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Explaining the rise of economic and rural-urban inequality in clean cooking fuel use in Tanzania

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ABSTRACT

Despite the high rate of economic growth and electrification in the last two decades in Tanzania, only 6.9 % of the nation's households have access to clean cooking fuel technology which is concentrated among the rich urban households. Analysing data from two waves of the Tanzania National Panel Survey (2014/15 and 2020/21), we estimate the economic and rural-urban inequalities in the use of clean cooking fuel. Using the concentration curve, Erreygers concentration index and non-linear Fairlie decomposition, we find an increase in economic inequality and rural-urban inequality in the use of clean cooking fuel. Based on our analysis, factors such as the household head's education, household economic status and household connection to electricity contribute to the rural-urban inequality in the use of clean cooking fuel. Policy changes are vital for ensuring both rural and urban households have equitable access to education, electricity connection and household economic status to address inequality in the use of clean cooking fuel.

1. Introduction

The primary objective of this study is to investigate economic and rural-urban inequality in the use of clean cooking fuel in Tanzania using a concentration curve, a concentration index, and Fairlie decomposition analysis. Clean cooking refers to the fuel characterized by very low emissions upon combustion such as biogas, LPG, electricity, ethanol, natural gas, and solar power (BLEENS) [1]. The use of clean cooking fuel has the potential to transform lives by improving health, protecting the environment, empowering women, and helping consumers save time and money [1]. A full transition to clean energy sources has a significant positive impact on individuals' happiness and overall life satisfaction [2].

Globally, clean cooking fuel use and technology adoption have increased significantly from 49.1 % in 2000 to 71.3 % in 2021 [3]. In Sub-Saharan Africa, the increase has been from 8.9 % in 2000 to 19.1 % in 2021, and in Tanzania, it has been from 0.6 % in 2000 to 6.9 % in 2021 [3]. This implies that a large proportion of the world population still uses dirty cooking fuels, especially in lower and middle-income countries including Tanzania. Studies have shown that energy poverty among households has an impact on health, education, income and the environment [4–6]. During the years from 2000 to 2019, worldwide indoor air pollution-related deaths declined from 7.29 % to 4.10 %, with sub-Saharan Africa registering a decrease from 10.45 % to 9.36 %. Tanzania recorded an increase from 10.05 % to 11.90 % [7]. The Energy Access Situation Survey conducted in Tanzania during the 2019/20 period reveals that the primary sources of cooking energy are: firewood (63.5 %), charcoal (26.2 %), LPG (5.1 %), electricity (3 %), and other sources (2.2 %)

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[8]. In Tanzania, a study conducted revealed significant effects of massive forest and land degradation resulting from excessive use of biomass for heating and cooking purposes [9].

The use of dirty cooking fuels interferes with the efforts to realize the Sustainable Development Goals (SDGs), specifically, SDG 3 (health and well-being), SDG 5 (empowering women and girls), SDG 7 (access to reliable, efficient modern energy), SDG 13 (combat climate change), and SDG 15 (sustainably manage forests and halt land degradation) [10]. Although there is empirical evidence indicating the holistic benefits of adopting clean cooking fuels to people's livelihoods, the transition to such fuels remains slow in lower and middle-income countries, including Tanzania. This could be attributed to barriers such as a lack of access to clean cooking fuel and affordability in developing countries [11].

Tanzania, a sub-Saharan African nation with a population that is poverty-stricken to a considerable extent grapples with a noteworthy increase in indoor pollution-related deaths surpassing the regional average over a decade. This underscores the need to scrutinize the factors behind the nation's elevated indoor mortality rates related to the use of unclean cooking fuels. Notably, while the country has made commendable strides in electrifying rural and urban settlements, electricity in this country is predominantly used for lighting rather than for cooking purposes. So, the significance of adopting clean cooking fuels cannot be overstated, given its implications for health, education, the economy, and the environment. This is further amplified by the fact that Tanzania is a nation where infrastructure for clean cooking fuels remains limited or absent.

The primary research question of this study is to examine the presence of economic disparities in clean cooking fuel utilization and to unravel the factors contributing to rural-urban inequality in the use of clean cooking fuel in Tanzania. We employ Fairlie's decomposition method to comprehensively analyze these aspects, considering the impact of various variables and their contributions.

Our results reveal that the use of clean cooking fuel is a pro-rich option, favouring richer households. Moreover, there is an increase in economic inequality in the use of clean cooking fuel. The widening rural-urban gap in the use of clean cooking fuel is explained by household economic status, household access to electricity and the level of education of household heads. Thus, economic growth and implementation of social programs such as education and the provision of subsidized gas cooking stoves during the study period were found to be plausible reasons for the results obtained. Therefore, the study recommends that the implementation of social programmes in the country should consider both poor and rich households, be it in rural and urban areas.

The subsequent sections of this paper are as follows: Section 2 reviews the literature, Section 3 outlines the methodology used, Section 4 presents the empirical results, Section 5 discusses the results, and, Section 6 offers concluding remarks.

2. Literature review

Numerous studies on household choice of energy sources to be used for domestic purposes highlight the influence of factors such as household income, household size, educational levels, and the sex of the household head [12–14]. Additionally, some studies have examined the accessibility of energy services in terms of physical availability, market supply and equipment. Comparisons between high and low-income consumers have revealed that individuals with limited financial resources have fewer options when it comes to fuel and equipment choices.

The conception of energy transition, specifically cooking and lighting energy transition supports the energy ladder hypothesis. It has been postulated that, as the income or wealth of the households increases, they usually shift from traditional biomass fuels to modern cooking fuels, a tendency that affirms the income-dependent nature of energy choices [15]. Several studies have come up with results that are consistent with the energy ladder theory's assumption that households tend to shift from dirty fuel options as their incomes increase [16,17]. Further, it has been found that higher monthly household expenditures discourage the use of traditional fuels [18].

