it} \leq \gamma) \tag{2.1}$$

$$y_{it} = \beta_2 x_{it} + u_i + \varepsilon_{it}\,(q_{it} > \gamma)$$

Where $y_{it}$ is the explained variable that represents household energy expenditure in this case, $x_{it}$ is the vector of independent variables with $\beta_1$ and $\beta_2$ being the corresponding coefficient vectors, $q_{it}$ is the threshold variable, $\gamma$ is the endogenously estimated threshold value that enables splitting the equation into two-regime providing two coefficients. The threshold value is not an imposed but represents the actual estimated household expenditure behavior as stated by Seo & Shin (2016). and $\varepsilon_{it}$ is the error term. To account for endogeneity that may exist, we extend equation (2.1) to follow the general method of moments approach (GMM) by including instrumental variables as per Arellano and Bond (1991). The dynamic model then follows Wu et al., 2019 specification as stated below:

$$lny_{it} = \alpha + \beta_1 lny_{it-1} + \beta_2 \pi_{it} I(q_{it} \leq \gamma) + \beta_3 \pi_{it} I(q_{it} > \gamma) + \theta x_{it} + \varepsilon_{it} \qquad (2.2)$$

Where the dependent variable is a log of $y_{it}$ and $\beta_1 lny_{it-1}$, is the lag of the dependent variable. The regime dependent variable is $\pi_{it}$ , which is the per capita household income, while *I* is the indicator function that depends on the regime estimated by the threshold. The threshold variable and its estimation are $q_{it}$ and $\gamma$ respectively as defined in equation (2.1), $x_{it}$ is a vector of independent variables, while $\theta$ is the associated vector of coefficients, and $\varepsilon_{it}$ is the error term. Lastly, we substitute our variables into equation (2.2) and the final model reads as follows:

*Lnelectricity Expenditure* $_{it}$ = $\beta_1$*lnelectricity expenditure* $_{it-1}$ + $\beta_2$*per capita household income (per capita household income*$_{it} \leq \gamma$*)* + $\beta_3$*per capita household income (per capita household income*$_{it} > \gamma$*)* + $\theta x_{it}$ + $\varepsilon_{it}$ (2.3)

We believe that previous electricity expenditures can influence the current ones. In addition, we used the dependent variable *lnelectricity expenditure* as an instrument to address potential endogeneity that may occur from the simultaneity of income and electricity expenditure, unobserved household preferences, and the bias that may stem from self-reported income. According to Arellano and Bover (1995), a dependent variable can be an instrument. The instrumentation condition requires the instrument to be correlated with the endogenous variable and uncorrelated with the error term. In household behaviors, past electricity consumption is expected to influence future use. We first run the baseline model without covariates and then add covariates $\alpha x_{it}$. In the model with covariates, we control for education, household size, household dwelling and household appliances, which are some of the determinants of household energy consumption in energy studies (see Choumert-Nkolo et al., 2019, Chen et a., 2022; Estiri, 2020). According to previous literature (Poblete-Cazenave, and Pachauri, 2021; Chen et al., 2019) household appliances have been found as one of the determinants of energy consumption, however, we acknowledge that appliances may be endogenous, i.e. increases in household appliances increases electricity expenditure. In our model, we address endogeneity using the lagged electricity expenditure, but not specifically targeting the appliances. This is a limitation that can be addressed in future studies. We then subsequently repeated Equation (2.3), but using grant income per capita as the threshold variable to determine how the thresholds change with general per capita income and per capita grant income. Grants are an important source of income for many households in South Africa.

### 2.4.2. Data

We used a South African household panel dataset called the NIDS to assess the income threshold at which households switch to clean energy sources. Five waves of the panel data were collected to track changes in household living standards including changes in income, poverty, inequality, health, education and household composition. The data provides a picture of how South African households respond to external shocks and life circumstances. The first wave was collected in 2008, with the second wave collected in 2010-2011, and the subsequent in 2012, 2014-2015 and the last wave in 2017. A total of 28,000 individuals in the dataset and 7,300 households were noted. The same households are in each and every wave, revealing the different transitions they experience. From the database, we can track how energy use has been changing over time.

## 2.5. Results

In this section, we present the descriptive statistics of the variables of interest and the results from the dynamic threshold model. We start with the descriptive statistics, which are presented for the full sample and in isolation for urban and rural subpopulations to indicate the differences among the subpopulations.

### 2.5.1. Descriptive Statistics

**Table 2-1.** Descriptive statistics for the five waves.

| Variables | Full sample | | | Urban sample | | | Rural sample | | |
|---|---|---|---|---|---|---|---|---|---|
| | Obs. | Mean | Standard Deviation | Obs. | Mean | Standard Deviation | Obs. | Mean | Standard Deviation |
| Electricity expenditure | 28 425 | 263.74 ($14)[2] | 263.739 | 17 631 | 325.64 ($17) | 562.17 | 12 014 | 158.92 ($8) | 364.629 |
| Other energy expenditures | 11 088 | 109.56 ($6) | 109.556 | 5 660 | 115.80 ($6) | 164.532 | 6 377 | 100.97 ($5) | 163.287 |
| Per capita household income | 35 769 | 2,561.42 ($135) | 2561.421 | 22 409 | 3,743.54 ($197) | 84191.32 | 16 063 | 957.66 ($50) | 4449.923 |
| Per capita grant income | 19 326 | 513.357 ($27) | 513.357 | 10 389 | 522.723 ($28) | 582.174 | 10 243 | 500.367 ($26) | 492.649 |
| Appliance index | 40 088 | 0.016 | 0.0160 | 25 212 | −0.294 | 1.036 | 17 802 | 0.394 | 0.932 |
| Dwelling | 40 300 | 1.52 | 1.524 | 25 363 | 1.70 | 1.130 | 17 882 | 1.3 | 0.802 |
| Gender (male = 1) | 40 475 | 0.44 | 0.438 | 25 490 | 0.49 | 0.500 | 17 954 | 0.33 | 0.485 |

The households in the sample spent an average of R264 ($14) on electricity and R110 ($6) on other energy expenditures on a monthly basis during the five waves. This is expected because South Africa has an electricity access of 90%. Most electricity is used in urban areas, where the expenditure was R326 ($17), compared with R159 ($8) in rural areas. This aligns with the national statistics. Stats SA (2023) reported that electricity access in urban areas is slightly more than the national average of 95%. Electricity access is 60% in rural areas.

[2]The exchange rate used is R19 for 1$

Household income in the sample is R2561 ($135) per capita over the five waves. In addition, we state the per capita grant income in South Africa because almost half of the population depends on grants. According to the Stats SA (2023), approximately 50% of households survived on grants. In this sample, the per capita grant income is R513 ($27). The split is almost equal in the urban and rural areas. In the database, the appliance index is a yes or no question wherein households are asked if they have specific appliances. We created and indexed the appliances using the multiple correspondence analysis (MCA). The negetive values in the appliance index do not reflect that household own less appliances, instead, the MCA method is centered around the mean, which means household with negatives fall below the sample mean. The dwelling variable is the type of dwelling in which households reside, it is a categorical variable with five categories. Most households in the sample resided in formal housing, which consisted of brick-structured houses, townhouses, and flats, which is category one and two in the sample. This is confirmed by the Stats SA (2023), which found that about 84% of South African households resided in formal dwellings. Approximately 44% of the household respondents were male and 64% were female.

### 2.5.2. Empirical Results

This section details the findings of the dynamic panel income threshold model. In the primary analysis, we used household income per capita to assess the threshold at which households switch to clean energy. Even though we are aware that electricity generation is mainly generated from coal in South Africa, in this analysis, we categorise electricity as a clean household energy source, because it is not combusted at the household level, affecting household health. We separately investigated the income threshold for electricity and other energy sources. Subsequently, we split the samples to assess how income thresholds change in urban and rural areas. Moreover, because social grants are the second most important income source in South African households, we ran the same analysis using grant income as a threshold variable. The last section presents the results.

Table 2-2 presents the results of the electricity expenditure income threshold effects, from a sample size of 9 780 households. The dependent variable is the log of the electricity expenditure.

**Table 2-2.** Electricity expenditure threshold effects.

| **Dependent variable: log electricity expenditure** | Baseline model | Model with covariates |
|---|---|---|
| Lag electricity expenditure | −0.049 (0.212) | −0.190 (0.282) |
| Below threshold | −0.009***(0.002) | −0.010***(0.003) |
| Above threshold | −2.520 (3.370) | −3.560 (4.420) |
| Threshold value | R372 ($20) | R370 ($20) |
| Lower threshold value | R260 ($14) | R260 ($14) |
| Upper threshold value | R493 ($26) | R493 ($26) |
| Appliance index | | 0.038 (0.448) |
| Dwelling | | 0.676 (0.620) |
| Age | | 0.003***(0.001) |
| Education | | 2.339 (7.153) |

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

We ran the model in a two-step process. We started by estimating the baseline model, which consists of the dependent variable and the income, excluding covariates. Income is the threshold variable, and the lag of the dependent variable (electricity expenditure) is the variable of interest. Moreover, the lag of the dependent variable also serves as an instrument. Second, we extended the baseline model by adding covariates often used in household energy studies.

As displayed in the baseline model results, the electricity expenditure of the previous period is not associated with that of the current period. The coefficient is –0.049, which is not significant. The income threshold is divided into two regimes: below and above the threshold. The below regime coefficient is –0.009 and is statistically significant at 1 percentage point. The results indicate that when the household per capita income reached R372 ($20), the expenditure on household electricity decreased by 1 percentage point. The above regime coefficient is –2.520 and not statistically significant, indicating no association between per capita household income and electricity expenditure above the R372 ($20) threshold. The income thresholds are endogenously determined by the model with 95% confidence intervals. In the model, the intervals are R260($14) and R493($26) (Seo & Shin, 2016)

The negative and statistically significant below regime signals affordability issues. When household income reaches R372 ($20), households may focus more on other basic needs, hence the decline in electricity expenditures. In such cases, households may introduce alternatives such as solid fuels, which may be cheaper or freely available, to supplement their energy needs.

Similarly, the model with covariates is statistically significant only for below the threshold regime, with a coefficient of –0.010. This suggests that household electricity expenditures declined by 1% when the per capita household income reached R370 ($19). The additional covariates were selected according to what has been used in the literature and data availability. The results indicate that the coefficients are not statistically significant for the appliance index, dwelling, and education. Age has a coefficient of 0.003 and is statistically significant at 1 percentage point. This suggests that as the household head ages, their electricity usage will likely increase by a third of a percentage point. Figure 2-1 presents the threshold effects.

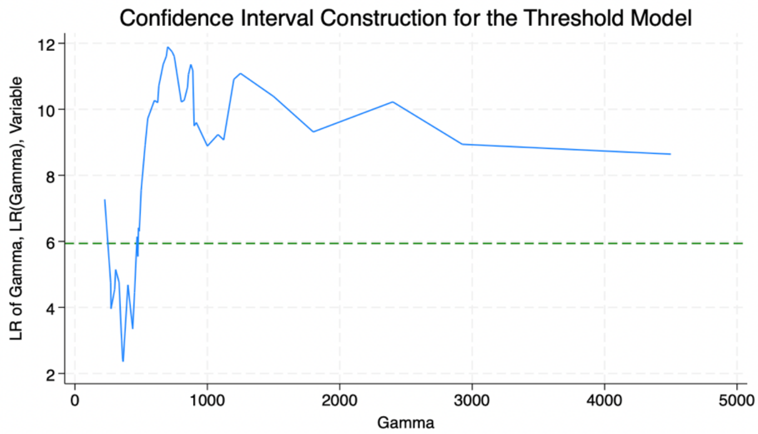


**Figure 2-1.** Per capita household income threshold effects on electricity expenditure.

As shown in Figure 2-1, one threshold wherein electricity consumption changed as per capita household income increased was observed.

To obtain a complete overview of the income threshold effects, we ran regressions for the urban and rural subpopulations presented in Table 2-3. Because most covariates were not statistically significant for the entire sample except for age, the same was true for the subsample analysis, and we decided not to report them in this section.

**Table 2-3.** Electricity expenditure threshold effects: urban and rural split.

| **Dependent variable: log electricity expenditure** | Urban sample | Rural sample |
|---|---|---|
| Lag electricity expenditure | −0.412 (0.596) | 0.188 (0.209) |
| Below threshold | 0.000 (0.000) | −0.005***(0.001) |
| Above threshold | 0.012** (0.006) | 0.000 (0.000) |
| Threshold value | R417 ($22) | R372 ($20) |
| Lower threshold value | R280 ($15) | R188 ($10) |
| Upper threshold value | R493 ($26) | R2000 ($105) |

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

The lag of electricity expenditure of the previous periods was insignificant for the urban and rural samples, with coefficients of –0.412 and 0.188, respectively. The results indicate no association between the last electricity expenditure and the current period.

For the urban subsample, the coefficient for the above regime is 0.012. It is significant at 5%, suggesting that the household electricity expenditure increases by 1 percentage point when the per capita household income reached R417($22) per month. The results support the energy ladder hypothesis that households with high incomes tend to move up the ladder using clean energy sources. On the contrary, in the rural subsample, the below threshold coefficient is –0.005 and statistically significant at 1%. The results indicate that when the per capita household income reached R372 ($20) per month, the household electricity expenditure declined by half a percentage. In such a situation, households may use solid fuels owing to affordability constraints. Solid fuels such as wood are often cheap or freely available, especially in rural areas.

Table 2-4 presents the income threshold results for other energy expenditures. We followed a similar process as with the electricity models. However, we only reported the entire sample. The urban and rural subpopulation results have characteristics identical to those of the entire sample.

**Table 2-4.** Other energy expenditure threshold effects.

| Dependent variable: log other energy expenditure | Baseline model | Model with covariates |
|---|---|---|
| Lag electricity expenditure | −0.713 (0.669) | −0.591 (1.015) |
| Below threshold | −0.003 (0.007) | −0.001 (0.015) |
| Above threshold | 2.590 (3.080) | 3.020 (3.690) |
| Threshold value | R667 ($35) | R667 ($35) |
| Lower threshold value | R175 ($9) | R175 ($9) |
| Upper threshold value | R1900 ($100) | R1900 ($100) |
| Appliance index | | −0.398 (1.130) |
| Dwelling | | 0.014 (1.889) |
| Age | | 0.003 (0 .004) |
| Education | | −2.340 (10.009) |

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

As in the other models, the lagged-dependent variable remains statistically insignificant. In addition, we did not find threshold effects for regimes below and above, suggesting the absence of an association between per capita household income and other energy expenditures. Adding covariates to the model does not improve the result; all the coefficients are statistically insignificant. This suggests that other energy used in the house are not income dependent, they may serve as security energy sources in the household, meaning since they easily avaiable and sometime free, they do not depend on household income. On the other hand, electricity may be viewed as a transition source that is used as an option when the income allows for specific uses like the lighting service.

Because almost half of the South African households depend on government grants, we also analyzed the threshold grant effects on electricity expenditures. This inspiration stems from the study of Li et al. (2020), who analyzed the income thresholds for appliance ownership among different-income households because poor households are often overlooked. We paid special attention to low-income people by adding all the grants received in a household and dividing them by the household size to make grants per capita. We ended up with a sample size of 6 079 households that receive grants. Table 2-5 displays the results of the grants received in South Africa.

**Table 2-5.** Grant income electricity expenditure threshold effects.

| Dependent variable: log electricity expenditure | Baseline model | Model with covariates |
|---|---|---|
| Lag electricity expenditure | 0.419 (0.352) | 0.862 (1.389) |
| Below threshold | 0.081 (0.074) | −0.081 (0.193) |
| Above threshold | 0.003 (0.005) | −0.005 (0.022) |
| Threshold value | R156 ($8) | R300 ($16) |
| Lower threshold value | R120 ($6) | R120 ($6) |
| Upper threshold value | R1067 (56) | R1067 ($56) |
| Appliance index | | 1.026 (4.359) |
| Dwelling | | 1.446 (4.414) |
| Age | | 0.0034 (0.008) |
| Education | | 151.295 (272.066) |

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

The results indicate that all variables are statistically insignificant, suggesting that grants have no income threshold effects on electricity expenditure in this case. This is expected given that people who receive grants have no other sources of income. The grant money most likely goes to food and other essential needs. Poor South Africans have been receiving 50 kWh of free electricity to meet their basic electricity needs.

#### 2.5.2.1. Robustness Checks

**Mann–Whitney U test**

We used the nonparametric Mann–Whitney U test to ascertain that our samples were statistically different. We did this only for the electricity expenditure model because the other energy expenditure and grant income models are not significant. When running a threshold model, determining whether a sample below the threshold differs from a sample above the threshold is useful. Table 2-6 presents the results.

**Table 2-6.** Mann–Whitney U test.

| Threshold Income | Full sample | Urban | Rural |
|---|---|---|---|
| Rank sum | 4.038 | 4.039 | 4.038 |
| z | 51.559 | 53.245 | 51.559 |
| Prob > \|z\| | 0.000 | 0.000 | 0.000 |

The results indicate a difference in the sample as displayed by the *z* variable and the *p* value that is strongly significant for all the samples. This shows the significance of the threshold variable in household electricity expenditure.

**Two-step system GMM**

We went further to validate our results using the two-step system GMM. Even though the model is not specifically created for threshold effects, it has principles similar to our main model; it addresses endogeneity using instrumental variables. We first run the main threshold model and then take the variables calculated from the threshold model and use them in the two-step system GMM as independent variables. We did this for the full sample and the urban and rural subpopulations. Table 2-7 presents the results.

**Table 2-7.** Two-step system GMM for the full population and subpopulations.

| Dependent variable: log electricity expenditure | Full sample | Urban | Rural |
|---|---|---|---|
| Lag electricity expenditure | 0.149 (0.100) | 0.168 (0.070)** | 0.115 (0.127) |
| Below threshold | −0.008***(0.002) | −0.007 (0.002)*** | −0.005(0.002)** |
| Above threshold | 0.000 (0.000) | 0.000 (0.000) | 0.000 (0.000) |
| Hansen test | 3.76 (0.288) | 0.88 (0.831) | 4.78 (0.189) |

*p* values of the Hansen test in parentheses

The results for the full sample are similar to those of the dynamic threshold model. The log electricity variable was 0.149 but statistically insignificant. The below threshold variable is 0.008 and is significant at 1%. The results of the two-step system GMM indicate the validity of the dynamic threshold model. For the urban and rural subpopulations, the results contradict the dynamic threshold model. In the threshold model, the above threshold variable was positive and significant, which is the opposite here. Similarly, in the rural threshold model, none of the variables were significant. This can be attributed to the differences in the model characteristics and specifications. The difference between the GMM models and the threshold models is that GMM models addresses endogeneity in the model and validates the instruments, while threshold models addresses endogeneity and also determine thresholds in nonlinear relationships. The GMM model lacks the ability to determine endogenous thresholds, hence a threshold model is appropriate in this case. However, to validate our instrument, the GMM model comes in handy.

The Hansen test from the two-step system GMM validates the relevance of the instrument, which is the log of the electricity consumption. The *p* value in parentheses is >0.05, failing to reject the null hypothesis.

## 2.6. Discussion

The results confirm the nonlinear and asymmetric effects of income on electricity expenditures of South African urban and rural households, revealing important insights into the dynamics of household energy transition. These findings align with and challenge several aspects of the existing literature, offering new contributions to the understanding of energy behaviors in developing countries. This section presents a detailed interpretation of the results, compares them with extant literature, and highlights their academic and policy implications.

The dynamic panel threshold model identifies distinct income thresholds for electricity expenditure, providing evidence of regime-dependent effects. The positive relationship between income and electricity expenditures above the threshold for urban households supports the energy ladder hypothesis. This suggests that as incomes increased, urban households increasingly use modern energy appliances and rely more on electricity for their energy needs. This trend reflects the broad accessibility of electricity infrastructure in urban areas and the economic feasibility of electricity consumption at high income levels.

In rural households, there is no association with electricity expenditure above the income threshold. This finding contradicts the energy ladder hypothesis and underscores the complex interplay of energy precarity, which entails affordability, access, and cultural factors in shaping energy use. One plausible explanation is the persistent reliance on traditional fuels, such as wood, which are freely or cheaply available in rural areas. In addition, the cultural attachment to conventional cooking methods and the unreliability of electricity in rural regions may further discourage households from adopting the use of electricity, even when incomes increased.

These dynamics suggest that rural households exhibit energy-stacking behavior, maintaining traditional fuel use alongside modern energy sources to hedge against supply and cost uncertainties. The drawbacks of energy-stacking behavior, particularly as households tend to incorporate dirty fuels, are the detrimental effects on physical and mental health. Misra et al. (2018) found evidence of self-reported chest tightness among rural South African women who used wood for cooking. This suggests that the health impacts could be significant when considering the use of all solid fuels.

The absence of significant effects on other energy expenditures suggests that traditional fuels remain dominant in household energy portfolios, mainly in rural areas. This finding aligns with some studies such as those of Choumert-Nkolo, J., et al. (2019) and Tinta (2024), who highlighted the prevalence of energy stacking in low-income contexts. In addition, the negligible impacts of grant income on electricity expenditure indicate that such income is likely allocated to immediate survival needs, such as food and healthcare, rather than to modern energy consumption. This is consistent with studies indicating that cash transfers in low-income settings often fail to trigger significant changes in energy use behaviors unless explicitly targeted at energy-related expenses.

This study contributes to the literature by providing evidence of nonlinear income effects and identifying specific thresholds that mark transitions in household energy use. Although earlier studies, such as those of Kumar et al. (2023) and Zheng et al. (2024), emphasized the positive correlation between income and energy use, they assumed linearity and failed to account for the nuanced behaviors observed in low-income settings. By contrast, this study highlights the asymmetric effects of income, indicating that increased income below the threshold has little to no impact on electricity use, likely owing to affordability constraints and subsistence priorities.

In addition, the findings extended the work of Li et al. (2020), who identified income thresholds for energy transitions in China. Unlike their results, which showed consistent transitions to clean energy sources above the threshold, this study revealed significant heterogeneity in urban and rural contexts. This heterogeneity underscores the importance of geographic and cultural factors, which are often overlooked in generalized models of energy transitions. Moreover, this study further builds on the insights of Walt et al. (2024), who noted the persistence of traditional fuel use among middle- and high-income South African households by demonstrating how such behaviors differed across income regimes and geographic locations.

Reexamining the effects of the grant income threshold reveals that grant income is an essential source of income for almost half of South African households. Chen et al. (2022) determined income threshold effects for poor-income households in China by examining their biomass demand. Studying the most popular solid fuel used by South African households can indicate their income threshold effects. The results can be starting points for targeted interventions using transfers.

This research advances the theoretical understanding of household energy transitions by integrating a dynamic panel threshold model that captures regime-dependent effects. In addition, it challenges the simplistic assumptions of the energy ladder hypothesis and provides empirical evidence of energy-stacking behaviors, particularly in rural areas. Moreover, this study highlights the limited role of grant income in driving energy transitions, offering a nuanced perspective on the interplay between social transfers and energy use. By disaggregating the results for urban and rural households, this study provides a more granular understanding of the socioeconomic and geographic factors influencing energy behaviors.

The findings indicate the significant effects of the energy policy in South Africa and similar contexts. First, they underscore the need for targeted interventions that address the distinct challenges faced by urban and rural households. For urban households, policies should focus on incentivizing the adoption of energy-efficient appliances and improving electricity affordability. Expanding subsidies for electricity use above the free basic allocation could encourage high-income urban households to rely more on clean energy.

The decline in electricity expenditures above the threshold highlights the need for infrastructure improvements and culturally sensitive awareness campaigns for rural households. Policies should enhance the reliability of the electricity supply in rural areas and promote the adoption of modern cooking and heating technologies that align with traditional practices. In addition, providing targeted subsidies or incentives for clean energy adoption could help mitigate the reliance on conventional fuels.

The negligible impact of grant income on electricity expenditures suggests that existing cash transfer programs do not effectively address energy poverty. Therefore, policymakers should consider introducing conditional cash transfers specifically tied to energy-related expenses, such as subsidies for modern energy appliances or renewable energy systems. Such programs could complement existing social protection measures and accelerate the transition to clean energy sources.

## 2.7. Conclusion

This study investigates the nonlinear and asymmetric effects of income on South African household energy expenditure, focusing on electricity consumption and the dynamics of urban and rural households. Employing a dynamic panel threshold model identifies specific income thresholds that mark significant shifts in energy behavior and reveals key distinctions between urban and rural contexts. The findings contribute to a deeper understanding of household energy transitions in developing countries and provide actionable insights for academics and policymakers.

The results indicate that urban households increase their electricity expenditure above the income threshold of R417 ($22), which is consistent with the energy ladder hypothesis. This indicates that high-income urban households are more likely to adopt modern energy sources that are supported by better infrastructure and great affordability. By contrast, rural households exhibit a decline in electricity expenditure above the threshold of R370 ($20), which challenges conventional theories of energy transitions. This behavior reflects a complex interplay of factors, such as persistent reliance on traditional fuels, cultural preferences, and the limited reliability of rural electricity infrastructure.

In addition, this study found no significant impacts of income on expenditures for other energy sources, underscoring the enduring dominance of solid fuels in rural energy portfolios. Similarly, the negligible influence of grant income on electricity expenditure suggests that social transfers are insufficient to drive substantial changes in energy use without targeted interventions.

From an academic perspective, this research challenges the linear assumptions of the energy ladder hypothesis and highlights the importance of regime-dependent effects in understanding energy transitions. Identifying income thresholds and their asymmetric impacts provides a nuanced framework for analyzing household energy behaviors. In addition, this study contributes to the literature on energy stacking, particularly in rural contexts where traditional fuels remain integral to household energy strategies. Moreover, the findings underscore the limited role of grant income in energy transition, opening avenues for further research into the interplay between social protection programs and energy use.

The policy implications of this study are substantial. Urban households above the income threshold could benefit from incentives to adopt energy-efficient appliances and expand their electricity reliance. Such policies could be targeted subsidies, tax incentives for modern energy technologies, and programs to raise awareness of the benefits of clean energy use. For rural households, the focus should be on improving the electricity infrastructure, ensuring reliable supply, and promoting affordable alternatives to traditional fuels. Culturally tailored awareness campaigns and subsidies for modern cooking and heating technologies could facilitate the transition to clean energy sources while respecting local preferences.

In addition, this study calls for reevaluating grant income programs to effectively address energy poverty. Conditional cash transfers linked to energy-related expenditures, such as subsidies for modern appliances or renewable energy adoption, could complement existing social protection measures and accelerate energy transitions. Moreover, policymakers should consider expanding the FBE policy to provide large allocations for needy households, particularly in rural areas.

While this research offers valuable insights, it also highlights the limitations and areas for future investigation. While previous studies have noted appliances as determinants of household energy consumption, endogeneity might exist between appliance acquisition and increased electricity consumption due to their co-dependence. Future studies can address the endogeneity using the appropriate methodologies. Secondly, the data used in this analysis may not fully capture the effects of informal income sources, seasonal energy use patterns, or recent shifts in renewable energy adoption. Therefore, future studies should explore these dimensions to provide a more comprehensive understanding of household energy behaviors. Thirdly, the grant income analysis can benefit from disaggregation wherein income thresholds for specific solid fuel use are analyzed. In this way, policymakers can offer tailored assistance based on household preferences. Lastly, this study could not access the disaggregated solid fuel consumption data. Examining the long-term impacts of targeted interventions and grant income programs on energy transitions would yield practical insights for designing sustainable policies.

Overall, this study underscores the importance of understanding the nonlinear and asymmetric effects of income on energy expenditure in diverse socioeconomic contexts. Addressing the complexities of energy stacking, urban–rural disparities, and the role of grant income provides a robust framework for analyzing household energy transitions and developing policies to promote the adoption of clean energy. These findings are relevant for South Africa and other developing countries grappling with similar challenges in achieving sustainable household energy transition.

The findings of this study indicate that the influence of income on energy choices is more complex than it seems, with enduring energy habits implying that other factors also play critical roles. In the next chapter, we highlight a significant nonincome factor: women's negotiating power within households. Chapter 3 explores how women's decision-making authority affects the adoption of clean energy sources, considering their role as primary household energy managers. Moreover, Chapter 3 discusses the utilization of a multinomial logit model to analyze whether empowering women in households can ease the transition from traditional fuels to new energy alternatives despite income limitations.

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# Chapter 3 : Women's Bargaining Power and the Energy Ladder Hypothesis: Evidence from South Africa


**Abstract**

Households in developing countries primarily rely on biomass fuels, such as firewood, which are associated with adverse health outcomes owing to indoor pollution. The existing literature often highlights household income as a key determinant of transitioning to clean modern fuels given the access conditions to these energy sources. However, the role of women's intrahousehold bargaining power in driving this transition has been largely understudied. Some existing literature conflates "sex" and "gender," often using a woman's biology as a proxy to measure women bargaining power, leading to measurement errors. This study addresses these gaps using household decision-making power as a proxy for bargaining power. Our investigation focused on the effects of women's intrahousehold bargaining power in terms of choosing clean fuels. Results from a panel multinomial logit model indicate that households in which women possess higher levels of intrahousehold bargaining power are more likely to adopt clean fuels than dirty ones. These findings highlight the significance of women's empowerment as a nonincome/price driver of household energy transition from traditional to clean fuels. Our findings underscore the importance of enhancing women's bargaining power to bolster household energy transitions in emerging economies contexts; empowering women to choose household fuels that do not cause household air pollution, negatively affect their health. Moreover, the need for gender-sensitive policies is discussed.



**Keywords:** bargaining power, gender, energy, indoor pollution

**JEL Codes:** D13, J16, Q40, Q54

## 3.1. Introduction

Many governments in Sub-Saharan Africa and other developing countries have pursued infrastructure programs and initiatives to expand access to modern energy services, such as by investing in rural electrification (Dinkelman, 2011). Therefore, the number of people without access to energy worldwide has declined (from 958 million in 2015 to 666 million in 2023) (International Energy Agency (IEA), 2025).

Nonetheless, many households, especially the poor, still heavily use traditional fuels such as coal, firewood, and paraffin, apparently owing to cost constraints of electricity (SEA, 2016). Approximately three billion people use solid fuels for cooking, heating, and lighting globally, which is most prevalent in Sub-Saharan Africa and Asia, accounting for about 95% of global use (Anderson et al., 2017). More significantly, the World Health Organization (WHO, 2022) reported that approximately 2.4 billion people, mostly the poor, use traditional cooking technologies, such as cooking with open fires or inefficient stoves, which results in approximately 3.2 million annual deaths from inhaling harmful smoke.

In addition to adverse health effects, household use of traditional solid fuels has gender and environmental ramifications. Reliance on solid fuel takes a heavy toll on women’s time and well-being, particularly in rural areas, as they are ordinarily in charge of collecting these fuels and cooking (WHO, 2022; Njenga et al., 2021; Blackden and Wodon, 2006; and Afridi et al., 2023). Thus, transitioning from traditional to clean energy sources redresses gendered welfare and health gaps at the household level.

Against these backdrops, this paper investigated whether women’s intrahousehold bargaining power drives the transition from traditional to clean fuels in the context of the emerging economy, South Africa. In the extant literature, household energy transition (fuel choice generally) has commonly been predicted and understood through the lens of the energy ladder hypothesis (Gelo et.al, 2023, Hosier and Dowd 1987, Leach 1992, Heltberg 2004), which posits that households switch to expensive modern fuels as their incomes increased. However, a small but growing body of literature has documented nonincome determinants of household energy transition. For instance, women's intrahousehold bargaining power is expected to be a nonincome determinant of household fuel choice. Admittedly, household fuel preference and choice are gender differentiated because women are at the forefront of household choices, mostly doing cooking (Farhar, 1998; Akter and Pratap, 2022). As such, women are more likely to prioritize household energy needs than men.[3] It follows that they prefer clean fuel and technology adoption. However, this preference can only bear on if they have the required bargaining power to make choices.

A large body of development economics literature has long documented the link between women's intrahousehold bargaining power and a range of household outcomes (Ambler et al., 2021; Basu and Maitra, 2020; Dong, 2022). Mostly, they confirmed that women's bargaining power within households is related to children's health and education, the general well-being of women and girls, and the allocation of labor to alternative activities such as housework, agricultural work, and wage work (Doss, 2021). Gilligan et al. (2020) found that women's intrahousehold bargaining power affects agricultural technology adoption in Uganda.

However, evidence on the link between women's intrahousehold bargaining power and the household's fuel choice is sparse and inconclusive. Using an experimental approach, in

[3]Energy use affects men when it compromises fridges and audio–visual appliances (Clancy et al., 2019; Nyoni, 1993; Makan, 1995).

Uganda, Beltramo et al. (2014) reported that women's bargaining power, proxied by the additional asset ownership, raised the willingness to pay for modern cookstoves. Similarly, Kishore and Spears (2012) and Mohapatra et al. (2017) found that women's intrahousehold bargaining power increased the adoption of improved cooking stoves in India. Regarding fuel choice, Adusah-Poku et al. (2023) found that female-headed households were more likely to use clean fuel. Moreover, Choumert-Nkolo et al. (2019) found that intrahousehold bargaining, proxied by women's education, increased clean fuel (electricity) use in Tanzania.

Another strand of studies indicates that clean energy sources are more likely to be adopted by female-headed than male-headed households (Beyene and Koch, 2013; Aryal et al., 2019; Dominguez et al., 2021). In Uganda, evidence shows little participation in adopting biogas technology among male-headed households that control resources and make decisions for the households (Kabir et al., 2013; Walekhwa et al., 2009). Moreover, in Indonesia, spouse participation in decision-making increased biogas technology adoption (Putra et al., 2017). Furthermore, in India, women's influence in household decision-making resulted in clean energy adoption such as LPG for cooking (Choudhuri, and Desai, 2020; Mohapatra and Simon, 2017).

Women prefer clean energy sources for the household because of their corresponding health benefits (Hou et al., 2018; Das et al., 2014; Pachauri and Rao, 2013; Parikh, 2011; Bhagowalia et al., 2012). Men may not prioritize the shift because they are not directly involved in using dirty fuels as household chores are women's job (Puzzolo et al., 2016; Mensah and Adu, 2015). Some evidence were found in a study in South Africa and Zimbabwe; men would opt to buy batteries for their use and not consider buying technologies that help women with their household chores (Nyoni, 1993; Makan, 1995). In addition, Clancy et al. (2019) showed that men are concerned about energy use when it affects audio–visual appliances and fridges.

In Kenya, Ochieng et al. (2021) found that men had more bargaining power but were not interested in buying clean cookstoves. Women had an interest but could not make such a decision. In addition, Mahat (2004) stated that men may even lean toward cheap and user-friendly energy sources and not consider their hazardous nature. According to Mohapatra and Simon (2017) and Gould and Urpelainen (2019), women can invest in better and clean energy sources when they are given the platform to make household decisions.

A closer look into these studies suggests the following observations. First, women's intrahousehold bargaining power is associated with the adoption of improved/modern stove technology or clean fuel. Second, they used varying proxies (one or other dimensions of female bargaining power) to measure intrahousehold bargaining power: relative education, asset ownership, and gender/sex. Given that intrahousehold bargaining power is multidimensional, these proxies are prone to measurement errors, leading to attenuation biases in the evidence that emerged from these studies. Third, for the most part, they relied on cross-sectional data from small surveys.

We respond to these empirical uncertainties in the following major ways. First, we employed a better measure of intrahousehold bargaining power involving a comprehensive composite index that accounts for its multidimensionality. To the effect, we used five decision-making questions in the household questionnaire of the NIDS data. Moreover, unlike most previous studies, we used panel data within a multinomial-choice setting to control for unobserved household heterogeneity, which otherwise may confound the relationship between women's intrahousehold bargaining power and household fuel choices. Third, unlike previous studies, we leveraged the nationally representative data within the context of the emerging/middle-income economy. Overall, our study provides an important addition to the growing empirical evidence on the role of women's bargaining power on household fuel choice.

The remainder of this chapter is organized as follows. The second section discusses the background of the study. The third section looks into the idea behind bargaining power, women empowerment, and intrahousehold decision-making. The fourth section presents the modeling. The fifth section discusses the results, which includes data used in this study, the descriptive statistics and empirical results. The sixth section presents the discussion of empirical results. Finally, the last section concludes this study.

### 3.2. Background

The South African residential electricity sector is one of the largest consumers, accounting for about 23% of the electricity consumed. In recent years, electricity access has increased owing to policies aimed at providing electricity to previously unconnected households. More than 86% of households are connected to the electricity grid (Stats SA, 2019). Electrification is more prominent in formal than informal housing areas in South Africa. However, more than 10% of households still do not have access to the electricity network.