There is a notable disparity in energy consumption patterns between well-off households and impoverished ones. Lower-income individuals typically rely on traditional energy sources to meet their needs, whereas higher-income individuals tend to climb up the energy ladder, transitioning to modern energy sources. This indicates that similar mechanisms drive fuel switching in both urban and rural areas, albeit to differences in the extent. The assumption is that the relatively lower rate of fuel switching observed in rural areas is attributed to the lower prevalence of the triggering variables in these regions. Moreover, larger cities are presumed to have a more conducive environment for the adoption of modern fuels [19].

The influence of income on the choice of cooking energy mix is evident in the context of energy stacking, particularly in developing countries. This poses a dilemma between energy transition and energy stacking. For instance, in rural areas of India, fuel stacking is common, with households continuing to use firewood even after adopting Liquefied Petroleum Gas (LPG) as a cooking fuel. Affordability remains a significant barrier preventing the completion of the transition from traditional biomass to clean cooking fuels [20]. Thus, wealthy households are more likely to use liquefied petroleum gas and fuel wood compared to poor households [21].

A considerable portion of households in Ethiopia, Tanzania, and Malawi rely on solid fuels for cooking, while a small fraction of the population has access to clean fuels like electricity or liquid petroleum gas due to the higher costs associated with clean cooking fuel and equipment [22]. Economic inequality persists in these countries and is evident in both urban and rural areas. Urban households with better socioeconomic and demographic conditions are more likely to use LPG as their primary cooking fuel compared to rural households and urban households with poorer socioeconomic and demographic conditions [17,23]. Additionally, urban households tend to rely more on modern and environmentally cleaner fuel sources compared to rural households [17,24].

Studies conducted in Tanzania have identified various patterns and factors that influence households' choices of cooking energy sources. In rural areas, firewood is dominantly used, while charcoal is the primary cooking fuel in urban areas. However, studies have shown that the conversion rates for these energy sources are low, indicating inefficiency in their utilization [25]. Like in India, some regions in Tanzania practice fuel stacking in the journey to energy transition where biomass, including firewood, remains the major source of cooking energy though some households use cleaner fuels in some cases [26].

Reliance on non-clean fuels is more common among rural and remote households in Tanzania just like in other parts of sub-Saharan Africa [27]. The choice of energy sources for cooking is influenced by factors such as education, household size, occupation, income, the availability of different fuel sources and age [17,22,27]. The determinants of fuel choice have been extensively studied, and various factors have been identified. In urban areas, household wealth is reported to be the primary determinant of clean cooking fuel choice, while education, coal price, and female labour participation also have an impact [28].

In peri-urban settings of Tanzania, the occupations of household heads, particularly female heads, have a significant influence on the choice to use LPG [22]. The decision-making authority regarding durable goods purchases held by females, or joint decision-making involving both genders discourages the utilization of traditional fuels [18]. Female-headed households are more likely to adopt and consume more clean fuels such as electricity and gas [12,14]. Additionally, female household heads possess and exercise authority in making decisions about household expenses, including the choice of fuel, whereby in most cases their decisions lead to the choice of more clean cooking fuel [12].

The type of residence and access to electricity are statistically significant factors that determine the type of cooking fuel used in households. Higher wealth status and smaller household sizes are positively associated with the use of modern energy sources such as electricity and LPG, while the lack of formal education, primary occupation in farming, larger household sizes, and greater distance to town centres are associated with lower chances of using clean energy. However, the relevance of household size as an explanatory factor may vary across places [14,23,25,29]. Several studies have confirmed the rural-urban disparity in the adoption of clean cooking fuels, consistently showing that rural households are less likely to utilize clean cooking fuels compared to urban households [25,30].

The present study addresses a notable gap in the existing literature on clean cooking fuel in Tanzania by employing nationally representative samples from panel surveys conducted in 2014/15 and 2020/21, in contrast to prior studies with limited sample sizes [13,22,27]. While most previous research has primarily focused on the determinants of fuel choice, our study seeks to investigate the contributing factors to disparities in clean cooking fuel usage, particularly examining rural-urban inequality and economic disparities between these areas. This research is essential due to the scarcity of studies on clean cooking fuel inequality in Tanzania, which is vital for the development of effective interventions and policies. While a study in Ghana by Tabiri et al. [23] addressed this issue, no specific study has explored clean cooking fuel inequality in the Tanzanian context. Additionally, our research introduces novel variables, such as household head marital status, to acknowledge the influence of partners in decision-making, including fuel purchase. In summary, our study overcomes the limitations of previous research by using nationally representative data and applying a more robust econometric approach, significantly advancing the understanding of fuel choice in Tanzania.

3. Methodology

3.1. Data and variables

The study uses the fourth and fifth Tanzania National Panel Surveys conducted in 2014/15 and 2020/21, respectively. The two surveys collected a wide range of information on agricultural production, non-farm income-generating activities, consumption expenditures, and other socioeconomic characteristics. They were both conducted by the Tanzania National Bureau of Statistics. All the surveys employed a stratified, multi-stage cluster sample design. The final samples used in this study were 3352 and 4709 households for the 2014/15 and 2020/21 surveys, respectively. Table 1 shows in NPS 2014/15, a total of 3352 households were surveyed, with 2096 from rural areas and 1256 from urban areas. The subsequent wave, NPS 2020/21, saw an increase in the sample size, with 4709 households surveyed, comprising 2560 rural households and 2149 urban households. The overall total of households surveyed in both waves was 8,061, with 4656 from rural areas and 3405 from urban areas. A detailed description of the methodology and sampling design of the study is presented in the main reports [31].

The outcome variable for the study is whether a household uses clean fuel for cooking. According to WHO guidelines clean fuels and technologies include households that primarily rely on electricity, biogas, natural gas, liquefied petroleum gas (LPG), and solar or alcohol fuels for cooking [32]. A binary variable was created and assigned a value of "1" for households using clean cooking fuel and "0" for those using non-clean options (such as firewood, charcoal, paraffin, etc.).