By contrast, other households have access to the electricity network. However, they are still not using electricity because of certain issues such as cost, preference, or other circumstances known to them (Essex and de Groot, 2019). In addition, the possibility of not having access to electricity is higher for male-headed than for female-headed households (Bohlman and Inglesi-Lots, 2018).

Households consume energy for cooking, heating, and lighting. The energy encompasses solid fuels such as firewood, coal, paraffin, LPG, electricity, and renewable energy sources. According to the NIDS (2016), dependence on fuels other than electricity is more prevalent among low-income households, whereas energy needs of middle- and high-income households are mostly satisfied by electricity. Households with no electricity depend on paraffin, firewood, LPG, coal, crop residue, and animal dung.

The South African energy use statistics reveal that despite lower-income households connected to the national grid receiving 50 kW/h of free electricity per month, a significant proportion still uses various energy sources, such as wood and paraffin. Solid fuels are predominantly used in rural areas where approximately 75% of households with no electricity rely on solid fuels for cooking, heating, and lighting. Low-income households consume between 5% and 10% of their energy in lighting; space heating and cooking account for 85%–90% of their total energy consumption (Bohlmann and Inglesi-Lotz, 2018). The disparity is high between urban and rural areas. For instance, even though solid fuels use has declined nationally from 20% in 2002 to around 7% in 2024, rural households in provinces like Limpopo and Mpumalanga still rely on solid fuels like wood for cooking. In Limpopo, 34% of the households used wood for cooking, while in Mpumalanga, household wood use accounted for around 19% in 2024 (Stats SA, 2024).

Households that depend on solid fuels are exposed to deadly air pollution. Among the diseases associated with air pollution are tuberculosis, asthma, heart disease, stroke, lung cancer, pneumonia, and low birth weight for pregnant women. Young children exposed to harmful gases are at risk of developing acute respiratory infections and have a higher risk of developing nutritional deficiencies (Jagger and Yeatts, 2017; Chen et al., 2022).

The damage caused by solid fuels is not limited to cardiovascular and respiratory illnesses. For fuels such as kerosene, negative effects such as dermatitis, memory loss, and blood and kidney function problems are prevalent. Small children exposed to kerosene can unintentionally ingest it, resulting in chemical pneumonia. In addition, burn injuries and fires ensue from the use of kerosene and candles. Moreover, solid fuels cause about 40% of household fires in South Africa. From the 40%, candles instigate 14% of burn injuries. Furthermore, almost 80,000 accidental cases of children ingesting paraffin are annually reported in South Africa. Note that using kerosene lanterns can cause poor sight problems and may increase the probability of being blind as people grow older (Mills, 2016).

Women and children are said to withstand the worst of harmful solid fuels; they are responsible for domestic chores in the household (WHO, 2020; UNDP, 2019; Blackden and Wodon, 2006). In most developing countries, gender norms exclude women from the economy. Women's roles mostly involve household duties and childbearing (Ding *et al.,* 2019). In addition, domestic chores that women are responsible for entail procuring household energy fuels, such as unsafe solid fuels, which are detrimental to their health because of their environmental impacts. The gender norms that exist in most developing countries widen gender inequality. Because women spend most of their time in the household, they are at the forefront of the energy sources used in the household. However, they often take a backseat in decision-making because they have little to no bargaining power. Decisions such as taking part in choosing the type of energy used in the household become farfetched. This subject requires significant attention to change the status quo.

### 3.3. Bargaining Power and Intrahousehold Decision-making

When examining the two strands of literature on intrahousehold decision-making—specifically, the aspects of bargaining power and women's empowerment—various decision-making models emerge, notably the unitary and collective models. The unitary model, originating from Becker (1965), conceptualizes households as a single entity with uniform choices and preferences wherein one individual makes decisions on behalf of the entire household. This decision-maker is typically the person who contributes the most income or possesses the most assets. However, this model is impractical because it overlooks the diverse preferences that exist within a household.

By contrast, the collective model, which is rooted in the Nash equilibrium framework (Nash, 1953), posits that decisions are made through agreements reached among participants in a cooperative setting. This model is more reflective of reality because it acknowledges that households consist of individuals with varying choices and preferences who can collaborate to reach a consensus. Therefore, assuming that the collective model is more applicable in typical household scenarios is reasonable.

Women have been subjected to gender roles in many places globally that have made them powerless. The most common norm entails gender inequality, where women are stationed in the household focusing on household activities and childbearing and men participate in economic activities (Tallontire et al., 2005; Malhotra and Schuler, 2005). In addition, women have been restricted not only to the household but also in the society as a whole. Various authors have defined female empowerment as women's freedom or power to make choices and to have control over their lives to achieve the goals they desire in life. More importantly, empowered women have access and control over any kind of resources (Mahmud et al., 2012;

World Bank, 2002; Malhotra et al., 2002; Kishor and Gupta, 2004). This leads to interest in determining if women are involved in the household decision-making regarding the use of household fuel choices.

Bargaining power is an unobservable characteristic that is not easy to quantify. However, measuring it by determining the household decision-making involvement by asking specific questions elicits credible results (Meurs and Ismaylov, 2019). On the contrary, having more bargaining power might not mean the individual will take part in decision-making. Gender roles may distort the decision-making process. For instance, a woman can make decisions on what the household eats even if she does not financially contribute. The husband trusts her judgment because, globally, a woman's role is to cook; therefore, she would know better what is good for the family. Similarly, a woman who has more money may allow her husband to make certain decisions because he is the man of the house (Bernard et al., 2020).

In addition, preferences play a role in decision-making. When thinking about expenditure, one must consider male and female preferences. An evidence of different expenditure patterns among men and women was observed when income increased. In most cases, women are natural-born nurturers; they may opt for choices that benefit the whole household, neglecting their welfare in the process (Croson and Gneezy, 2009). Moreover, a woman or man may choose not to participate in decisions that are not of their interest.

In the equality discourse, women are active recipients of welfare, and their empowerment can positively influence the economic productivity and well-being of those around them. Gender equality is central to achieving some of the SDGs; hence, this study aimed to assess women's bargaining power in terms of energy decisions made in the household. In addition, Kohlin et al. (2011) stated that energy policies should consider the available local energy alternatives, gender roles, and intrahousehold decision-making processes.

### 3.4. Methodology

Several types of fuels are used in the household. In our data, the available fuels are electricity from the grid, generator, solar, gas, coal, wood, candles, dung, paraffin, and others. Each household is bound to choose a suite of fuels to use, depending on their preferences. Because our data cover 5 years, we adopted a panel multinomial logit approach to assess women's bargaining power and the energy ladder. Multinomial logit models stem from the traditional discrete choice models used when respondents choose among several options. According to Greene et al. (2022), the assumption is that a choice will be made among the alternatives. The choice made depends on the individual's preferences. Individuals make choices that maximize their utility, which is called the RUT.

The traditional logit regression focuses on the choices made on binary-dependent variables. This is not suitable for our analysis because we have several fuel options. In addition, the fuel options cannot be ordered because we deal with heterogeneous households with certain characteristics and preferences. Against this background, we cannot also use ordered models. Multinomial logit models can handle dependent variables without natural ordering (Liao et al., 2019). A standard pooled multinomial logit is a starting point in most studies of this nature. However, using a pooled multinomial logit model ignores the presence of individual heterogeneity. In such a model, the independence of choices and alternatives over time is assumed. To ease the assumption, a random-effect specification is required (Alem *et al.,* 2016).

In multinomial logit models, a reference category is required to serve as baseline, enablig easy comparison with the other possible choices (Manski and McFadden, 1981)—following the use of the panel multinomial logit model in energy ladder studies (Rahut et al., 2017; Alem et al., 2016; Choumert-Nkolo et al., 2019). We modeled the drivers of different household fuel choices for cooking, heating, and lighting. The other energy sources are grouped into various categories according to their cleanliness. We have four categories: electricity from the grid and electricity from the generator encompass the first category; solar and gas encompass the second category; coal, wood, candles, dung, and paraffin encompass the third category; and other sources encompass the fourth category. We group gas and solar as clean in the analysis, even though their cleaniliness is not the same. We are aware that gas also emits different types of emissions, while solar is completely clean. However, as stated by Waleed and Mirza (2023), gas is part of the transition fuels in the energy ladder/stacking theory. Moreoever, in the sample, the sources each account for less than 5% of the energy used in the household, and modeling them may result to inconsitent estimates.

To specify our empirical model, we draw on a random utility framework. This asserts that individual choices are not entirely deterministic but are affected by alternatives not included in the survey and other unobservable individual and alternative characteristics (Hanemann and Kanninen 1996). McFadden (1974) used this intuition to develop the random utility model, which was accomplished by including an error term in Equation (3.1)

$$V_{ijt} = \alpha_{ij} + \beta_j x_{it} + \varepsilon_{ijt} \tag{3.1}$$

This specification assumes a linear-in-parameter specification for indirect utility, denoting the individual with subscript and an alternative with $j$ at time $t$. In addition, note that the time-invariant household heterogeneity that captures the intrinsic preference for the alternative $\beta_j$ captures systematic preference heterogeneity related to the site attributes. $x_{it}$ is the vector of the household-level covariate and attributes (including costs) for alternative $j$. Moreover, is $\varepsilon_{ijt}$ a random error term that is uncorrelated with the observed components.

Assuming that $\varepsilon_{ijt}$ follows a type I extreme value distribution, the probability of choosing fuel type, the choice probability of alternative j at time alternative at time *t* conditional on $x_{it}$ and $\alpha_{ij}$ is given by the following:

$$P_i(j\ /x_{it}, \alpha_{ij}) = \frac{exp(\beta_j x_{it}+\alpha_{ij})}{\sum_{l=1}^{J} exp(\beta_j x_{it}+\alpha_{ij})} \tag{3.2}$$

Note that conditioning the choice probability $\alpha_{ij}$ would mean integrating out Equation (3.2) across $\alpha_{ij}$ the distribution to obtain the marginal/unconditional choice probability, generating a random parameter logit model specification.

## 3.5. Results

### 3.5.1. Data Description

Confusion exists between gender and sex in bargaining power studies. Most studies have investigated sex, which is biologically determined (Aryal et al., 2019; Bradshaw, 2018; Ryan, 2014). On the contrary, according to Fathallah and Pyakurel (2020), gender is socially constructed by associating males and females with specific roles, depending on where a person originates.

However, bargaining power and empowerment are not easily measured. Several socioeconomic and demographic factors were used as proxies. These are, but are not limited to, age, education, employment, income, ownership of assets, access to information, and legal power (Choumert-Nkolo et al., 2019; Bernard et al., 2020; Meurs et al., 2022). Bargaining power can change over time when the measures are used to quantify power change (Meurs and Ismaylov, 2019). For instance, a woman may have access to income/employment or new information, which may change her outlook on life and behavior.

Using such proxies may not be a true reflection of the bargaining power. According to Meurs and Rita (2019), most of the variables used to proxy bargaining power are a generalization that may not apply in all contexts. For instance, education does not improve bargaining power when employment opportunities are scarce. In addition, having an educated mother may have a greater influence on decisions related to children's schooling than other decisions. Questions about household decision-making are a robust measure of bargaining power. Moreover, differences were found between decisions made by women alone and those made jointly with other people in the household.

We used the nationally representative South African NIDS five-wave panel dataset (2008–2017). The NIDS is a panel study that tracks households every 2–3 years to assess their livelihoods. The data were collected between 2007 and 2017 and comprised over 27,000 families, with about 7,300 households nationwide.

Our variable of interest is bargaining power, which is constructed using the household decision-making questions asked in the survey. Table 3-1 presents the questions.

**Table 3-1.** Decision-making in the household.

| Household decisions |
|---|
| 1. Who makes decisions about day-to-day household expenditures (e.g., groceries?) |
| 2. Who makes decisions about large, unusual purchases such as appliances, vehicles, or furniture? |
| 3. Who decides who should live in the household as part of the household (e.g., if a relative or family member does not have a place to stay)? |
| 4. Who decides where the household should live? |
| 5. Who decides about where your children should go to school? |

Source: National Income Dynamics Study

Based on the above questions, we created a principal component index to represent women's bargaining power. The responses included the primary and second decision-makers, who refused and did not know. Even though deciding alone may have more weight, we combined the main and second decision-makers because a couple may choose to divide labor and leave specific decisions to the wife or husband. Li and Wu (2011) stated that decisions deemed necessary when made alone can be given more weight if needed.

Our dependent variable is household energy source. In the database, we grouped different energy sources into four categories according to their cleanliness. The first category is electricity; followed by gas and solar; then wood, coal, animal dung, and paraffin; and other[4]. The first and second categories are clean energy sources. Although electricity is mainly produced from coal in South Africa, the combustion process does not occur at the household level. The third category is dirty because it encompasses burning coal and other dirty sources

[4]Other cooking sources represent the gel and aga stoves. Other heating sources represent fireplace, water bottles, imbaula (this is a Zulu word for making fire inside a steel container using charcoal, which is common among the poorest households). Other sources for lighting represent chargeable lights, radio light, and battery power.

in the household. Figures 3-1 and 3-2 present the share of energy sources used by households for different energy services. Figure 3-1 displays how different household energy sources have been used on average for different energy sources. Over the five waves, South African households have frequently used electricity (cooking, heating, and lighting). This is not too far from what Stats SA (2019) reported: 81% of the electricity is used for cooking by South African households; heating accounts for 61% and lighting for 87%.

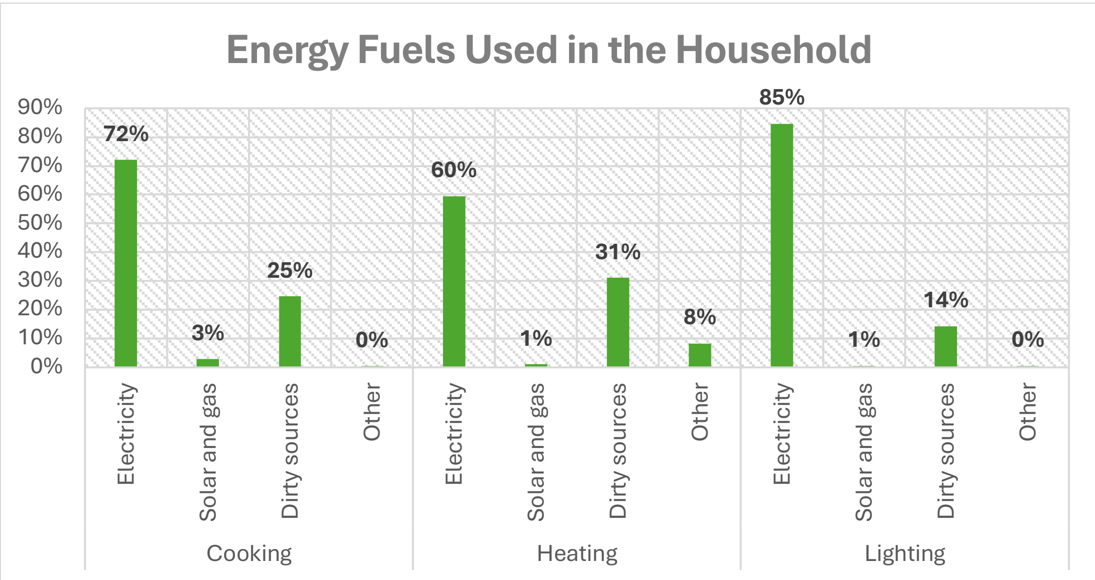


**Figure 3-1.** Energy fuels used in a South African household across five waves.

Figure 3-2, shows how South Africans have used different household energy sources in each of the five waves. In all the waves, the green bars represent cooking, the purple bar represents heating, and the blue bar represents lighting. All the different colour energy sources add up to 100 in each wave/year(i.e. 62% , 3%, 34%, and 1%). As displayed in the table, South African households have on average used electricity for cooking. The electricity usage for cooking increased from 62% in year 1 to 81% in year 5. The second most used energy source is dirty energy: coal, firewood, animal dung, and paraffin. Solar and gas take the third spot.

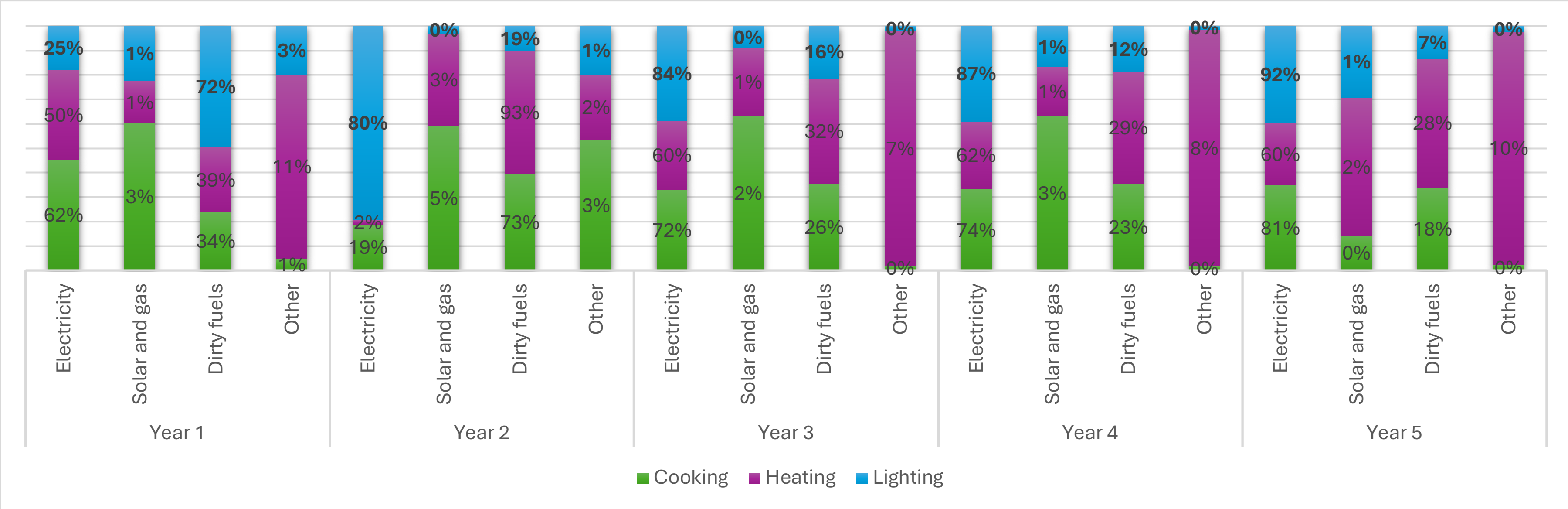


**Figure 3-2.** Energy usage by household during each wave.

The good news is that dirty energy use has declined from 34% in year 1 to 18% in year 5, as shown in Figure 3-2. The same applies to heating and lighting; dirty energy use has been on a downward trajectory. The use of solar and gas has not improved; it has fluctuated. In addition, we calculated the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy table for the bargaining power variable for all waves. The KMO confirms the suitability of the data to construct the index using principal component analysis.

**Table 3-2.** Kaiser–Meyer–Olkin measure of sampling adequacy.

| Variables | Wave 1 | Wave 2 | Wave 3 | Wave 4 | Wave |
|---|---|---|---|---|---|
| 1. Day-to-day household expenditures (e.g., groceries) | 0.936 | 0.919 | 0.930 | 0.9109 | 0.903 |
| 2. Large, unusual purchases such as appliances | 0.929 | 0.917 | 0.913 | 0.909 | 0.892 |
| 3. Decisions about who is allowed to live in the household as part of the household | 0.830 | 0.859 | 0.841 | 0.822 | 0.833 |
| 4. Decisions about where the household should live | 0.836 | 0.871 | 0.841 | 0.825 | 0.845 |
| 5. Decisions about where your children should go to school | 0.973 | 0.960 | 0.965 | 0.952 | 0.965 |
| Overall KMO | 0.893 | 0.901 | 0.889 | 0.874 | 0.879 |

The KMO statistic should lie between 0 and 1. Higher values suggest a high variable among the variables under consideration, which ensures that meaningful components are extracted from the sample size. In our sample, the statistics is over 85%, as shown Table 3-2, which validates the data suitable for using principal component analysis to construct the index.

**Table 3-3.** Variable description and descriptive statistics.

| Variables | Explanation | Observations | Mean | Std. | Minimum | Maximum |
|---|---|---|---|---|---|---|
| Cooking fuel type | 1 = Electricity; 2 = Gas and solar; 3 = Dirty Fuels; 4=Other[4] | 169975 | 1.535 | 0.877 | 1 | 4 |
| Heating fuel type | 1 = Electricity; 2 = Gas and solar; 3 = Dirty Fuels; 4=Other[4] | 169975 | 1.881 | 1.106 | 1 | 4 |
| Lighting fuel type | 1 = Electricity; 2 = Gas and solar; 3 = Dirty Fuels; 4=Other[4] | 169975 | 1.305 | 0.726 | 1 | 4 |
| Bargaining power | Constructed women bargaining power index | 298385 | −0.000 | 0.999 | -.3800 | 4.241 |
| Log income | Log of income | 147640 | 147640 | 1.026 | 0 | 17.728 |
| Employment | 0=Not economic Active; 2=Discouraged; 3=Unemployed Strict; 3=Employed | 104201 | 104201 | 1.387 | 0 | 3 |
| Education | 1=No Schooling; 2=High School; 3=Degree; 4=Postgrad; 5=Other | 189497 | 2.104 | 2.104 | 1 | 5 |
| Household size | Number of members residing in the household | 170829 | 5.897 | 3.494 | 1 | 41 |
| Area | 1 = Traditional; 2 = Urban; 3 = Farm | 183028 | 1.637 | 0.604 | 1,00 | 3,00 |
| House owner | 1 = Yes; 0 = No | 169709 | 0,792 | 0.406 | 0,00 | 1,00 |
| Race | 1 = African; 2 = Colored; 3 = Asian/Indian; 4 = White | 189467 | 1.310 | 0.727 | 1,00 | 4,00 |

The variable of interest is the bargaining power variable created from the household decision-making questions (see Table 3-1). The average South African has a high school education. Regarding employment, 48% of the respondents in the sample were not economically active, followed by 36% who were employed. There is on average 5 people in a South African household, who generally reside in urban areas. Our sample consists of mostly households who are owners of their houses (79%) as shown in Table 3-3. The majority of the households in the sample are African, which reflects the reality of the South African population.

### 3.5.2. Empirical Results

In this section, we discuss and interpret the results of our econometric analysis, focusing on the relationship between women's intrahousehold bargaining power and fuel choice for cooking, heating, and lighting. Table 3-4 presents the results of the fixed-effect multinomial logit regression model estimating the determinants of fuel choice for cooking. The choice of the model stems from the heterogeineity that exists from different household that are not captured in pooled models. We are also aware that some household characteristcs are time-invariant. Against this background, we ran both the random and fixed effects models. We then perfomed the Hausman test to assist us in decided on the optimal model for our analysis. The results from the Huasman test favoured the fixed effects model. The dependent variable in the model is a fuel source, such as electricity, gas, solar, or others, with a traditional/dirty fuels as the base category.

**Table 3-4.** Multinomial logit results of the cooking service (baseline: dirty energy sources)

| Cooking | Electricity | Gas and solar | Other[4] |
|---|---|---|---|
| Bargaining power | 0.068*** (0.015) | 0.051 (0.032) | 0.058 (0.094) |
| *Employment (base: economically inactive)* | | | |
| 1. Unemployed, discouraged | −0.148* (0.081) | 0.163 (0.178) | 0.450 (0.454) |
| 2. Unemployed, strict | 0.040 (0.047) | 0.057 (0.111) | −0.322 (0.312) |
| 3. Employed | −0.037 (0.041) | 0.083 (0.087) | −0.107 (0.234) |
| *Education (base: no schooling)* | | | |
| 1. High school[5] | 0.544*** (0.041) | 0.473*** (0.119) | 0.615** (0.360) |
| 2. Degree | 0.367 (0.336) | −0.644 (0.540) | 0.890 (1.636) |
| 3. Postgraduate | 0.277 (0.608) | 0.121 (0.824) | 1.111 (2.492) |
| 4. Other | 0.349*** (0.095) | 0.228 (0.209) | 1.348 (1.056) |
| Log income | −0.348**(0.148) | −0.580** (0.229) | -2.680*** (0.759) |
| Income squared | 0.061*** (0.010) | 0.080*** (0.015) | 0.168*** (0.050) |
| *Area (base: traditional)* | | | |
| 1. Urban | 1.726*** (0.070) | 0.958*** (0.145) | 1.437***(0.393) |
| 2. Farm | −0.037 (0.101) | 0.088 (0.214) | -1.489* (0.694) |
| *House owner (dummy)* | | | |
| 1. House owner | −0.438*** (0.034) | −0.246*** (0.076) | 0.204 (0.199) |
| LR chi-square (39) | 3319.24 | | |
| Prob > chi-square | 0.000 | | |

* p < 0.10; ** p< 0.05; *** p < 0.01

Throughout our analyses, we considered electricity, gas, and solar as clean energy sources because their use does not negatively impact the health of the households compared with burning dirty fuels such as coal or wood. A positive association exists between electricity use and bargaining power. The coefficient is 0.068 and is statistically significant. Moreover, no association exists between bargaining power and gas and solar and other sources. The

[5]High school includes primary and secondary schools.

coefficients are 0.051 and 0.058, respectively, and they are both not statistically significant.

The results indicate that intrahousehold women's bargaining power affects the household choice of electricity for cooking. As women's bargaining power improved, the odds of choosing electricity for cooking increased by 0.068, with no association with all other fuel categories. Similarly, urban residence, the household head's high school level education, and the household income increased the odds of using electricity for cooking. The income variable also signals that income is important for energy transitions. However, the log of income suggests poor households may not automatically switch to using electricity for cooking with increased income, they may just continue with using dirty energy sources, and dedicate the additional incomes to other needs. The negative and significant coefficient applies to all energy sources. On the other hand, the positive and significant squared income coeffient suggests that there is a likelihood of high income households switching to electricity, gas and solar, and other sources with increased incomes. The positive coefficient on the bargaining power index suggests that intrahousehold women's bargaining power drives the transition from traditional to clean fuel use in the household. The overall model is statistically significant as validated by the high chi-square statistic and the *p* value that is statistically significant.

**Table 3-5.** Multinomial logit results of the heating service (baseline: dirty energy sources)

| Heating | Electricity | Gas and solar | Other[4] |
|---|---|---|---|
| Bargaining Power | 0.046***(0.012) | 0.040 (0.048) | 0.043**(0.018) |
| *Employment (base: economically inactive)* | | | |
| 1. Unemployed, discouraged | −0.092 (0.069) | 0.370 (0.284) | 0.162 (0.100) |
| 2. Unemployed, strict | −0.144***(0.040) | −0.020 (0.171) | 0.101 (0.059) |
| 3. Employed | −0.141***(0.033) | −0.177 (0.134) | 0.168***(0.050) |
| *Education (base: no schooling)* | | | |
| 1. High school[5] | 0.119**(0.041) | −0.009 (0.193) | 0.207***(0,064) |
| 2. Degree | −0.059 (0.231) | 0.473 (0.500) | 0.030 (0.064) |
| 3. Postgraduate | −0.155 (0.435) | −0.747 (0.911) | 1.399 (0.805) |
| 4. Other | 0.093 (0.077) | −0.326 (0.355) | 0.091 (0.123) |
| Log income | 0.050 (0.105) | −0.553*(0.259) | 0.041 (0.159) |
| Income squared | 0.011 (0.007) | 0.065***(0.017) | 0.002 (0.010) |
| *Area (base: traditional)* | | | |
| 1. Urban | 1.769***(0.007) | 1.147***(0.242) | 1.715***(0.088) |
| 2. Farm | 0.512***(0.091) | 0.289 (0.401) | 0.604***(0.140) |
| *House owner (dummy)* | | | |
| 1. House owner | −0.409***(0.029) | −0.085 (0.120) | −0.530***(0.043) |
| LR chi-square (39) | 2238.93 | | |
| Prob > chi-square | 0.000 | | |

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Table 3-5 presents the results for the heating service. Women's bargaining power will likely impact their choice of electricity and other sources. The odds of choosing electricity increased by approximately 0.046 and 0.043 for different energy sources. The coefficients are statistically significant at 1% and 5%. The results indicate that women's bargaining power can also encourage energy stacking for heating. Bargaining power does not likely affect the use of gas and solar in households.

Similar to the cooking service, the household head's high school-level education increased the odds of choosing electricity and other energy sources to keep the household warm. High odds of heating with gas and solar energy were observed as income increased, especially for high income households as reflected in the income squared coeffient that is positive and significant at 1%. Middle and high-income households mostly use gas and solar energy because they are costly for the general public. This is also suggested by the urban variable that is significant for solar and gas; most well-off households reside in urban areas. No association was observed between gas and solar energy on farms; however, farm households are most likely to heat their homes with electricity and other energy sources. The overall model is validated by the probability of the chi-square, indicating a significance level of 1%.

**Table 3-6.** Multinomial logit results of the lighting service (baseline: dirty energy sources).

| Lighting | Electricity | Gas and solar | Other[4] |
|---|---|---|---|
| Bargaining power | −0.009 (0.019) | −0.052 (0.072) | −0.028 (0.103) |
| *Employment (base: economically inactive)* | | | |
| 1. Unemployed, discouraged | −0.180* (0.103) | 0.466 (0.337) | −0.531 (0.512) |
| 2. Unemployed, strict | 0.165*** (0.064) | 0.051 (0.260) | −0.300 (0.366) |
| 3. Employed | −0.059 (0.057) | −0.256 (0.224) | 0.031 (0.298) |
| *Education (base: no schooling)* | | | |
| 1. High school[5] | 0.261 (0.193) | 0.095 (0.852) | 0.962 (1.348) |
| 2. Degree | 0.814 (0.527) | 1.133 (1.750) | −0.541 (0.000) |
| 3. Postgraduate | 0.950 (1.231) | 1.889 (2.507) | 1.308 (0.000) |
| 4. Other | 0.583 (0.526) | −0.378 (1.553) | 0.538 (0.000) |
| Log income | 0.046 (0.279) | 5.016*** (1.381) | 2.475** (1.194) |
| Income squared | 0.056*** (0.019) | −0.240*** (0.086) | 0.174** (0.079) |
| *Area (base: traditional)* | | | |
| 1. Urban | 0.535*** (0.092) | 0.466 (0.429) | 1.440** (0.736) |
| 2. Farm | −0.877*** (0.135) | 0.879 (0.737) | 0.373 (0.892) |
| *House owner (dummy)* | | | |
| 1. House owner | −0.848*** (0.059) | −0.055 (0.223) | −0.512** (0.262) |
| LR chi-square (37) | 3203.70 | | |
| Prob > chi-square | 0.000 | | |

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Table 3-6 presents no association between women's bargaining power and all energy sources. The bargaining power coefficient is statistically insignificant for all the energy sources. Mixed results for the unemployed were observed. The discouraged job seekers have few odds of bargaining for electricity, whereas the strict unemployed have high odds of using electricity. Education has no association with bargaining power. The log income coeffient suggests that with increased income, household may spend on things like solar operated lighting equipment since the coefficient is positive and significant at 1%. There are high odds of using electricity and other sources for lighting were associated with high income as diplayed by the income squared cofficients. Unlike farm households, urban households are likely to bargain for electricity and other energy sources.

The following section outlines the predicted probabilities of using electricity, gas, solar, dirty energy, or other energy sources for different energy services.

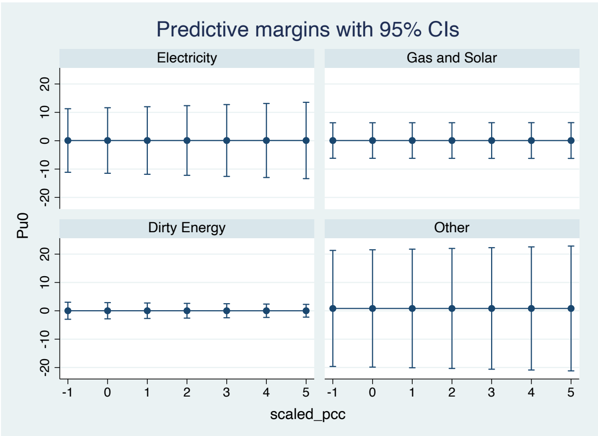


**Figure 3-3.** Predictive margins for cooking.

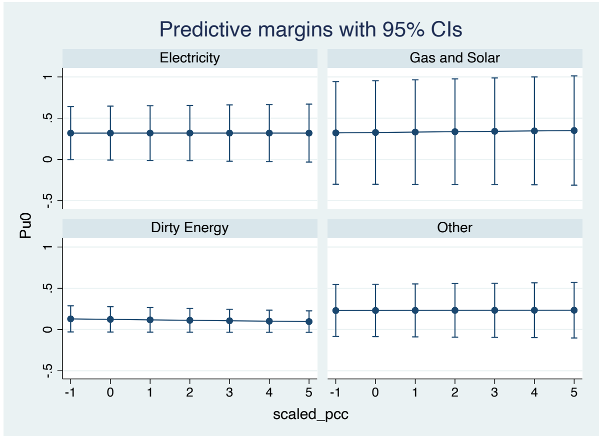


**Figure 3-4.** Predictive margins for heating.

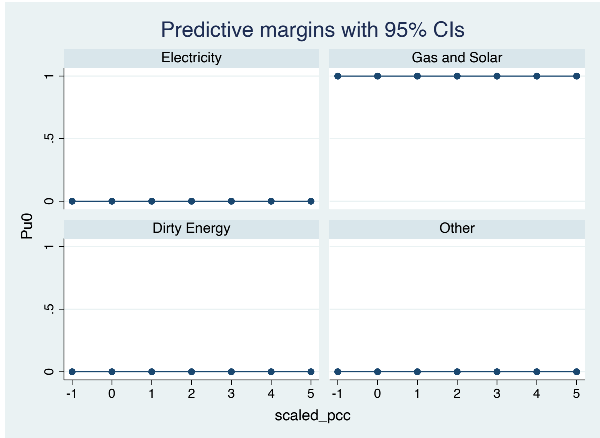


**Figure 3-5.** Predictive margins for lighting.

Figure 3-3 presents a high probability of bargaining with other energy sources and electricity. Different energy sources consist of gel and aga stoves. Poor or low-income households mostly use such stoves. Electricity is widely used in the country because most households are connected to the grid. However, poor households may choose to use gel and aga stoves for cooking and allocate electricity to lighting or heating. For heating (Figure 3-4), gas and solar are likely chosen, followed by electricity and other energy sources. This is a positive sign because it may be easy to select dirty sources such as charcoal and firewood for heating, which may be readily available. Figure 3-5 presents a high probability of choosing gas and solar, followed by electricity for lighting.

#### 3.4.3.1. Bargaining Power and Cooking Choice in the Household

Our database also contains information about household appliances. We expanded the analysis to determine if women's bargaining power applies to cooking appliances. We chose cooking appliances because most of them were included in the survey, and women dedicate most of their time to cooking for the household. Table 3-7 presents the results of a fixed-effects model approved by the Hausman test.

**Table 3-7.** Fixed-effects model of appliance choice in the household.

| | Electric stove | Gas stove | Paraffin stove |
|---|---|---|---|
| Bargaining power | 0,002 (0,014) | −0,031 (0,015) ** | −0,023 (0,013) * |
| *Employment (base: economically inactive)* | | | |
| 1. Unemployed, discouraged | −0,233 (0,075) *** | 0,284 (0,087) ** | 0,365 (0,069) *** |
| 2. Unemployed, strict | 0,273 (0,046) *** | 0,078 (0,052) | 0,047 (0,042) |
| 3. Employed | 0,144 (0,040) *** | 0,155 (0,043) | 0,067 (0,036) * |
| *Education (base: no schooling)* | | | |
| 1. High school | 0,283 (0,144) ** | 0,083 (0,185) | 0,030 (0,138) |
| 2. Degree | 0,1000 (0,305) | −0,034 (0,263) | −0,279 (0,259) |
| 3. Postgraduate | −0,065 (0,645) | −0,395 (0,394) | −0,354 (0,446) |
| 4. Other | 0,42 (0,309) *** | 0,09 (0,315) | 0,158 (0,304) |
| Log income | 0,95 (0,191) *** | −0,413 (0,125) *** | 0,270 (0,127) ** |
| Income square | −0,016 (0,013) | 0,041 (0,008) *** | −0,028 (0,008) *** |
| *Location (base: traditional)* | | | |
| 2. Urban | 0,638 (0,07) *** | −0,351 (0,088) ** | −0,190 (0,067) *** |
| 3. Farm | −0,495 (0,112) *** | −0,175 (0,149) | 0,160 (0,114) |
| *Houseowner (dummy)* | | | |
| 1. Yes | −0,245 (0,040) *** | 0,213 (0,045) *** | 0,319 (0,038) *** |

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

The results indicate a negative impact on bargaining for gas and paraffin stoves. Gas stoves may not be preferred because they are unfamiliar to most households. In addition, the descriptive statistics show that over 80% of households use electricity for cooking. Even though our electric stove bargaining power variable is insignificant, Phogole et al. (2022) showed that South African households are more familiar with electric stoves. Appliances that use LPG are not favored for safety reasons. The respondents in our study might have had the same sentiments.