Explanatory variables were selected from previous research on economic and rural-urban disparities in clean cooking fuel use [23]. Additional variables were derived from studies on the determinants of fuel choice [12,13,13,21,33]. Household economic status was assessed using the actual total household consumption expenditure per adult equivalent which in the literature was identified to influence the choice of cooking fuel [23]. Using expenditure as an indicator of economic status might not capture households engaged in non-market transactions, especially rural ones which are heavily dependent on cash, but it remains a valuable metric of household wealth [34].

Table 1
Sample Distribution by survey wave and place of residence.

Survey wave	Full sample	Rural	Urban
NPS 2014/15	3352	2096	1256
NPS 2020/21	4709	2560	2149
Total	8061	4656	3405

Source: Author's computation from NPS 2014/15 and NPS 2020/21

Other variables that influence cooking fuel choice include household size, household head sex, marital status, age, and education status as identified in previous studies [12,22,23,33]. The household head's education for instance affects fuel choice through increased awareness and thus education is positively associated with the choice of clean fuel [12–14]. On the other hand, female-headed households are more inclined to choice of clean cooking fuel compared to men [35]. Household size is positively associated with the use of solid fuels such as firewood due to increased demand for fuel and excess supply of labour for collecting wood in rural areas [36]. The marital status of the household head is expected to impact the fuel choice, where the decision to use cleaner fuel is expected to be influenced by the joint decision making on household purchases [18].

Additionally, access to mass media, like radio and TV, enhances awareness of clean cooking fuel safety and efficiency, thereby promoting health consciousness among household members and increasing the use of clean cooking fuel. Also, the zone of residence influences the choice of clean cooking energy. For instance, studies have revealed that rural centralized residence has a significant positive effect on the use of clean cooking fuel [37]. Residents who are dispersed are less likely to use clean cook fuel, it has been noted that a greater distance to town centres is associated with lower chances of using clean energy [28]. Electricity connection also influences the choice of clean cooking fuel, as households with electricity are more likely to use electricity or LPG for cooking compared to households without electricity [33]. Table 2 provides variable descriptions used for this study.

3.2. *Statistical analysis*

This study utilized a three-stage analysis, including the concentration curve, concentration index, and Fairlie decomposition analysis.

3.2.1. *Concentration curve*

A concentration curve was constructed to visualize the disparity in the use of clean fuel among different economic strata. The concentration curve was used to determine if the economic inequality in the use of clean fuel was more pronounced at specific times or in particular places. The curve was used in this research to assess the variation in the use of clean fuel use for cooking between 2014/15 and 2020/21. It plotted the cumulative share of clean cooking fuel (y-axis) against the cumulative percentage of the population (x-axis), ranked from the poorest to the richest [34].

3.2.2. *Concentration index*

Since the concentration curve alone does not provide a direct measure of the extent of inequality that can be compared across periods, a concentration index was estimated to quantify the level of economic inequality in the use of clean fuel for cooking. This concentration index quantifies the degree of economic inequality in the use of clean cooking fuel. Given that the dependent variable is binary (i.e. clean cooking fuel used for cooking), Erreygers' Corrected Concentration Index (EI) was used to measure the economic inequality in the use of clean cooking fuel [38]. The EI is estimated using the following formula:

$$EI(CCF) = (1/n)\sum_{i=1}^{n}\{4CCF_i(2R_i - 1)\} \tag{1}$$

Here, *'n'* represents the sample size, *CCFi* denotes the binary outcome variable (i.e., clean cooking fuel use) for household *'i'*, and $(R_i = (i - 0.5)/n)$ is the fractional rank of household *'i'* based on cumulative household consumption per adult equivalent [39]. The EI ranges from −1 to 1. A negative value indicates that the variable is concentrated among the poorer segments of the population, while a positive value indicates the opposite. A value of zero suggests perfect equality.

A concentration curve, which visually represents the EI, indicates the cumulative percentage of the study sample ranked by household consumption per adult equivalent (on the x-axis) against the cumulative percentage of the sample that uses clean fuel for cooking. If the curve lies above the line of equality (a 45° line), it suggests that the variable is disproportionately concentrated among the poor (similar to a negative concentration index value), and vice versa will be true if it lies above the line of equality.

Table 2
Variable definition.

Variable	Definition
Clean cooking fuel use	A dummy variable (1 for clean cooking fuel usage, 0 otherwise).
Household size	Total number of household members
Household economic status	Actual total household consumption expenditure per adult equivalent
Age of household head	Age in years
Sex of household head	A dummy variable (1 if the household head is female, and 0 if male)
Marital status of head of household	A dummy variable (1 if married, and 0 otherwise)
Media Access	A dummy variable (1 if the household owns a television set and/or radio receiver, 0 if none is owned by the household)
Household head education level	A categorical variable (1 = No formal education, 2 = Primary education, 3 = Secondary education, 4 = Tertiary education, 5 = University)
Electricity	A binary variable (1 if connected, 0 if not
zone of residence	Household administrative zone

3.2.3. Fairlie decomposition analysis

A non-linear decomposition was applied using the Fairlie decomposition technique to estimate the rural-urban inequality in the use of clean fuel in Tanzania. The technique is an extension of Blinder-Oaxaca for the nonlinear models such as logit and probit. It can be implemented in STATA as proposed by Jann [40]. The specification of Fairlie decomposition is as follows:

$$\underline{Y}^U - \underline{Y}^R = \left[\sum_{i=1}^{N^U} \frac{F\left(X_i{}^U \widehat{\beta}^U\right)}{N^U} - \sum_{i=1}^{N^R} \frac{F\left(X_i{}^R \widehat{\beta}^W\right)}{N^R}\right] + \left[\sum_{i=1}^{N^R} \frac{F\left(X_i{}^R \widehat{\beta}^U\right)}{N^R} - \sum_{i=1}^{N^R} \frac{F\left(X_i{}^R \widehat{\beta}^R\right)}{N^R}\right] \tag{2}$$

in our study, we considered two groups, rural and urban groups with sample sizes denoted as N^j, where *'j'* represents either rural *(R)* or urban *(U)*. We were interested in analysing the average probability of clean fuel use for these groups denoted as $\underline{Y}^j$. In equation [2], the first term in the brackets represents the portion of the gap in the use of clean energy resulting from differences in the characteristics between the rural and urban groups. On the other hand, the second term captures the part of the differences in clean fuel use inequality arising from households with similar observable characteristics. Moreover, the second term captures the contribution of unmeasurable or unobserved endowments in explaining inequality. For our analysis, we chose not to focus on the unmeasurable portion of the gap due to the difficulty in interpreting the results, consistent with previous studies that have applied similar decomposition techniques [41].

The Fairlie decomposition technique was employed to assess the degree to which the inequality in the use of clean fuel between rural and urban areas can be attributed to variations in the variables considered in the analysis. Additionally, this method allowed us to estimate the individual contribution of each variable in explaining the differences in clean fuel use between the two areas. According to the Fairlie decomposition technique, a negative coefficient would lead to a negative contribution to rural and urban inequality in clean fuel use. These positive coefficients indicate an increase in the inequality between rural and urban areas in the use of clean fuel, especially when the existing inequality is positive, as observed in this study.

4. Results

4.1. Descriptive statistics

The descriptive statistics in Table 3 show key socioeconomic and household variables from the two waves of data, encompassing 8061 households by conducting a *t*-test to determine if there was a significant change in the variable between the study periods. The analysis shows intriguing trends and changes over time. Firstly, the use of clean cooking fuel was 3.3 % in 2014/15 but significantly increased to 11.9 % in 2020/21. The full sample of households that use clean cooking fuel was 8.3 %. This is indicative of an increase in environmental awareness and in the efforts to promote the use of clean energy sources. Additionally, household size remained

Table 3
Descriptive statistics.

	Full sample			1-NPS 2014/15		2-NPS 2020/21		[1−2]
Variable	Obs	Mean	Stdv	Mean	Stdv	Mean	Stdv	Diff
Clean fuel use	8061	0.0832	0.2763	0.0334	0.1797	0.1187	0.3235	−0.0853***
Household size	8061	4.8805	2.9455	4.8467	2.8464	4.9047	3.0141	−0.0580
Age of head of household	8061	45.0682	15.0520	44.4153	14.9867	45.5330	15.0827	−1.1177***
Household head (Female)	8061	0.2758	0.4469	0.2849	0.4514	0.2693	0.4436	0.0156
Married head of household	8061	0.6864	0.4640	0.7058	0.4557	0.6725	0.4693	0.0333***
Mass media access	8061	0.5898	0.4919	0.6184	0.4858	0.5693	0.4952	0.0491***
Economic status	8061	127,210.90	178,545.40	120,976.70	192,117.50	131,648.50	168,098.60	−10671.79***
Place of residence (Urban)	8061	0.4224	0.4940	0.3747	0.4841	0.4564	0.4981	−0.0817***
Education of household head								
No formal education	8061	0.1950	0.3962	0.2163	0.4118	0.1799	0.3841	0.0364***
Primary education	8061	0.5679	0.4954	0.5689	0.4953	0.5672	0.4955	0.0017
Secondary education	8061	0.1592	0.3658	0.1339	0.3406	0.1771	0.3818	−0.0432***
Tertiary education	8061	0.0551	0.2282	0.0653	0.2472	0.0478	0.2133	0.0176***
University education	8061	0.0228	0.1494	0.0155	0.1236	0.0280	0.1651	−0.0125***
Electricity	8061	0.3627	0.4808	0.2915	0.4545	0.4135	0.4925	−0.1220***
Zone of residence								
Western	8061	0.0739	0.2617	0.0764	0.2656	0.0722	0.2588	0.0042
Northern	8061	0.1082	0.3106	0.0931	0.2906	0.1189	0.3237	−0.0258***
Central	8061	0.0712	0.2572	0.0573	0.2324	0.0811	0.2731	−0.0238***
Southern Highlands	8061	0.0561	0.2301	0.0621	0.2413	0.0518	0.2217	0.0102**
Southern	8061	0.0665	0.2492	0.0692	0.2539	0.0646	0.2458	0.0047
South West Highlands	8061	0.0758	0.2647	0.0621	0.2413	0.0856	0.2798	−0.0235***
Lake	8061	0.2182	0.4131	0.2172	0.4124	0.2189	0.4136	−0.0018
Eastern	8061	0.1894	0.3919	0.2196	0.4140	0.1680	0.3739	0.0516***
Zanzibar	8061	0.1407	0.3477	0.1432	0.3503	0.1389	0.3459	0.0043

Notes: Standard error in parentheses; *p $<$ 0.10, **p $<$ 0.05, and ***p $<$ 0.01.
Source: Author's computation from NPS 2014/15 and NPS 2020/21

relatively stable between the two periods, with an average of approximately 4.9 members per household. However, within the two periods, head of household with primary education level was the most prevalent category in the sampled households and has remained relatively the same at approximately 57 % between 2014/15 and 2020/21. It is important to note that there has been a significant decrease in household heads with no formal education and tertiary education. Also, a significant increase for households with secondary and university education levels. The proportion of households with access to electricity increased significantly from 29.2 % in 2014/15 to 41.4 % in 2020/21 indicating improvement in access to electricity. The proportion of urban households significantly increased from 37.5 % in 2014/15 to 45.6 % in 2020/21. The household consumption expenditure per adult equivalent (i.e., household economic status) showed a significantly higher mean in 2020/21 (TZS 131,649) compared to 2014/15 (TZS 120,977). The mean age of household heads was significantly lower in 2014/15 (44.4 years) compared to 2020/21 (45.5 years) in 2020/21. Additionally, there was no significant change in the proportion of female household heads between 2014/15 and 2020. Moreover, household media access significantly declined between the two waves with 2020/21 having lower access at 57 % compared to 62 % in 2014/15.