With regard to the control variables, the unemployed discouraged individuals from using electric stoves. The power outage situation may be one of the reasons for such an outcome. They may prefer gas, solar, and paraffin stoves because they are not in the hands of the government, making them more reliable. For the employed and unemployed (strict) respondents, a strong positive impact on electric stoves compared with the other stoves exists. Similarly, those with a high school education preferred electric stoves. This indicates that education can influence clean energy use. In South Africa, most of the population has a high school education; high school is deemed a valid measure of an educated population. Moreover, Mobarak et al. (2012) echoed the same sentiments in Bangladesh, stating that the lack of education delayed the uptake of improved cookstoves in Bangladesh.

### 3.6. Discussion

These findings are consistent with existing evidence. For cooking, previous studies have indicated that women's bargaining power positively influences the adoption of clean energy for cooking. According to Choudhuri and Desai (2020) and Mohapatra and Simon (2017), women's influence in household decision-making resulted in the adoption of clean energy for cooking in India. In addition, Baek et al. (2020) showed a high likelihood of choosing modern fuels in female-led Kenyan households. In a similar vein, Dim (2023) stated that in Nigeria, a shift toward clean cooking fuels is facilitated when women possess bargaining power. Such results may also arise because of preferences, as stated by Puzzolo et al. (2016), who found that women may prefer clean energy sources because of their health benefits. The same was also found in Bangladesh; Das et al. (2021) stated that the willingness to pay for improved cookstoves was high because of the provided information stating the health benefits of using improved cookstoves.

Cooking is of significant importance in households. It is performed several times a day and mostly indoors, increasing the exposure to harmful gases in households that use solid fuels. Women and children are mostly affected. The promising findings of women's bargaining power necessitate policymakers to consider gender-sensitive policies that empower women to make energy-related household decisions to support energy transition. Gender planning is essential to better understand the different energy needs in other parts of the world. Targeted policies often yield better results.

The heating stacking results align with those reported in Nepal, where households filled metal pans as a heating mechanism seasonally (Lam et al., 2017). In South Africa, the heated steel is called *imbaula* and is usually used in winter for warmth. Moreover, previous studies (Phogole et al., 2022; Wernecke et al., 2024) have shown that households continue to stack household energy fuels, regardless of income. Introducing clean energy sources improves the quality of the stacked fuels. Our results indicate that women's bargaining power can boost clean fuel stacking in households.

Contrary to what was found in studies of this nature, highly educated people have less odds of advocating for all electricity, gas, solar, and other energy sources, contrary to what is found in most studies wherein clean energy use is associated with educated individuals (Haddad and Hoddinott, 1998; Israel, 2002; Peng *et al.,* 2010; Pandey and Chaubal, 2011; Van Aelst, 2014; Anderson et al., 2017). According to Aziz et al. (2022), this can be attributed to the lack of information on the pros and cons of clean energy use and its impacts on health and the environment.

Like cookstoves and water heaters that governments in different countries have rolled out, policymakers may need to consider assisting households with heating appliances like wall heaters instead of using *imbaula* (steel buckets used to burn dirty energy sources) for warmth. Even though the appliances are used during the winter, they are fuel efficient and have less impact on the health of households.

Even though the bargaining power variable is insignificant in the lighting results, the income variable, which is a determinant of energy transition, is positive for electricity and other sources. In the survey, other sources mentioned for lighting were rechargeable and battery-operated lights, which may be primarily used during power outages. Like cooking and heating services, fuel stacking in the lighting service might not be clean. In addition, Harrington et al. (2020) showed that stacking increases the household energy fuel cost burden, so households may look for the following readily accessible supplement, which are solid fuels.

The bargaining power has no associations with appliances; however, a positive relationship exists between income and electric stoves. The main reason may be that electricity is widely used in South African households. When income of a household increased, the study suggests that households may buy an electric stove because they are connected to the grid. On the other contrary, the relationship is negative for the gas and solar stoves. This echoes what has been stated in the electricity source results; having more income may not translate to switching to clean energy sources, such as gas and solar, but there is a likelihood of stacking with different energy sources, energy sources such as the dirty ones. In addition, the log of income is significant and positive for paraffin stoves, the second most used household energy source in

South Africa, as displayed in the descriptive statistics. This is not surprising because paraffin stoves are required for this purpose. Paraffin is mostly likely stacked with other sources of energy by low-income households.

Even though this study focuses on household, the results suggest important pathways that could affect women businesses. Since we analyse the behaviour, which is household energy choice, household behavious may trickle down to behaviours at work or businesses. In their businesses, women may also opt for clean energy source, if given a chance and resources. Against this background, this warrants further investigation in order to explore such linkages that may exist. In that way, policymakers could consider supporting women-led businesses geared toward sustainable energy development. Having women at the forefront of the clean energy sector could potentially improve the uptake of clean energy sources, such as the improved cookstoves available in other countries. The stacking behaviors of households must be closely studied because it was evident in the heating and lighting services that households are likely to stack with electricity and other sources. This knowledge could assist policymakers to design relevant, clean policies that align with these behaviors. For instance, policies may include subsidizing rechargeable lights so that households can limit kerosene use while reducing the overall cost of supplementary energy fuels. The proposed policies must be subjected to quantitative analyses, such as cost-effectiveness analysis, to identify interventions that offer significant health benefits and enhance fuel efficiency, especially considering the constraints of our already strained public finances.

### 3.7. Conclusion

This study investigated the relationship between women's intrahousehold bargaining power and fuel choices. Our analysis yields key findings that contribute to the existing literature on household energy transition.

First, our results indicate a statistically significant positive relationship between women's intrahousehold bargaining power and the choice of clean fuel (electricity) for cooking and heating. Specifically, compared with the base category, women's bargaining power odds of using electricity increased by 0.068 percentage points and 0.046 for heating. These findings support the hypothesis that women's intrahousehold bargaining power contributes to household energy transition.

Second, we found evidence that women's intrahousehold bargaining power is associated with a high probability of transitioning from traditional to mixed fuels for heating. Compared with the base category, a considerable women's bargaining power increased the odds of using mixed fuel by  0.043 for heating, confirming the evidence of fuel stacking (using multiple fuels). This finding indicates that although women's intrahousehold bargaining power is positively associated with clean fuel choice, it does not guarantee a complete transition from traditional to clean fuel use.

Overall, our findings underscore the importance of women's bargaining power as a nonincome/price driver of household energy transition in emerging economies. Moreover, beyond traditional income/prices instruments, policies that enhance women's bargaining power can contribute to household energy transition, thereby reducing indoor pollution and its harmful health effects associated with traditional fuel use. Such policies may include cash transfers targeting women, especially divorced mothers, bolstering women's labor market participation via daycare service provision, defining marital property, and regulating its division upon divorce. In a broad sense, our research demonstrates that improving women's bargaining power is a viable response to climate change because it would reduce traditional/biomass fuel use.

Although women's negotiating power significantly influences household energy decisions, affordability remains a substantial obstacle to adopting sustainable energy, particularly for marginalized groups. Chapter 4 examines the influence of social transfers, particularly the OAP, on energy poverty in senior households. This chapter employs an RDD to investigate whether increasing household income via pension payments can promote a shift toward clean energy sources. This inquiry is particularly significant within the framework of the South African comprehensive social grant system and the escalating energy expenses faced by senior households.

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# Chapter 4 : Energy Poverty Effects of South African Unconditional Cash Transfer: Evidence from RDD Analysis


**Abstract**

Electricity access remains a significant challenge across many African countries, where households without access to electricity often rely on dirty fuels, resulting in energy poverty and harmful indoor pollution. This study uses an RDD to evaluate the impacts of OAP on energy poverty in South Africa. Findings indicate a significant reduction in energy poverty, with households that include at least one pension-eligible member experiencing a decrease in energy poverty by approximately 4 percentage points. Findings for the urban subpopulation indicate a significant reduction in energy poverty by approximately 10 percentage points, suggesting the effectiveness of financial support in improving energy access in urban settings. However, the analysis results exhibit no significant impacts on rural households, suggesting the need for complementary policies to address infrastructure and clean energy access in rural areas. This study contributes to the literature by providing a nuanced understanding of the differential impacts of OAPs on energy poverty across urban and rural contexts. The findings have significant policy implications, underscoring the importance of integrating social welfare programs with targeted energy solutions to alleviate energy poverty and improve the well-being of vulnerable populations.



**Keywords:** energy poverty, old-age pensions, energy, indoor pollution

**JEL Codes:** D13, J10, Q40, Q53

## 4.1. Introduction

Electricity access remains a significant challenge in many African countries, with approximately 600 million people living without electricity globally. Sub-Saharan Africa accounts for more than half of this population, with about 565 million people lacking access to electricity (Timmermans and Birol, 2021; International Energy Agency [IEA], 2025). The lack of access to electricity forces households to rely on traditional dirty fuels such as firewood, charcoal, and biomass. This reliance results in energy poverty, which is characterized by the inability to access clean and modern energy sources. In addition, using dirty fuels results in significant indoor air pollution, contributing to severe health problems, such as respiratory diseases and premature deaths (Jessel et al., 2019; Moniruzzaman and Day, 2020; Alem and Demeke, 2020; Wang and Lin, 2022). According to the World Health Organization (2010), approximately 2.5 million people die annually from household indoor pollution.

The situation is exacerbated by fluctuations in fossil fuel prices, making it increasingly difficult for low-income households to satisfy their energy needs (Lee and Shepley, 2019). This challenge is particularly acute in countries such as South Africa, where energy poverty intersects with other forms of socioeconomic disadvantage. Despite significant progress in electrification, from 61% in 1994 to 86% in 2022 (Lemanski et al., 2025), many households still rely on solid fuels for specific energy uses owing to the high electricity cost and the instability of supply. Energy poverty is not merely a technical problem related to infrastructure access; it is deeply intertwined with a broad socioeconomic condition.

Besides the commendable improvement in household electricity access, electricity prices have increased outpacing inflation. According to Bohlmann and Inglesi-Lots (2021), electricity prices have increased by around 25% since 2008, wherease South African inflation has been around 5%. Boardman (2011)'s energy poverty threshold states that households who spend more than 10% of their income on household energy consumption are regarded as energy poor. Bohlmann and Inglesi-Lotz (2018) stated that some households in South Africa spend more than 20% on household energy. Households that cannot afford clean energy often resort to cheap, more polluting alternatives, which creates a vicious cycle of poverty and health risks. This issue is especially pronounced for vulnerable groups such as the older population, who typically have low incomes and spend more time at home, increasing their exposure to inadequate energy access and its negative health impacts (Sanchez-Guevara et al., 2019; Chesser et al., 2022). In South Africa, OAP is a critical source of financial support for the elderly. However, whether this support is sufficient to mitigate energy poverty remains. Although the general welfare benefits of cash transfers are well documented, their specific impacts on energy poverty have not been thoroughly explored, particularly in the contexts of demographic and geographic disparities.

While extensive, the literature on energy poverty reveals several critical gaps, especially concerning the intersection of cash transfers and energy poverty. Most existing research (Davis *et al.,* 2016) has focused on the broad welfare impacts of programs like the OAP, such as their effects on income, health, and education. However, relatively little attention has been paid to how cash transfers influence energy access, particularly in addressing the ability of households to transition from traditional, polluting fuels to modern, clean energy sources. This lack of focus is particularly evident in studies that examined vulnerable populations, such as older people, who face acute challenges in accessing clean energy owing to their limited financial resources and high energy needs. Because they spend more time at home and rely more on energy for heating and other basic needs, older people are likely to experience the acute effects of energy poverty. Moreover, their specific circumstances are often overlooked in the broad discourse on energy access.

A further gap in the literature is the geographic context of energy poverty. Most of the existing research has focused either on rural areas, where access to energy infrastructure is limited, or on general populations without specific attention to the urban–rural divide. Studies such as those by Gelo et al. (2023) have explored household energy transitions but have not adequately addressed the acute challenges that urban populations face wherein energy poverty is often driven by affordability rather than access. In urban areas, households may have grid connectivity but still face energy poverty owing to high electricity costs and the unreliability of supply. This creates a complex form of energy poverty that is distinct from the challenges faced by rural households with no access to the electricity grid, which heavily relied on traditional fuels such as wood and charcoal. However, most studies, such as those by Moniruzzaman and Day (2020) and Gafa and Egbendewe (2021), focused on rural populations and failed to capture the full spectrum of energy poverty, mainly because it affects urban households.

Another significant gap is the lack of a nuanced understanding of how energy poverty affects different demographic groups. Older people, in particular, are often marginalized in energy poverty discussions despite being disproportionately affected owing to their low incomes and high energy needs. Although studies on cash transfers and welfare programs have documented the overall benefits of financial support for households, these studies frequently failed to analyze how such programs impact specific forms of deprivation, such as energy poverty. This is a critical oversight given the expected rise in the global elderly population, particularly in developing countries such as South Africa. The World Health Organization (2022) projected that by 2050, the global population of people over 60 will nearly double, with significant growth in Northern and Sub-Saharan Africa. As the population ages, understanding how social programs such as OAPs affect access to energy becomes increasingly important.

The South African unique social grant system, one of the largest in the developing world, provides a crucial opportunity to explore the interaction between social welfare programs and energy poverty. Despite its broad reach, considerably few studies have examined how this system, particularly the OAP, influences energy poverty outcomes. This gap in the literature is particularly relevant given the complex and multidimensional nature of energy poverty in South Africa. Rural households often face significant infrastructure deficits, whereas urban households, although connected to the grid, struggle with energy affordability. The distinct nature of energy poverty across urban and rural settings requires a more granular analysis of how cash transfers impact different populations. Understanding how pensions influence energy consumption in these different contexts can offer valuable insights into how social programs can be leveraged to effectively reduce energy poverty.

Moreover, while several studies have explored the health impacts and economic consequences of relying on traditional fuels, few have examined how financial support from social grant programs directly influences household energy choices. Existing research on energy poverty has emphasized technical or infrastructural aspects, such as expanding grid connectivity or promoting renewable energy sources. Although these are important drivers, they do not fully capture the role of financial constraints in shaping household energy behavior. For instance, even when clean energy is available, households may continue to rely on cheap, polluting fuels if they lack the financial resources to pay for electricity or clean alternatives. This is where cash transfers such as the OAP could play a transformative role; however, the literature remains sparse on this topic.

Our research aimed to respond to this paucity by providing a detailed analysis of the impact of South Africa's OAP on energy poverty. First, it addresses the underexplored link between cash transfers and energy poverty by applying a rigorous econometric approach—RDD—to estimate the causal effect of pension eligibility on household energy consumption patterns. By isolating the effects of pension income, this study offers robust causal evidence on how financial support influences household decisions about energy consumption, such as whether households can shift away from traditional fuels and toward modern energy sources.

Second, our study contributes to the literature by examining the differential impacts of the OAP on energy poverty in urban and rural settings. Although much of the existing research focuses on rural areas (Moniruzzaman and Day, 2020; Gafa and Egbendewe, 2021; Baozhong et al., 2022; Ren and Xiong, 2023), where infrastructure deficits are prominent, this study includes a comprehensive analysis of energy poverty across urban and rural contexts. In rural areas, the key issue is often the lack of access to electricity infrastructure. By contrast, the primary challenge in urban areas is the increasing energy cost despite grid access. This distinction allows us to make more nuanced policy recommendations tailored to the acute needs of each context. For instance, while investments in infrastructure may be critical for reducing energy poverty in rural areas, urban households may benefit more from policies aimed at making energy more affordable, such as subsidies for clean energy technologies or energy-efficient appliances.

By specifically focusing on the elderly population, our research adds a new dimension to the literature on energy poverty. Older people, who typically have low incomes and high energy needs, are often overlooked in studies on energy access. This study demonstrates how the OAP can be a vital safety net for this vulnerable group, reducing their reliance on dirty fuels and allowing them to access clean, more affordable energy. The findings of this study provide important insights for policymakers seeking to address the growing issue of energy poverty among aging populations, particularly in developing countries with rapidly aging societies.

Finally, this study extends beyond academic contributions by offering practical policy implications. The results provide evidence-based recommendations for integrating social welfare programs with energy policies, indicating that cash transfers such as the OAP can effectively reduce energy poverty when complemented by targeted energy interventions. This integration is crucial for achieving long-term, sustainable energy solutions that improve access to modern energy services while enhancing the overall well-being of vulnerable populations.

Overall, this research advances the understanding of energy poverty by bridging the gap between social welfare programs and energy access. In addition, it offers critical insights into how cash transfers can alleviate energy poverty, particularly among vulnerable groups such as older people and across diverse geographic contexts. By providing a detailed and context-specific analysis, this study contributes to the academic literature and practical policy discussions on reducing energy poverty and improving the quality of life for disadvantaged populations.

The remainder of this chapter is organized as follows: Section 2 provides an overview of the OAP and its assignment mechanism. Section 3 discusses energy poverty measurements.

Section 4 details the methodology used in this study. Section 5 and 6 presents the results and discussions. Finally, Section 7 concludes the paper with a summary of the findings and policy implications.

### 4.2. OAP and Its Assignment Mechanism

The OAP is an unconditional cash transfer received by individuals aged 60 and older. Old-aged individuals in less developed countries are often poverty stricken; most survive on OAPs. According to Kakwani et al. (2006) and Peresypkina and Nesterenko (2023), countries globally have used social protection to assist struggling households. Social protection policies are a safety net for vulnerable households; they are designed to reduce inequality and ensure that the citizens are protected from hardships and economic shocks.