4.2. Cooking fuel use among households

The data in Table 4 reveals trends in the use of clean cooking fuel in rural and urban areas. Firewood remains the dominant choice in rural households, with approximately 82.84 % of the sampled households using it for cooking. In contrast, urban households rely less on firewood, as only 22.85 % use it. Urban areas show a higher preference for gas (16.92 %) and charcoal (54.68 %) as cooking fuels, compared to rural areas where the use of these fuels is very low (1.50 % for gas and 14.45 % for charcoal). Thus, the data depict a significant disparity in the use of clean cooking fuel between rural and urban regions, with potential implications for the sustainability of the environment and access to energy sources. The comparison between NPS 2014/15 and NPS 2020/21 reveals several interesting key findings on cooking fuel preferences. In rural areas, firewood remains the dominant choice, with the usage percentages being around 82.92 % in NPS 2014/15 and 82.77 % in NPS 2020/21. However, there is a noticeable shift in urban regions towards cleaner energy sources, with the use of gas has increased significantly from 6.77 % in NPS 2014/15 to 22.85 % in NPS 2020/21. Additionally, the use of charcoal has been on a slight decline in both rural and urban areas. This is an indication of a growing awareness of environmental sustainability, which has prompted more urban households to adopt environmentally friendly cooking fuels.

4.3. Concentration curve

Fig. 1 presents three Concentration Curves (CCs) depicting the use of clean fuel for cooking in Tanzania. Panel 1 displays the CC for the full sample, while Panels 2 and 3 show the CCs for rural and urban households, respectively. All curves lie below the line of equality, indicating that the use of clean fuel for cooking is more concentrated among the wealthier households. Notably, the curves for different survey periods in the rural sub-sample are closely grouped, suggesting no significant increase in economic inequality compared to the full sample and the urban sub-sample. Overall, the CC has shifted outwards between the two survey periods, signifying an increase in economic inequality. This increase is observed in the urban sub-sample and the full sample, but not in the rural sample. Therefore, the economic-related inequality in the use of clean fuel for cooking has risen between the two survey periods. Meanwhile, there is a modest or no change in economic-related inequality in the use of clean cooking fuel in rural areas, but a vivid change is evident in urban areas, favouring well-off households. These results could be attributed to the higher income inequality reported between 2000 and 2017/18 in urban areas compared to rural areas [42]. This income inequality in urban areas translates into disparities in clean cooking energy usage compared to rural households, who predominantly rely on dirty cooking energy sources such as charcoal and firewood. Urban households with higher incomes can more easily access clean cooking fuel than rural households, given

Table 4
Cooking fuel use among households.

	Full sample					
Residence	Firewood	Paraffin	Electricity	Gas	Charcoal	Other Solid fuels
Rural	82.84	0.32	0.21	1.50	14.45	0.67
Urban	22.85	3.82	0.44	16.92	54.68	1.29
Total	57.50	1.80	0.31	8.01	31.45	0.93
	NPS 2014/15					
Residence	Firewood	Paraffin	Electricity	Gas	Charcoal	Other Solid fuels
Rural	82.92	0.52	0.29	0.67	15.12	0.48
Urban	24.12	6.53	0.56	6.77	60.19	1.83
Total	60.89	2.77	0.39	2.95	32.01	0.98
	NPS 2020/21					
Residence	Firewood	Paraffin	Electricity	Gas	Charcoal	Other Solid fuels
Rural	82.77	0.16	0.16	2.19	13.91	0.82
Urban	22.10	2.23	0.37	22.85	51.47	0.98
Total	55.09	1.10	0.25	11.62	31.05	0.89

Source: Author's computation from NPS 2014/15 and NPS 2020/21

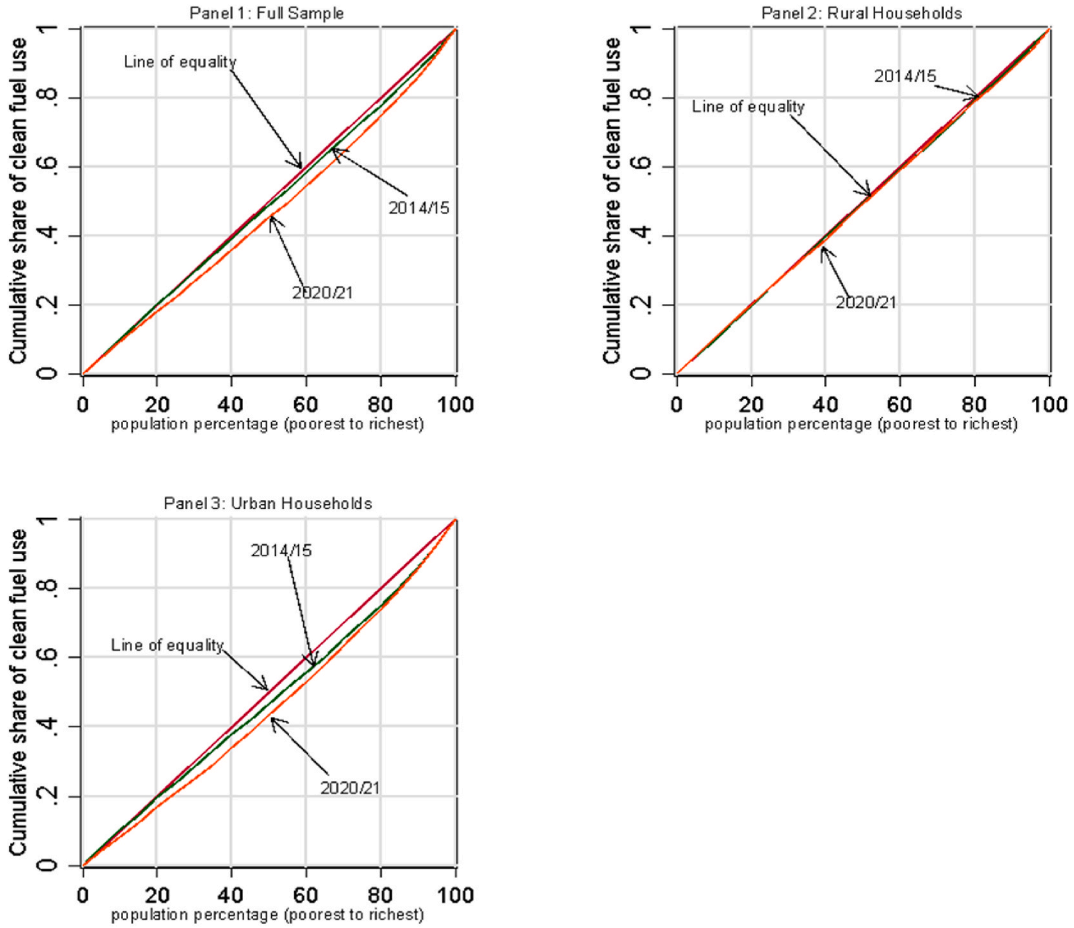

Fig. 1. Concentration curve for clean fuel use for cooking.

limited infrastructure development in rural areas that hinders access to clean fuel even for higher-income households.

4.4. Concentration index

The changes in economic inequality in the use of clean energy, as measured by the Erreygers Concentration Index, are summarized in Table 5. The positive values of the Erreygers Concentration Index (EI) indicated that the distribution of the use of clean cooking fuel was more concentrated among wealthier households. In the full sample, the EI for the use of clean fuel increased by 0.102 points, suggesting a significant rise in inequality over time. Similarly, in the urban sub-sample, the EI increased by 0.105 points, signifying a significant increase in the inequality among urban households. However, no significant change in the EI was observed for the rural sub-sample. Thus, there is a growing disparity in the use of clean cooking energy, the greater concentration being among wealthier households.

Table 5
Change in economic-related inequality in clean fuel use for cooking in rural and urban areas.

	NPS 2014/15	NPS 2020/21	Change over time
Full sample	0.047***	0.149***	0.102***
	(0.011)	(0.009)	(0.015)
Rural	0.025*	0.029**	0.004
	(0.014)	(0.012)	(0.019)
Urban	0.109***	0.215***	0.105***
	(0.019)	(0.015)	(0.024)

Notes: Standard error in parentheses; *p < 0.10, **p < 0.05, and ***p < 0.01.
Source: Author's computation from NPS 2014/15 and NPS 2020/21

4.5. Decomposition analysis

Table 6 presents an estimate of nonlinear decomposition for rural-urban inequality in clean cooking fuel use for the full sample, NPS 2014/15 and NPS 2020/21 sub-samples, including the contribution of variables used. The decomposition for the full sample (column 1) shows that urban households have a 0.1735 likelihood of using clean cooking fuels, as compared with 0.0172 for rural households. Additionally, the full sample shows the inequality between rural and urban households in the use of clean fuel for cooking is 0.1564. However, 81.59 % of the gap is explained by the variables in the model while 18.41 % is explained by unobserved factors. Thus, our decomposition model explained 81.59 % of the inequality in the use of clean cooking fuel between rural and urban households. Of the explained gap, the major contributors to the inequality are household head education (22.1 %), household having electricity (21.3 %) and household economic status (14.5 %). Additionally, household media access, zone of residence, household size and married household head respectively contribute significantly and positively to the existing inequality by 9.3 %, 6.97 %, 5.4 % and 5.3 %. Moreover, female household heads contribute significantly to the reduction of the existing inequality by 3.8 %.

NPS 2014/15 (column 2) shows that urban households have a 0.0732 likelihood of using clean cooking fuels, as compared with 0.0095 for rural households. Also, the inequality in the use of clean fuel for cooking between rural and urban households is 0.063 and 93.7 % of the gap is explained by variables in the model while 6.28 % is explained by unobserved variables. The decomposition model explains 93.7 % of the inequality in the use of clean cooking fuel between rural and urban households. The major contributor to the existing inequality is household head education (32.2 %), households having electricity (21.98 %) and zone of residence (20.9 %). Moreover, household economic status, household size and household access to mass media contribute significantly to the existing inequality by 9.5 %, 8.3 % and 7.6 %, respectively.

Lastly, the NPS 2020/21 (column 3) shows that urban households have a 0.2322 likelihood of using clean cooking fuels as compared with 0.0234 for rural households. The inequality in the use of clean fuel for cooking between rural and urban households is

Table 6
Decomposition of the inequality in clean fuel use for cooking between rural and urban residences.

	[1]	[2]	[3]
VARIABLES	Full Sample	NPS 2014/15	NPS 2020/21
Panel A			
Pr (Clean fuel = 1|Urban)	0.1735	0.0732	0.2322
Pr (Clean fuel = 1|Rural)	0.0172	0.0095	0.0234
Gap	0.1564	0.0637	0.2088
Explained gap	0.1276 (81.59 %)	0.0597 (93.72 %)	0.1727 (82.71 %)
Unexplained gap	0.0288 (18.41 %)	0.0040 (6.28 %)	0.0361 (17.29 %)
Panel B			
Household size	0.00841***	0.00529*	0.00802**
	(0.00249)	(0.00320)	(0.00346)
	[5.38 %]	[8.31 %]	[3.84 %]
Sex of household head	−0.00588***	−0.00635	−0.00370**
	(0.00192)	(0.00397)	(0.00184)
	[-3.76 %]	[-9.97 %]	[-1.77 %]
Age of household head	0.000761	−0.00486	0.00122***
	(0.000989)	(0.00337)	(0.000432)
	[0.49 %]	[-7.63 %]	[0.58 %]
Married household head	0.00835***	0.00705	0.00810***
	(0.00243)	(0.00457)	(0.00279)
	[5.34 %]	[11.07 %]	[3.88 %]
Mass media access	0.0146***	0.00481*	0.0264***
	(0.00289)	(0.00247)	(0.00522)
	[9.34 %]	[7.55 %]	[12.64 %]
Household head education	0.0346***	0.0205***	0.0413***
	(0.00321)	(0.00381)	(0.00471)
	[22.12 %]	[32.18 %]	[19.78 %]
Economic status	0.0226***	0.00603*	0.0392***
	(0.00308)	(0.00325)	(0.00484)
	[14.45 %]	[9.47 %]	[18.77 %]
Electricity	0.0333***	0.0140***	0.0356***
	(0.00398)	(0.00445)	(0.00585)
	[21.29 %]	[21.98 %]	[17.05 %]
Zone of residence	0.0109***	0.0133***	0.0165***
	(0.00188)	(0.00467)	(0.00299)
	[6.97 %]	[20.88 %]	[7.90 %]
Observations	8061	3352	4709