Generally, in Sub-Saharan Africa, cash transfer programs have been administered to increase people's welfare. South African social programs account for 3.3% of the gross domestic product (World Bank, 2020). Of the total grant recipients in South Africa (18.3 million beneficiaries), the old-age grant has the second most beneficiaries (3.9 million beneficiaries) after the child support grant (13.1 million beneficiaries) (National Treasury, 2024).

Cash transfers have several positive benefits. According to the International Labor Organization (2016), old-age grants reduced poverty among older people from 56% in 2006 to 36% in 2011. In addition, many studies also found that cash transfer programs increase general household expenditures (Attanasio and Lechene, 2014; Bazzi et al., 2015; Cahyadi et al., 2020; Shapiro and Haushofer, 2016). Moreover, the programs benefit the recipient and the entire family (Chepngeno-Langat et al., 2019).

In South Africa, age is the first, but not the only, condition for eligibility for the old-age grant. In addition, individuals should have an annual or monthly income of less than R86,280 ($4541[6]) or R7190 ($378). The monthly income currently received for the OAP is R2180 ($115). The grant variable in the survey is represented by a "yes" or "no" question that asks if an individual receives an OAP (South African Government, 2024).

### 4.3. Energy Poverty Measurements

Currently, no universal measurement for energy poverty exists. It is an evolving concept that has been differently quantified (Thomson et al., 2017). The most common definition concerns the lack of access to modern fuels, such as electricity, natural gas, liquefied natural gas, and other deemed modern fuels (Pachauri et al., 2012). The definition of energy poverty differs in different parts of the world and is culturally sensitive; hence, its measurement is also multidimensional.

In developed countries, energy poverty is related to costs, that is, when a household spends a lot of money on household energy fuel, also called fuel poverty. A household is considered energy poor if it spends more than the average energy expenditure (Isherwood and Hancock, 1978; Bonatz et al., 2019). On the contrary, in developing countries, energy poverty is often related to the lack of modern energy access. Inadequate energy provision may result in the consumption of dirty energy sources such as biomass and firewood (Karpinska and Smiech, 2020; Reddy and Srinivas, 2009).

Objective and subjective measures have been previously used in the literature. Objective approaches are embedded in the relationship between income and expenditure, whereas

[6]The exchange rate used is R19 for 1$

subjective approaches are self-reported based on household perceptions (Awaworyi, 2020; Churchill and Smyth, 2021; Aristondo and Onaindia, 2023). Critics of subjective approaches claimed that objective measures are more accurate and provide credible evidence for policymaking (Charlier and Legendre, 2019). On the contrary, the subjective approach enthusiasts believe that individuals know their circumstances and what they need in their households. Hence, they are better suited to measure their needs (Thomson et al., 2017). However, both approaches have advantages when used in different settings (Price et al., 2012; Wang et al., 2020).

According to Aristondo and Onaindia (2023), a subjective indicator can be measured using the perpetual line, which entails using subjective variables. In this approach, the basic energy requirements for a decent life are established. These requirements are being able to pay for the electricity required by the household, keeping the house warm, and not having leaking roofs or damp walls. If households cannot satisfy these basic requirements, they are deemed energy poor.

The most common objective energy poverty indicators mentioned in the literature (Wang *et al.,* 2023) are economic indicators, composite indicators, and multidimensional indicators (MEPI). The economic indicators used household income and energy costs to quantify energy poverty. Composite indicators consist of different information that are aggregated into a single indicator. Multidimensional Energy Poverty Index (MEPI) were proposed by Nussbaumer et al. (2012) and include several dimensions and indicators, making them more comprehensive. We used the MEPI in this study to quantify the energy poverty indicator. MEPI follow a two-step approach (Crentsil et al., 2019) wherein energy-poor households are identified based on specific thresholds and weights are used and the indicators are combined to form one uniform indicator. Subsequently, energy poverty was determined from the threshold of the general indicator (Wang et al., 2023).

MEPI have evolved overtime with different authors using different weights based on the country of interest (Nussbaumer et al., 2012; Sher et al., 2014; Bollino and Botti, 2017; Yip et al., 2020; Ugembe et al., 2022; Wang et al., 2023). We followed the approach of Ye and Koch (2023) who used MEPI to estimate energy poverty in South Africa.

**The South African case**

In South Africa, energy poverty is characterized by access and affordability issues. Some households still have no access to electricity (10%). Energy poverty continues to widen in South Africa, regardless of the amount of electricity invested. However, the cost of energy for households is also high (Monyei and Adewumi, 2017). Huge electricity spending can prompt households to make poor energy choices that may be more affordable. This is evident in South Africa. In addition, Bohlmann and Inglesi-Lotz (2018) found that despite the high electrification rate of the country and the FBE policy that the government introduced to assist struggling households by giving them 50 kW/h of free electricity per month for basic needs, low-income households still use firewood and paraffin for cooking owing to their low cost and perhaps their availability.

## 4.4. Methodology

### 4.4.1. Econometrics

We used an RDD to estimate the causal impacts of OAP eligibility on energy poverty in South Africa. Thistlethwaite and Campbell initially introduced the identification strategy in 1960 (Thistlethwaite and Campbell, 1960). RDD is a powerful quasi-experimental method, especially suited for cases wherein treatment assignment depends on a cutoff point, as it does here, with aged 60 being eligible for the OAP. The pension eligibility age provides a clear and exogenous threshold, allowing for a comparison between households just above and below this threshold. In addition, according to Yuan et al. (2023), allowing this study to isolate the effects of pension receipt from other potentially confounding factors and ensures that the comparison between treated and untreated households is valid.

The distinction between sharp and fuzzy RDD is essential here. In a sharp RDD, treatment assignment is strictly determined by whether an individual is above or below the cutoff point (Yuan et al., 2023). In a fuzzy RDD, compliance is imperfect. Individuals who qualify for the treatment may not take the treatment, whereas those who do not qualify may take the treatment (Cattaneo et al., 2024). In this case, individuals aged 60 or older qualify for the OAP, whereas those younger than 60 do not, ensuring a clean distinction between the treatment group (those aged 60 or above) and the control group (those below 60). The analysis here focused on a sharp RDD because the eligibility for the pension is strictly determined by the age threshold, making the assignment clear and unambiguous (Cattaneo et al., 2019). Although there are additional income-based eligibility requirements for the pension, this analysis concentrates on the age threshold as the primary assignment variable, assuming that those who reach the age of 60 receive the retirement and those younger than 60 do not. The econometric model can be specified as follows:

$$Y_h = \beta_0 + \beta_1 D_h + \beta_2 f(age_i) + X_h \gamma + \varepsilon_h \tag{4.1}$$

where $Y_h$ is the energy poverty for household - $h$, is the multidimensional energy poverty index that we construct in the section that follows . The treatment indicator $D_h$ takes the value of 1 if the household has a member aged 60 or older (eligible for the pension) and 0 otherwise. The function $f(age_i)$ accounts for the flexible relationship between age and the outcome variable, ensuring that the comparison between households near the age cutoff is valid and smooth. This function can take a linear form or includes higher-order polynomials to capture nonlinearities in the relationship between age and energy poverty. The vector $X_h$ consists of additional control variables such as household size, income, and urban/rural status, whereas $\varepsilon_h$ is the error term capturing unobserved factors affecting energy poverty. The key parameter of interest is $\beta_1$, which measures the causal impacts of pension eligibility on energy poverty. Moreover, the function $f(age_i)$ ensures correct modeling of the age variable near the cutoff.

The RDD approach must hold several assumptions to provide valid causal estimates. First, a continuity in the conditional mean of the outcome variable around the cutoff must exist. In other words, households above and below the age of 60 must be comparable, with the only systematic difference between them being their eligibility for the pension. This ensures that any observed difference in energy poverty can be attributed to the pension receipt. Including the smooth function $f(age_i)$ in the model helps account for this by allowing the relationship between age and energy poverty to smoothly vary around the cutoff.

In addition, it is assumed that the running variable (age) is not manipulated. Because age is determined long before pension eligibility and cannot be easily manipulated, this assumption is highly plausible in this context.  We verify this assumption using a McCrary test, which examines for any discontinuity in the density of observations around the cutoff. The results of the McCrary test confirmed that age was not manipulated and that the running variable was valid for this analysis.

Another critical assumption in RDD is local randomization. The idea here is that households near the cutoff can be regarded as if they were randomly assigned to receive or not receive the pension. This assumption is critical because it allows us to interpret the differences in outcomes between households that are just above or below the threshold as causal effects of pension eligibility. The assumption of local randomization strengthens the causal interpretation of the findings and justifies the use of RDD as a reliable method in this context.

One of the key decisions in the RDD analysis is the choice of bandwidth—the range of observations around the cutoff included in this study. A smaller bandwidth focuses the analysis on households significantly close to the cutoff, reducing bias but increasing variance owing to the small sample size. A large bandwidth increased the number of observations, potentially reducing variance but introducing bias by including households further from the threshold (Hagemeier et al., 2022). To optimize this tradeoff, this study employed a data-driven bandwidth selection method recommended by Cattaneo et al. (2019, 2024), which minimized the mean squared error of the treatment effect estimate. This approach ensures that the bandwidth is wide enough to provide sufficient observations for analysis while remaining narrow enough to maintain comparability between treated and untreated households near the cutoff. To further ensure robustness, different bandwidths are tested, and the consistency of the results across bandwidth sizes strengthens the credibility of the findings.

Regarding the functional form of the running variable, linear and higher-order polynomials are considered $f(age_i)$ to capture the potential nonlinear relationships between age and energy poverty. Although a linear form might suffice in some cases, a higher-order polynomial can better capture any complexities in the relationship between age and the outcome variable. To avoid overfitting, this study utilized local linear regressions, which fit separate linear regressions on either side of the cutoff, minimizing the risk of model misspecification. Goodness-of-fit criteria and robustness checks guide the choice of the functional form to ensure that the treatment effect estimates are not sensitive to the choice of model.

Several robustness checks were conducted to validate the results. One crucial check involves placebo tests wherein the RDD framework is applied at false cutoffs (e.g., ages 40, 50, 70, and 80) to verify that the observed effects are specific to the age 60 cutoff and not a product of random variation or unobserved confounding factors. If the results show significant treatment effects at other age cutoffs, this would cast doubt on the validity of the analysis. In addition, covariate balance tests were conducted to ensure that households just above and just below the threshold were comparable in terms of observable characteristics, such as household size, education, and income. The balance of these covariates around the cutoff value supports the validity of the RDD design.

#### 4.4.2. The Multidimensional Energy Poverty Index (MEPI)

MEPI comprises several energy dimensions and indicators. The dimensions are the elemental energy needs a typical household should have. The originator of MEPI, Nussbaumer et al. (2012), used five dimensions and six indicators. In recent years, the authors have used different dimensions and indicators to quantify MEPI, depending on the problems and data availability of a county. We followed the approach of Ye and Koch (2023), who used two dimensions: electricity access and affordability. The authors used five dimensions: fuels for cooking, lighting, space heating, and water heating and the ratio of household required energy expenditure to total expenditure. Weights are allocated to the dimensions, which are supposed to add up to one. Ye and Koch (2023) used a 50/50 split between access and affordability.

Subsequently, the allocated weights were distributed among the indicators based on their relative importance. We display the weights below.

**Table 4-1.** MEPI dimensions and indicators by Ye and Koch (2023)

| Dimension (weight) | Indicator (weight) | Deprived if? |
|---|---|---|
| Access to electricity (0.5) | Clean fuels for cooking (0.15) | The household primarily used fuel other than electricity, gas, or solar energy. |
| | Clean fuels for lighting (0.15) | |
| | Clean fuels for space heating (0.1) | |
| | Clean fuels for water heating (0.1) | |
| Affordability (0.5) | The ratio of household required energy expenditure to total expenditure (0.5) | The ratio is greater than 10%. |

We followed the same process as presented in Table 4-1. However, we slightly differ in terms of fuels for space heating because we do not have the space heating data in isolation in our sample. Hence, our study consists of five indicators. Table 4-2 presents our indicators and weights.

**Table 4-2.** MEPI dimensions and indicators adapted from Ye and Koch (2023)

| **Dimension (weight)** | **Indicator (weight)** | **Deprived if?** |
|---|---|---|
| Access to electricity (0.5) | Clean fuels for cooking (0.2) | The household primarily used fuel other than electricity, gas, or solar energy. |
| | Clean fuels for lighting (0.1) | |
| | Clean fuels for heating (0.2) | |
| Affordability (0.5) | The ratio of household energy expenditure to total household expenditure (0.5) | The ratio is greater than 10%. |

In addition, we slightly altered the weighing in the access indicators and allocated equal weights to the cooking and heating fuels. According to Bohlmann and Inglesi-Lotz (2018), South African households consume approximately 90% of their household energy by cooking and heating; the remaining 10% is for lighting. Moreover, the General Household Survey (2023) revealed that approximately 30% of households preferred to cook with solid fuels (wood). Furthermore, cooking is said to have a higher risk of indoor air pollution because food is often cooked indoors more than once a day. Koomson and Churchill (2022) also weighed more on cooking (0.2) when calculating the MEPI for similar reasons.

Moreover, the survey indicates that wood was the most preferred solid fuel for heating. According to Walt et al. (2024), inhaling firewood smoke is more detrimental than smoking. Therefore, we decided to slightly lower the lighting fuel weight and put more weight on cooking and heating, as shown in Figure 4-2.

We allocated a significant weight to affordability because increasing electricity prices have been a major issue in South Africa. Even though South Africans have had to deal with regular power outages, electricity prices have kept increasing to fund the necessary electricity infrastructure (DOE, 2018). Households have been battling high cost of living, coupled with high energy tariffs. When comparing South Africa's energy tariffs to other countries like the BRICS countries, South Africa tariffs range between 15% and 64% higher. For example, in 2023, the electricity tariff for South Africa was R3.29 ($0.173) per kWh, while it was R2.79 ($0.147) for Brazil and R1.41($0.074) for India (MyBroadband, 2024).

Note that our affordability measurement differs from that of Ye and Koch (2023), who used required energy expenditure, which requires prices. Meanwhile, we did not have the price variable in our database. Instead, we used the per capita energy expenditure ratio relative to per capita household expenditure. The resultant variable is a dummy, 1 if the ratio is more than 10% and 0 otherwise.

The energy ratio measurement stems from the study of Boardman (1991), who proposed a 10% threshold indicator stating that households that spend 10% more on household energy needs are energy poor. However, we are aware of the downsides to the indicator; high-income households may appear energy poor when they spend more than the stated 10% threshold (Herrero, 2017; Churchill et al., 2020; Aristondo and Onaindia, 2023). The other indicators in the access dimension will cream off the well-off households during the weighing process.

The MEPI was constructed using the Alkire–Foster (AF) method. The dimension weights should sum up to 1. After deliberating on the indicators and their weights, they are averaged to obtain the deprivation score *k*. Households are considered energy deprived when the deprivation score is more than *k*,0. 33. This deprivation cutoff has been used in several previous studies (Ugembe et al., 2022; Crentsil et al., 2019). For instance, Ugembe et al. (2022) also considered *k* 0.4 in their study. However, other studies used the *k* 0.2 cutoff (Awan et al., 2014; Ye and Koch, 2023), which Ye and Koch termed as moderate energy poor, meaning that households are deprived of at least one-fifth of the indicators. It is worth testing moderate energy poverty in a country with high energy access such as South Africa (90%). In our study, we used the *k* 0.2 cutoff, which means that households are deprived of at least a quarter of the weighted indicators. Because we have four indicators, a cutoff of *k* 0.33 may mean that we are estimating extreme energy deprivation.

The next step was to obtain a headcount ratio, which consists of the aggregate of the deprived households (those with a cutoff of *k* 0.2 in our study) divided by the total number of households in the sample as follows:

$$\text{MEPI} = \text{H} \times \text{A} \qquad (4.2)$$

where $H$ is the headcount ratio and $A$ is the deprivation score. Similar to the approach used by Koomson and Churchill (2022), we converted MEPI to a binary variable and used it as a dependent variable in our RDD analysis.

### 4.4.3. Data

We used a rich nationally representative panel survey dataset called the NIDS, which covers five waves. The University of Cape Town collected the data. The first wave was collected in 2008, and subsequent waves were collected every second year. The same households are tracked over the five waves. The panel tracks over 28,000 individuals and 7300 families, revealing the structure of South African households and their changing living conditions. The database provides a robust basis on which to assess the impacts of OAPs on energy poverty.

## 4.5. Results

The first section of the results presents the descriptive statistics, followed by the empirical results.

### 4.5.1. Descriptive Statistics

Table 4-3 presents the descriptive statistics for the five waves used in this study. The sample includes 52,247 rural and urban households.

**Table 4-3.** Descriptive statistics.

| Variables | Full sample | | | Urban sample | | | Rural sample | | |
|---|---|---|---|---|---|---|---|---|---|
| | Obs. | Mean | Standard Dev. | Obs. | Mean | Standard Dev. | Obs. | Mean | Standard Dev. |
| Electricity expenditure | 29 423 | 157.840 ($8) | 123.448 | 15 486 | 183.392 ($10) | 131.828 | 12 541 | 130.600 ($7) | 104.710 |
| Other energy expenditures | 13 808 | 40.448 ($2) | 44.341 | 6 225 | 36.878 ($2) | 45.302 | 6 433 | 43.857 ($2) | 42.881 |
| Total energy expenditure | 52 247 | 173.104 ($9) | 387.41 | 26 781 | 224.383 ($12) | 455.524 | 17 246 | 142.835 ($8) | 217.627 |
| Household expenditure | 38 956 | 2617.031 ($138) | 3824.810 | 21 000 | 3364.525 ($177) | 4610.679 | 15 122 | 1676.546 ($88) | 2173.478 |
| Household size | 42 477 | 4.088 | 2.776 | 23 047 | 3.572 | 2.353 | 16 339 | 4.888 | 3.103 |
| Education | 43 385 | 11.982 | 6.339 | 23 581 | 11.848 | 5.554 | 16 336 | 12.232 | 7.197 |

On average, households in the sample spend R173 ($9) on household energy, with electricity amounting to R158 ($8) of this expenditure, and other fuels, for example, dirty fuels, such as wood or cow dung making up R40 ($2). Generally, approximately 23% of household energy expenditure goes to other fuels. The share of solid fuels in the rural sample was higher (31%) than in the urban sample (17%). This is expected because most households with no access to electricity are in the rural areas. Moreover, the 17% share in the urban sample indicates that the dirty fuel issue is prevalent not only in rural areas but also in urban areas. There are approximately four people in the household in the sample, and most households have 12 years of education, which is high school education in South Africa. Table 4-4 presents the distribution of household energy expenditure for different energy services.