Standard errors in parentheses, contribution to the gap in square brackets.
***p < 0.01, **p < 0.05, *p < 0.1.
Source: Author's computation from NPS 2014/15 and NPS 2020/21

0.2088 and 82.71 % is explained by variables in the model while 17.29 % is explained by unobserved factors. Thus, the model explains 82.71 % of the inequality in the use of clean cooking fuel. The decomposition model explains 82.71 % of the inequality in the use of clean cooking fuel between rural and urban households. The main contributors to this inequality are household head education status (19.8 %), household economic status (18.8 %), household having electricity (17.1 %), and household mass media access (12.6 %). Additionally, zone of residence (7.9 %), household size (3.8 %), married household head (3.9 %) and age of the head of household also contribute to the existing gap. However, female household heads play a significant role in narrowing the existing gap by 1.8 %. These findings underscore the importance of addressing education, electricity access, economic conditions, and media access in both rural and urban areas to reduce the inequality in clean fuel use for cooking and promote more equitable energy utilization across the population.

4.6. Robustness checks

To assess the robustness of our results, we examined how the order of variables in the decomposition impacts the outcomes. Due to the nonlinearity of the decomposition equation, the estimated results could be influenced by the random ordering of the variable across replications of the decomposition (i.e. path dependency) [41]. Additionally, the ordering of variables shows how sensitive are the obtained results [41]. Decomposition with the ordering of variables, the total contribution remains unchanged, as the sum of individual contributions must always equal the total contribution defined in Equation [2], regardless of their order [41].

Table 7 presents estimates with reversed variable distribution ordering. Overall, these estimates are quite similar to the original ones, with some notable differences. In the full sample (column 1), the primary factors contributing to inequality in the use of clean cooking fuel between rural and urban areas include household access to electricity, household head education level, household economic status, household access to the mass media, and the marital status of the household head (i.e., married). This indicates that

Table 7
Robustness check Fairlie Decomposition.

	[1]	[2]	[3]
VARIABLES	Full Sample Reverse Order	NPS 2014/15 Reverse Order	NPS 2020/21 Reverse Order
Panel A			
Pr (Clean fuel = 1|Urban)	0.1735	0.0732	0.2322
Pr (Clean fuel = 1|Rural)	0.0172	0.0095	0.0234
Gap	0.1564	0.0637	0.2088
Explained gap	0.1276 (81.59 %)	0.0597 (93.72 %)	0.1727 (82.71 %)
Unexplained gap	0.0288 (18.41 %)	0.0040 (6.28 %)	0.0361 (17.29 %)
Panel B			
Household size	0.00678***	0.00370	0.00586**
	(0.00219)	(0.00276)	(0.00274)
	[4.34 %]	[5.81 %]	[2.81 %]
Sex of household head	−0.00256**	−0.00255	−0.00177
	(0.00128)	(0.00259)	(0.00126)
	[-1.64 %]	[-4.00 %]	[-0.85 %]
Age of household head	0.000801	−0.00294	0.00291***
	(0.00110)	(0.00257)	(0.000976)
	[0.51 %]	[4.62 %]	[1.39 %]
Married household head	0.00656***	0.00384	0.00568***
	(0.00166)	(0.00283)	(0.00176)
	[4.19 %]	[6.03 %]	[2.72 %]
Mass media access	0.00940***	0.00262*	0.0169***
	(0.00206)	(0.00155)	(0.00370)
	[6.01 %]	[4.11 %]	[8.09 %]
Household head education	0.0316***	0.0172***	0.0372***
	(0.00310)	(0.00369)	(0.00460)
	[20.21 %]	[27.00 %]	[17.82 %]
Economic status	0.0229***	0.00600*	0.0398***
	(0.00312)	(0.00312)	(0.00486)
	[14.64 %]	[9.42 %]	[19.06 %]
Electricity	0.0436***	0.0155***	0.0479***
	(0.00494)	(0.00480)	(0.00772)
	[27.88 %]	[24.33 %]	[22.94 %]
Zone of residence	0.00866**	0.0164**	0.0182***
	(0.00341)	(0.00676)	(0.00559)
	[5.54 %]	[20.75 %]	[8.72 %]
Observations	8061	3352	4709

Standard errors in parentheses, contribution to the gap in square brackets.
***p < 0.01, **p < 0.05, *p < 0.1.
Source: Author's computation from NPS 2014/15 and NPS 2020/21

achieving equal access to electricity could reduce the rural-urban disparity in the use of clean cooking fuel by 27.9 % for the full sample, 24.3 % for the 2014/15 sample, and 22.9 % for the 2020/21 subsample. Equalizing access to education would decrease inequality by 20.2 % (full sample), 27 % (NPS 2014/15), and 17.8 % (NPS 2020/21) while equalizing household economic status would lead to a reduction of 14.6 % (full sample), 9.4 % (NPS 2014/15), and 19.1 % (NPS 2020/21) in rural-urban disparity in the use clean cooking fuel.