**Table 4-4.** Household energy expenditure distribution.

| Household fuel types | Full sample | Urban | Rural |
|---|---|---|---|
| **Cooking fuel** | | | |
| Electricity | 75% | 89% | 58% |
| Gas and solar | 3% | 4% | 2% |
| Dirty fuels | 22% | 8% | 39% |
| **Heating fuel** | | | |
| Electricity | 62% | 76% | 46% |
| Gas and solar | 1% | 2% | 1% |
| Dirty fuels | 28% | 14% | 45% |
| **Lighting fuel** | | | |
| Electricity | 86% | 93% | 78% |
| Gas and solar | 1% | 0% | 1% |
| Dirty fuels | 14% | 7% | 20% |
| **Cooking fuel if pension = 1** | | | |
| Electricity | 66% | 88% | 52% |
| Gas and solar | 3% | 3% | 2% |
| Dirty fuels | 31% | 9% | 46% |
| **Heating fuel if pension = 1** | | | |
| Electricity | 53% | 74% | 39% |
| Gas and solar | 1% | 2% | 1% |
| Dirty fuels | 38% | 15% | 52% |
| **Lighting fuel if pension = 1** | | | |
| Electricity | 82% | 94% | 75% |
| Gas and solar | 1% | 0% | 1% |
| Dirty fuels | 17% | 6% | 23% |

As shown in Table 4-4, households mostly use electricity as the main fuel for cooking and lighting in rural and urban areas. However, almost 40% of cooking used dirty fuels in rural areas. Clean energy sources such as gas and solar only account for 3% of cooking and 1% of heating in the total sample. Dirty fuels are mostly used in heating (almost 30%).

A striking observation is the use of dirty fuel for heating by rural households, with almost a 50/50 split for electricity and dirty fuels. In urban households, over 10% of heating used dirty fuels. In addition, this emphasizes that dirty fuels are prevalent not only in rural areas but also in urban households. Walt et al. (2024) alluded to this, stating that high-income South Africans utilize indoor fireplaces using firewood to keep their house warm during cold days. On the contrary, poor households burn charcoal or firewood indoors to keep their house warm; hence, the use of dirty fuels for heating is not surprising and cuts across all income groups. Moreover, less dirty fuel was used for lighting compared with cooking and heating in the sample. Rural households have a high share of dirty lighting fuels (20%), which is expected because access to electricity is mostly lacking in rural areas.

Pensioners mostly use electricity in all three energy services. For the full sample of pensioners, dirty sources were mostly used for heating (38%), which is higher than the general heating fuel use. In addition, the share of dirty fuels used by rural pensioners is 7% higher (52%) than the average rural household heating. Studies have shown that the elderly may require more heating (Bardazzi and Pazienza, 2017) because they spend more time at home. This underscores the need to create targeted policies that are inclusive of the elderly. For lighting, pensioners' household energy use follows the same trend with the full sample; dirty fuel lighting is less compared with cooking and heating.

As shown in Figure 4-1, the number of households that are energy deprived in the sample was presented. In our sample, we have 52,247 households.

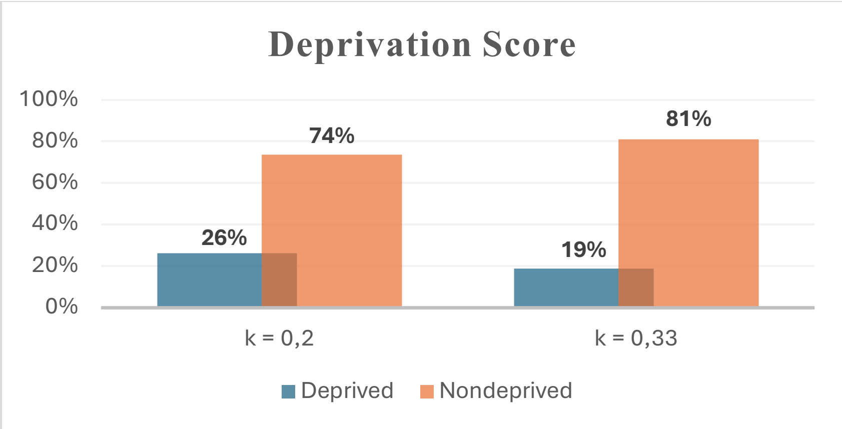



**Figure 4-1.** Share of moderate and extreme energy deprivation.

Approximately 26% of households are deprived of at least a quarter of the energy indicators. Using the *k* 0.33 threshold reveals that there is <20% of households that are in almost extreme energy deprivation.

We further split the deprivation picture of our threshold of interest *k* 0.2 in Figure 4-2 to present the urban and rural energy deprivations.

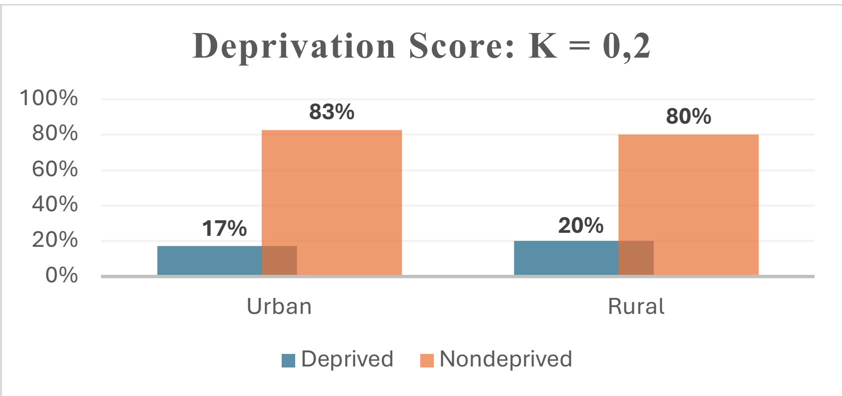



**Figure 4-2.** Share of moderate energy deprivation among urban and rural subsamples.

More households are deprived in the rural subsample than in the urban sample. In addition, Figure 4-2 presents that energy deprivation is not limited to rural populations. Even though most of the urban populations are have access to electricity, they suffer from one or more forms of energy deprivation.

### 4.5.2. Empirical Results

This section details the findings of the RDD analysis, focusing on the impacts of OAP on energy poverty among South African households with at least one member eligible to receive the OAP. We first plotted the outcomes and exposure variables on the graph, as shown in Figure 4-3. The breakpoint in the graph above is evidence of the need to investigate the causal impacts of the OAP on energy poverty. If OAP had no impacts on pensions, the curve would have been continuous and smooth around the age 60 cutoff.

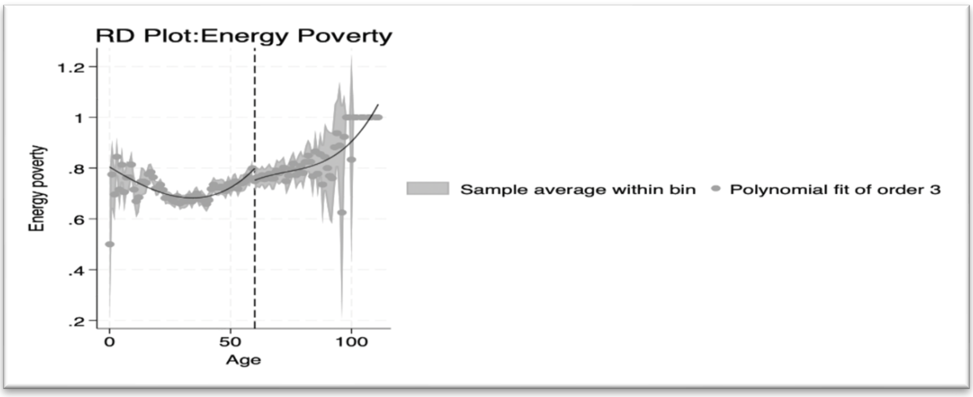



**Figure 4-3**. Discontinuity in energy poverty around the age eligibility cutoff for the OAP.

#### a. Validity of the results

One of the main RDD assumptions is the validity of the eligibility criteria. The density should be smooth around the eligibility cutoff (age 60). Figure 4-4 validates the assumption because it is smooth in our study. Second, the eligibility criteria need not suffer from manipulation. Age, which is our eligibility criteria for the OAP program, is highly unlikely to be manipulated because one cannot choose when to be born. The birth date occurred way before the program. Therefore, age cannot be tampered with to qualify for the program.

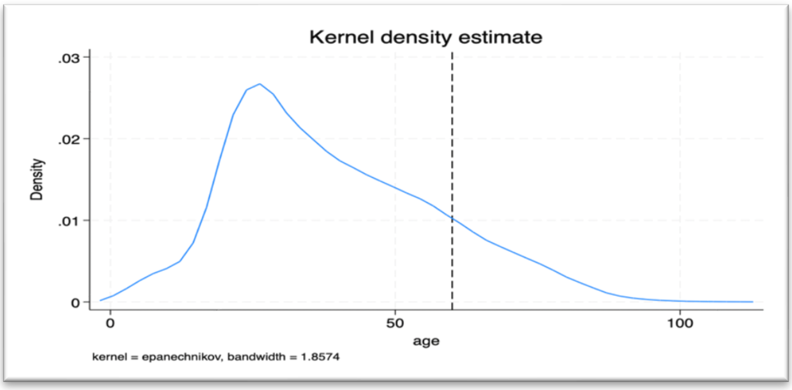
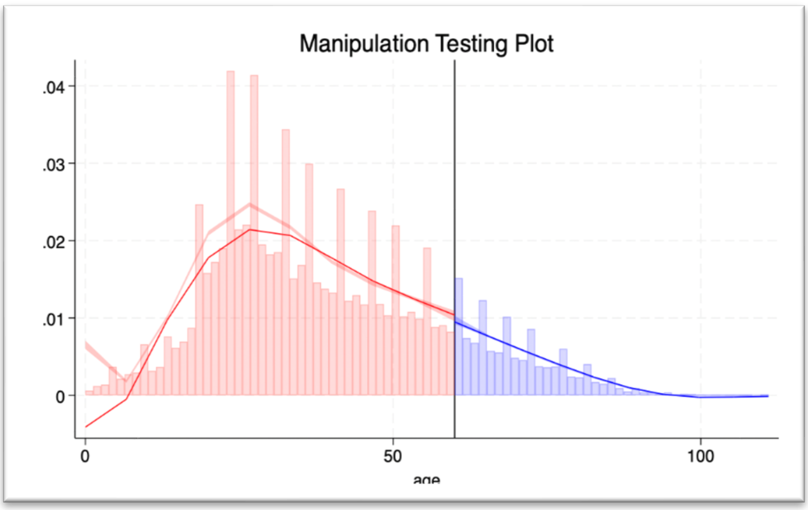



**Figure 4-4.** Kernel density estimation.

We used the McCrary (2008) test to validate the assumption that no manipulation was present. Figure 4-4 presents a discontinuity with a *p* value from the test of 0.44. We failed to reject the null hypothesis that no discontinuity exists in the density of the age at the cutoff.




| Method | T | P>T |
|---|---|---|
| Robust | -1.281 | 0.200 |

**Figure 4-5.** RD manipulation test using local polynomial density estimation.

### b. Placebo results: different ages

The other validity assumption states that the causal impact must not be as a result of other points along the eligibility criteria. Because age is our eligibility criterion, we test the causal impact on hypothetical ages 40, 50, 70, and 80 years to validate that only the 60-year-old government retirement age has an impact on energy poverty. Table 4-5 presents the average treatment effect (ATE) estimates for the above-stated ages. These coefficients indicate that no impacts were observed on the other ages.

**Table 4-5.** ATE estimates for other ages in the general population.

| Methods | c = 40 years | c = 50 years | c = 70 years | c = 80 years |
|---|---|---|---|---|
| Conventional | −0.003 | −0.008 | 0.005 | −0.004 |
| | (0.017) | (0.016) | (0.023) | (0.036) |
| Bias-corrected | −0.003 | 0.010 | −0.003 | −0.009 |
| | (0.017) | (0.016) | (0.023) | (0.036) |
| Robust | −0.003 | 0.010 | −0.003 | −0.009 |
| | (0.027) | (0.025) | (0.036) | (0.058) |
| Observations | 50 817 | 50 817 | 50 817 | 50 817 |
| Bandwidth | 8.642 | 10.760 | 9.987 | 7.433 |

Standard error in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Note that the presence of a similar social transfer can invalidate the results. Although South Africa has several social income transfers, none are identical to the OAP. The other transfers have different requirements and age group eligibility and do not include 60-year-olds.

RDD studies are often conducted with and without covariates, strengthening the results. In our research, we included the education covariate. Previous studies (Apergis et al., 2022; Ang'u et al., 2023; Paudel et al., 2023) have demonstrated that education has positively impacted clean energy adoption. However, for covariate validity, education should not have a causal impact on energy poverty. The results in presented in Table 4-6 prove this.

**Table 4-6.** ATE estimates for the education covariate for the general population.

| Methods | Coefficients |
|---|---|
| Conventional | −0.115 |
| | (0.381) |
| Bias-corrected | 0.364 |
| | (0.381) |
| Robust | 0.364 |
| | (0.591) |
| Observations | 43 359 |
| Bandwidth | 9.526 |

Standard error in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

The education covariate is valid. This shows that education does not have causal impacts on energy poverty. We are confident that the covariate can be included in the model.

### c. Estimates of the econometric analysis

Table 4-7 presents the ATE estimates for the total sample, including urban and rural populations.

**Table 4-7.** ATE estimates for the general population.

| Methods | No covariate | With covariate |
|---|---|---|
| Conventional | −0.022 | −0.028* |
| | (0.014) | (0.015) |
| Bias-corrected | −0.043*** | −0.049*** |
| | (0.014) | (0.015) |
| Robust | −0.043** | −0.049** |
| | (0.021) | (0.023) |
| Observations | 50 817 | 43 359 |
| Bandwidth | 16.869 | 15.630 |
| Covariate (education) | N | Y |

Standard error in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

The bias-corrected estimate in the regression with no covariates indicates a significant reduction in energy poverty. The coefficient is statistically significant at 1%, suggesting an energy poverty reduction of approximately 4 percentage points for the general population in the sample. This indicates that OAP eligibility has causal impacts on reducing energy poverty. The results are similar to the inclusion of the education covariate in the regression; energy poverty could be reduced by 5% because of the OAP social transfer. Moreover, our results solidify the assumption that educated households are mainly likely to switch to clean energy sources with increased income, thereby reducing energy poverty. Since we used a deprivation score of 0.2 in the study, to test the robustness, we also assessed the OAP causal impact on energy poverty using the 0.33 deprivation score. The results are in line with the 0.2 deprivation score, the OAP has a causal impact on energy poverty reduction. This solidifies the confidence in the results signaling that the results are not affected by the threshold choice.

Table 4-8 presents the ATE estimates for the urban and rural subpopulations in isolation.

**Table 4-8.** ATE estimates for the urban and rural subpopulation.

| | Coefficients | | Coefficients | |
|---|---|---|---|---|
| Methods | Urban | Rural | Urban | Rural |
| Conventional | −0.061* | 0.003 | −0.073* | 0.007 |
| | (0.028) | (0.023) | (0.030) | (0.024) |
| Bias-corrected | −0.095*** | −0.004 | −0.101*** | −0.002 |
| | (0.028) | (0.023) | (0.030) | (0.024) |
| Robust | −0.095** | −0.004 | −0.101* | −0.002 |
| | (0.043) | (0.035) | (0.046) | (0.282) |
| Observations | 26 751 | 17 228 | 23 571 | 16 326 |
| Bandwidth | 9.476 | 11.749 | 9.476 | 11.749 |
| Covariate (education) | N | N | Y | Y |

Standard error in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1

The coefficients across the columns represent the ATE of OAP eligibility on energy poverty in urban and rural populations, with and without covariates. The estimates reveal a reduction in energy poverty in urban areas. The conventional estimate has a weak statistical significance for the rural subpopulations, whereas the bias-corrected estimate for the urban subpopulation has a strong statistical significance of 1%. This suggests that OAP may have a causal impact on reducing energy poverty by 10 percentage points. This indicates that OAP may significantly impact the reduction of energy poverty in urban areas compared with rural areas. In addition, the results indicate no statistical significance for the rural areas.

Our results echo those of other studies: Government spending can reduce energy poverty through economic growth and income inequality. In this case, the income inequality channel is social transfers (Nguyen and Su, 2022). Reducing energy poverty through social transfers improves people's well-being.

We tested the education variable for the two subpopulations in isolation to further validate the results of the urban and rural dimensions.

**Table 4-9.** ATE estimates for the education covariate for the urban and rural subsamples

| Methods | Urban | Rural |
|---|---|---|
| Conventional | 0.406 | −0.045 |
| | (0.410) | (0.726) |
| Bias-corrected | 0.267 | 0.017 |
| | (0.410) | (0.726) |
| Robust | 0.267 | 0.017 |
| | (0.618) | (1.157) |
| Observations | 23 571 | 16 326 |
| Bandwidth | 11.727 | 8.886 |

Standard error in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

The coefficients for both subpopulations presented in Table 4-9 are not statistically significant, validating the subpopulation samples. As we did in the primary sample, we also assessed the validity of the results for the ages near the cutoff for the urban and rural subsamples. The results for other ages in the urban subpopulation met the criteria of no causal impact, as presented in Table 4-10.

**Table 4-10.** ATE estimates for other ages of the general population for the urban subpopulation

| Methods | c = 40 years | c = 50 years | c = 70 years | c = 80 years |
|---|---|---|---|---|
| Conventional | −0.003 | −0.008 | 0.029 | −0.004 |
| | (0.016) | (0.023) | (0.043) | (0.063) |
| Bias-corrected | −0.003 | 0.002 | 0.045 | −0.066 |
| | (0.016) | (0.023) | (0.043) | (0.063) |
| Robust | −0.003 | 0.002 | 0.045 | −0.066 |
| | (0.026) | (0.036) | (0.071) | (0.065) |
| Observations | 26 751 | 26 751 | 26 751 | 26 751 |
| Bandwidth | 9.129 | 10.508 | 7.985 | 7.216 |

Standard error in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

For the rural subsample presented in Table 4-11, no causal associations with other ages were observed except for age 70, which appears to be a spurious result because the robust estimate is weakly statistically significant.

**Table 4-11.** ATE estimates for other ages of the general population for the rural subpopulation

| Methods | c = 40 years | c = 50 years | c = 70 years | c = 80 years |
|---|---|---|---|---|
| Conventional | 0.037 | 0.018 | −0.014 | 0.014 |
| | (0.027) | (0.024) | (0.025) | (0.042) |
| Bias-corrected | 0.038 | 0.033 | −0.064*** | −0.029 |
| | (0.027) | (0.024) | (0.025) | (0.042) |
| Robust | 0.038 | 0.033 | −0.064* | −0.029 |
| | (0.043) | (0.039) | (0.036) | (0.067) |
| Observations | 17 228 | 17 228 | 17 228 | 17 228 |
| Bandwidth | 9.436 | 9.944 | 11.596 | 8.698 |

Standard error in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

### d. Robustness checks

We conducted robustness checks by running a linear regression and a fixed-effects model using the panel sample of the five waves. Table 4-12 presents the results.

**Table 4-12.** Linear and fixed-effects models.

| Dependent variable: energy poverty per capita | Linear regression | Fixed effects |
|---|---|---|
| 1.d | −0.090 (0.048)*** | −0.021 (0.053) |
| Age | 0.001 (0.00)*** | −0.000 (0.001) |
| d#c.age | 0.002 (0.000)*** | 0.000 (0.001) |
| Cons | 0.689 (0.006) | 0.661 (0.007) |

Standard error in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

The linear regression estimates suggest that being in the treatment group reduces energy poverty by 9%. The coefficient is statistically significant at 1%. Moreover, the interaction term suggests that the likelihood of being in the treatment group increases with age. On the contrary, the fixed-effects model treatment variable was negative, but not statistically significant. Overall, the robustness tests across both models indicate that OAP may reduce energy poverty in the treated households.

## 4.6. Discussion

The findings of this study demonstrate the significant impacts of the OAP of South Africa on reducing energy poverty. Using a sharp RDD, this study establishes a causal link between pension eligibility and alleviation of energy poverty, particularly in households with at least one pension-eligible member. The overall reduction in energy poverty, approximately 4 percentage points for the general population, underscores the importance of financial support in helping vulnerable households meet their energy needs. Even after controlling for various household characteristics, these robust results underscore the effectiveness of pensions in mitigating energy poverty.

A key contribution of this study is the differentiated impact between urban and rural households. The results indicate that urban households experience a more significant reduction in energy poverty, approximately 10 percentage points. This suggests that urban households rely more heavily on pensions to meet their basic energy needs. This is not surprising in a country such as South Africa with high levels of unemployment (33%),[7] where all household members depend on the OAP. Even though a better access to electricity and energy infrastructure exists in urban areas, affordability remains a critical issue.

In addition, South Africa has seen rapidly rising electricity prices. According to the Department of Energy (2018), the average price of electricity in South Africa has more than doubled from 2008 to 2018, outpacing inflation. An increase of this nature raises the energy cost burden on households. The Department of Energy (2013) stated that almost half of the South African households spend more than 10% on residential energy needs. Bohlmann and Inglesi-Lotz (2018) highlighted that some South African families spend more than 20% of their income on electricity. Moreover, Ye and Koch (2023) further found that households that experience extreme energy poverty are income poor, and in urban areas, extreme energy poverty is driven by affordability deprivation.

Urban households benefit from the pension primarily by alleviating the financial burden of high energy costs. Even with access to electricity, urban pensioners often face rising energy

[7]Statistics South Africa. 2024. Quarterly Labour Force Survey. 2024. Available on https://www.statssa.gov.za/publications/P0211/Presentation%20QLFS%20Q1%202024.pdf

prices, which strain household budgets. The pension helps mitigate these pressures by allowing households to maintain their energy consumption levels and avoid disconnections. However, the findings indicate that urban households would benefit from additional policies to improve energy affordability, such as subsidies or energy efficiency programs that target low-income consumers.

In the rural subpopulation, the reduction in energy poverty is less pronounced. Even though rural areas often lack adequate electricity infrastructure, many households continue to rely on traditional, polluting fuels. Pensions seem to be an essential source of income that helps reduce reliance on these fuels. Despite pension support, the persistence of energy poverty in rural areas indicates the need for complementary policies to improve energy infrastructure, mainly through investments in off-grid renewable energy solutions such as solar power.

This study contributes to the broader literature on cash transfers by demonstrating that pensions are crucial in reducing energy poverty, particularly among the elderly. The elderly are disproportionately vulnerable to energy poverty owing to their low incomes and high energy needs, especially heating and other essential services. Pensions is a reliable source of income, which helps alleviate the financial pressures associated with energy consumption.

The observed reduction in energy poverty among pension recipients aligns with some findings in the existing literature. For instance, Li and Liu (2024) found that OAPs in rural China reduced the use of solid fuels and increased the adoption of clean energy sources. Similarly, Gelo et al. (2023) studied the impacts of OAP transfers on household energy transition, highlighting the role of pensions in promoting a transition from traditional to modern energy sources. However, our study extends these insights by providing a detailed analysis of the urban–rural divide in South Africa, demonstrating that OAPs are particularly adequate in urban contexts where energy costs are higher and supply can be less stable.

In addition, this study emphasizes the need for integrated policy interventions that combine social welfare programs with targeted energy policies. Although the pension effectively reduced energy poverty, it cannot address the structural challenges underlying the issue. In urban areas, policies focused on reducing energy costs through either price regulation or support for energy-efficient technologies could further alleviate energy poverty. In rural areas, investments in energy infrastructure are necessary to improve access to clean, affordable energy sources. The differential impacts observed between rural and urban areas highlight the importance of context-specific interventions that address affordability and access.

Moreover, the findings underscore the importance of tailoring energy policies to the specific needs of vulnerable populations, particularly the elderly. As the South African population ages, the number of pension-eligible households will increase, making it critical to design policies that account for their acute energy needs. In addition, policymakers should consider expanding social welfare programs and combining them with targeted energy interventions to provide a more comprehensive solution to energy poverty. This study contributes to the "universal versus targeted" policy debate. The elderly are a heterogeneous group and should not be viewed as part of a homogeneous group when creating policies. There must be specific policies that target their acute needs. Otherwise, homogenous policies may have unintended consequences that widen the inequalities.

Moreover, policymakers must consider that although direct energy cash transfers to the elderly can offer immediate relief by reducing reliance on solid fuels, they may also result in inefficiencies within the energy market. The intended purpose of the cash transfers may be compromised if recipients allocate the funds to unintended uses. Hence, it is crucial to develop well-considered strategies to determine whether the emphasis should be on enhancing energy efficiency to reduce costs or on providing cash transfers to help with energy expenses. Conducting thorough cost-benefit analyses is essential to identify strategies that will be advantageous in the short and long terms. Innovative financing solutions are necessary to support these additional transfers or measures given the constraints of the South African already strained fiscal resources. With a limited tax base and nearly half of the population dependent on social grants, finding sustainable funding methods is imperative.

Moniruzzaman and Day (2020) investigated the relationship between gender and energy poverty as a matter of energy (in)justice, highlighting the acute vulnerabilities faced by women. Although their study focused on gender dynamics, it complements our findings by emphasizing the need for targeted interventions to address specific socioeconomic groups' energy needs. Our research, by focusing on the elderly, provides additional evidence of the importance of tailored policies for different demographics.

A closer examination of the results reveals several key insights. First, the significant reduction in energy poverty among pension recipients suggests that the current level of pension benefits is generally adequate to cover energy costs, particularly in urban areas. This finding is significant given the high proportion of household income spent on energy by these households, which can easily exceed the traditional 10% threshold used to define energy poverty by Boardman (1991).[8] Second, the robust effects observed in the general population

[8] In the literature, some researchers used twice the median of the average household energy expenditure to reflect the high energy cost burden faced by households in alternative contexts (Liddell et al., 2012).

(combined urban and rural samples) indicate that energy poverty is widespread. However, the lack of a significant effect in rural areas suggests that these populations face additional barriers to accessing clean energy, such as limited infrastructure and the availability of clean energy sources. This finding implies that although pensions help in urban areas, rural areas might need additional targeted policies that address challenges related to infrastructure and renewable energy adoption.

In conclusion, this study demonstrates that OAPs play a vital role in reducing energy poverty, especially in urban areas, even though energy poverty has been considered a rural phenomenon. Addressing energy poverty requires a multifaceted approach that combines financial support with targeted infrastructure investments and energy policy reforms. By integrating social welfare with energy interventions, policymakers can create more sustainable solutions that improve the quality of life of vulnerable populations and reduce the long-term effects of energy poverty.

### 4.7. Conclusion

This study investigated the causal impact of OAPs on energy poverty among households with at least one member eligible for the OAP in South Africa. The critical research problem addressed was whether the financial support provided through OAPs effectively alleviates energy poverty, a condition characterized by the reliance on dirty fuels and the inability to access clean energy sources. Given the vulnerability of these households, who often have limited incomes and higher energy needs, understanding this relationship is crucial for designing effective social welfare policies.

The analysis, conducted using an RDD, reveals that OAPs significantly reduce the likelihood of experiencing energy poverty. Specifically, the bias-corrected estimates conclusively indicate a decrease in energy poverty by approximately 4 percentage points for households with at least one pension-eligible member. The results are more striking for urban subpopulations wherein OAP reduces energy poverty by 10 percentage points. These effects underscore the critical role that social welfare programs play in improving vulnerable populations' access to energy. This effect is robust across different model specifications. The findings highlight that households with OAP financial support are better able to access affordable and clean energy, particularly in urban areas where energy costs are higher and supply can be less stable.

The findings have several important implications. Academically, they underscore the need to consider context-specific factors when evaluating the impacts of social welfare programs. The differential effects observed between urban and rural settings suggest that a one-size-fits-all approach may not be practical. For policymakers, the results indicate that although OAPs provide essential financial support, additional measures are necessary to fully address the energy needs of households with pension-eligible members. Comprehensive energy policies that include subsidies for clean energy technologies, targeted energy efficiency programs, and investments in reliable energy infrastructure are crucial. In addition, policies must address the acute vulnerabilities of urban populations, such as high energy costs and supply instability.

While this study provides valuable insights, it is not without limitations. Using self-reported income and energy expenditure data may introduce reporting biases. In addition, the RDD provides local estimates around the age cutoff, which may not generalize to households with members significantly younger or older than the threshold. We also only did the analysis based on the age eligibility of 60 years; other methodologies like the fuzzy RDD can be used for a holistic picture that includes the income eligibility. Moreover, this study focuses on South Africa, and the findings may not be directly applicable to other contexts with different social welfare systems and energy market dynamics. Furthermore, the cross-sectional nature of the data limits their ability to capture the long-term effects and dynamic changes in energy poverty over time.

Future research should address these limitations using longitudinal data to capture the dynamic nature of energy poverty and its long-term implications. It would also be interesting to see the results of the recent data because the wave used in this study was collected in 2017. In recent years, South Africa has experienced more pronounced power outages, possibly resulting in increased energy poverty. In addition, comparative studies across different countries and contexts would provide a broad understanding of how social welfare programs impact energy poverty globally. Moreover, future studies should explore the intersectionality of energy poverty with other socioeconomic disadvantages, such as health issues and education, to provide a more holistic view of the problem. Furthermore, more granular data on energy consumption and expenditure are needed, which can help refine the measurement of energy poverty and better inform policy interventions.

In conclusion, this study provides critical insights into the importance of OAPs in addressing energy poverty among households with at least one member eligible for OAP in South Africa. The findings highlight the need for a multifaceted approach that integrates social welfare with comprehensive energy policies. By addressing the acute challenges these households face, particularly in urban areas, policymakers can design more effective interventions to alleviate energy poverty and improve the well-being of vulnerable populations. As the global population ages, these insights will become increasingly relevant for ensuring that all households have access to the energy resources necessary for a healthy and dignified life.

The results demonstrate that elderly pensions can alleviate energy poverty, particularly in urban settings, highlighting the potential and the constraints of social transfers in facilitating energy changes. Chapter 5 synthesizes the principal findings from the three studies—income thresholds, women's bargaining power, and the impact of pensions—to develop a comprehensive explanation of household energy transitions in South Africa. The thorough analysis of these findings yields policy recommendations that address the interrelated challenges of income limitations, gender dynamics, and social protection, all designed to facilitate the adoption of renewable energy in diverse geographical settings.

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# Chapter 5 : Conclusion

This study examined three critical research problems related to energy transitions and energy poverty among South African households. First, this study investigated the extent to which household income influences the transition to clean energy sources, recognizing that many households still rely on solid fuels despite global efforts to promote clean alternatives. Understanding the income threshold required for this transition is essential for effective policy design. Second, this study explored the role of women's bargaining power in household energy decision-making. In many developing contexts, women play a central role in household energy consumption. They are often responsible for activities like cooking and collecting households energy fuels. However, they are not in the forefront of household decision-making with regards to choosing clean energy alternatives. This study assessed whether increased bargaining power allows women to influence household energy choices, particularly in terms of transitioning from solid fuels to electricity. Third, this study analyzed the impacts of social transfers, specifically the OAP, on reducing energy poverty among the elderly. Given that older individuals often rely on fixed incomes and are disproportionately affected by energy poverty, this research sought to determine whether social grants play a meaningful role in alleviating their energy hardships.

This study confirmed the nonlinearity of energy transitions, revealing that households reach a specific income threshold before transitioning to clean energy. Specifically, household electricity consumption decreased by 1 percentage point when per capita household income reached R370 ($20) per month. However, urban households continued increasing their electricity consumption at an income threshold of R417 ($22) per month, whereas there was no effect for rural household electricity expenditure above the income threshold of R372 ($20) per month. These variations highlight the complexity of the energy transition processes and the need for localized policy responses.

Regarding women's bargaining power, the findings indicate that women were more likely to advocate for electricity use, particularly for cooking, reinforcing the importance of women's participation in household decision-making. Although fuel stacking remains prevalent, particularly for heating, the findings indicate that when women have greater influence in household decisions, a high likelihood of transitioning to clean energy sources exists.

This study further established that social transfers, such as the OAP, reduced energy poverty among the elderly. The RDD indicated a 4% reduction in energy poverty owing to the OAP, with the impacts being more pronounced in urban areas, where the OAP reduces elderly energy poverty by up to 10%. These findings challenge the traditional notion that energy poverty is primarily a rural problem, emphasizing that urban households also experience significant energy access challenges.

The study also spotlighted the importance of the electricity infrastructure for rural households. In the income threshold chapter, we saw a decline in the electricity expenditure at the threshold. Similarly in the OAP transfers chapter, grants do not reduce energy poverty in rural areas. This shows that without the infrastructure, households will stay depending on solid fuels even if they are given transfers.

Academically, this study contributes to the literature by demonstrating the nonlinearity of energy transitions and their region-specific effects. It extends the energy ladder hypothesis by incorporating the role of bargaining power and social grants as nonincome determinants of energy transitions. Moreover, this study provides novel insights into how OAPs influence household energy choices, an area often overlooked in discussions on social transfers.

From a policy perspective, the findings highlight the need for differentiated energy transition strategies tailored to specific demographic groups. Policymakers should consider targeted interventions rather than one-size-fits-all approaches. Urban households may benefit from energy subsidies to manage high electricity costs, whereas rural households require infrastructure investments, such as grid expansion and clean off-grid technologies. In addition, women's empowerment programs should integrate energy decision-making to ensure that women can actively advocate for clean energy use. Moreover, social protection programs such as the OAP should be optimized to provide targeted energy-related support for vulnerable elderly populations.

While promoting social transfers as a means to alleviate energy poverty, policymakers must also mitigate potential dependency risks. Overreliance on energy-related social assistance could create sustainability concerns and result in unintended consequences, such as increased energy consumption without corresponding efficiency improvements. Investing in energy efficiency programs that provide upfront financing for clean household technologies could offer a more sustainable approach to energy transitions.

Despite its contributions, this study has limitations. The reliance on survey-reported income may not fully capture household financial dynamics, particularly in informal labor markets where earnings can be volatile and underreported. In addition, the measure of women's bargaining power was constructed using general household decision-making indicators rather than energy-specific decision-making metrics. Future studies could refine this measure by collecting primary data on women's role in household energy choices. Moreover, it would also be beneficial to use methodologies that account for endogeneity that may exist among indexes that are constructed to measure bargaining power.

Moreover, while this study identifies income thresholds for energy transitions, it does not fully capture the behavioral aspects of household energy choices. Cultural preferences, risk perceptions, and awareness of clean energy alternatives may also influence household decisions. Understanding these behavioral factors could enhance the design of more effective energy transition policies.

Future research should explore the behavioral dimensions of household energy transitions. Although income plays a crucial role, households may make energy decisions based on other factors such as perceived reliability, social norms, and environmental concerns. Therefore, examining these influences could provide deeper insights into the complexities of energy choices.

Further research should also analyze the long-term impacts of social transfers on energy consumption patterns, using the most recent econometric techniques, like the ones that account for multiple criteria to qualify for transfers. Given that the OAP has a measurable effect on energy poverty, future studies could assess whether these benefits persist over time or if they diminish owing to inflation and increasing energy costs. In addition, cross-country comparative studies could explore whether similar effects of social transfers on energy poverty exist in other developing economies.

Finally, given the increasing challenges of energy insecurity in South Africa, future studies should analyze the implications of ongoing power outages and grid reliability issues. Investigating how energy poverty intersects with the broader issues of energy governance and infrastructure resilience would provide valuable insights for policymakers.

The findings of this study underscore the complexity of energy transitions and the diverse factors influencing household energy choices. Although income remains a critical determinant, nonincome factors such as bargaining power and social transfers also play crucial roles in shaping energy consumption patterns. These insights highlight the importance of adopting a multifaceted approach to energy policy—one that integrates economic, social, and behavioral dimensions.

Moving forward, policymakers must prioritize tailored, context-specific interventions to ensure an inclusive energy transition. Programs that empower women in household decision-making, provide targeted social transfers, and promote sustainable energy infrastructure can collectively enhance energy security and improve household well-being. Energy transitions are not merely technical challenges but deeply socioeconomic processes requiring holistic, adaptive policy frameworks.

As South Africa and other developing nations continue their pursuit of energy justice, it is imperative to acknowledge the structural barriers that impede progress. By leveraging empirical insights and adopting evidence-based policy strategies, governments can foster an equitable transition that ensures access to clean energy for all, ultimately improving health outcomes, economic stability, and environmental sustainability.