Fairlie decomposition with variable reordering reveals the key factors driving rural-urban inequality in the use of clean cooking fuel. Household access to electricity is the most significant contributor, explaining 27.9 % (full sample), 24.3 % (NPS 2014/15), and 22.9 % (NPS 2020/21) of the explained gap. Household head education level plays a substantial role, accounting for 20.2 % (full sample), 27 % (NPS 2014/15), and 17.8 % (NPS 2020/21) of the inequality, while household economic status contributes 14.6 % (full sample), 9.4 % (NPS 2014/15), and 19.1 % (NPS 2020/21) to rural-urban inequality in the use of clean cooking fuel.

In general, the previous results remain robust and persistent. The rural-urban inequality in the use of clean cooking fuel is consistently explained by the chosen variables. However, the decomposition reveals that when variables are ordered differently, there is a slight change in the percentage contribution for these variables. For example, in the Fairlie decomposition with variable ordering, we found that household head education, household economic status, and electricity connection contributed to inequality by 20.2 %, 14.6 %, and 27.9 %, respectively. This contrasts with the decomposition without variable ordering, where their contributions were 22.1 %, 14.5 %, and 21.3 %.

5. Discussion

This study was conducted to enrich the existing literature on energy use in developing countries with a specific focus on Tanzania. Building on prior studies conducted in Africa, we investigated the economic and rural-urban inequality in the use of clean cooking fuel in Tanzania. This is in line with the National Energy Policy of 2015 which aligns with the UN Sustainable Development Goals to achieve universal access to affordable, reliable and modern energy services by 2030. The policy emphasizes increasing access to modern energy services and promoting the use of renewable energy sources in the electricity generation mix to enhance the supply availability and reliability of environmentally friendly energy sources.

This study expands the existing stock of knowledge on the factors that influence the choice of cooking fuel by conducting a comprehensive analysis to illuminate the economic and rural-urban inequality in the use of clean cooking fuels in Tanzania. The study is useful in informing the policies on improving access to clean energy for all segments of the population. The study analysed economic and rural-urban inequality in the use of clean cooking fuel in Tanzania and its contributing factors using NPS 2014/2015 and NPS 2020/21. First, we plotted a concentration curve and estimated the Erreygers concentration index for the use of clean fuel. Finally, the nonlinear decomposition technique was applied to estimate the factors that contribute to rural-urban inequality in the use of clean fuel. This was done by using Fairlie decomposition analysis.

The findings revealed important insights into the changes in the inequality in the use of clean cooking fuel. First, we found that the use of clean fuel for cooking is more concentrated in richer households. Additionally, we observed a significant increase in inequality by wealth over six years, suggesting that much of the increase in the use of clean energy occurred in richer households. This could be supported by the increased consumption inequality from a Gini coefficient of 0.34 in 2011/12 to 0.38 in 2017/18 in Tanzania [42]. This observation aligns with the findings by Tabiri et al. [23] in Ghana, whose findings indicated an increase in wealth-related inequality in the use of clean fuel. This means that the better-off households have greater access to clean cooking fuel.

Second, an evident gap between rural and urban households in the use of clean cooking fuel (0.156) was revealed. Further, the rural-urban inequality in the use of clean cooking fuel was found to have increased from 0.0637 in 2014/15 to 0.2088 in 2020/21 (see Panel A of Table 5). This could be explained by the increase in consumption inequality in urban and rural areas between 2011/12 and 2017/18 [42]. Urban households are more likely to use clean cooking fuel compared to rural households as emphasized by previous studies carried out in Afghanistan [21], Pakistan [12] and sub-Saharan Africa [14].

Regarding the factors that contribute factors to the rural/urban inequality in the use of clean cooking fuel, our nonlinear decomposition analysis (see Panel B of Table 5) indicated that household size positively and significantly contributes to the existing gap by 5.4 %. However, we observed a change in the contribution of household size in the use of clean cooking fuel from 8.3 % in 2014/15 to 3.8 % in 2020/21. A study conducted in Pakistan revealed a non-linear impact of household size on clean fuel consumption intensity [12] but a positive connection with the use of dirty cooking fuel in Afghanistan [21].

Overall, female-headed households contribute significantly to narrowing the existing gap in the use of clean cooking fuel. Despite the female-headed households not being significant in explaining the existing inequality in the use of clean cooking fuel in 2014/15, they contributed significantly to narrowing the gap by 1.8 % in 2020/21. This phenomenon can be attributed to several factors, including the convenience women find in using modern fuels, the autonomy they have in making choices on fuel use, and the allocation of resources towards cooking and food preparation in their homes. In Tanzania, there has been a decline in gender inequality from 0.556 in 2013 to 0.539 in 2019 [43]. The role of female household heads in the adoption of modern energy sources such as electricity and LPG has been emphasized by previous studies in sub-Saharan Africa [14], and Pakistan [12]. However, the study conducted in Tanzania revealed that male-headed households were willing to switch from charcoal too [13].

Consequently, programmes aimed at enhancing the affordability of energy sources should take into consideration the specific needs of women and their pivotal role in narrowing the energy inequality gap. This aligns with the arguments made by Mohideen [44] emphasizing that modern energy technologies are not only technical solutions but also social products. In developing countries like Tanzania, where women's lives are heavily burdened with traditional gender roles within households, improved technology can alleviate some of these burdens and promote gender equity. Therefore, energy initiatives must recognize and address gender-specific needs to ensure access to equitable energy for all.

Also, the married household heads significantly contribute to the gap between rural and urban areas in the use of clean cooking fuel by an overall percentage of 5.3 % and by 3.9 % in 2020/21 but was not significant in 2014/15. This indicates that urban married women prefer clean fuels to traditional fuels, unlike the rural married household heads. This can be attributed to the entrenched traditional gender roles, impoverished economic conditions, inadequate infrastructure, restricted accessibility, limited awareness, deficient education, and prevailing cultural norms in rural areas when juxtaposed with their urban counterparts. Household heads were found to have a positive effect on the choice of LPG as compared to traditional fuels in Afghanistan [21]. This could be attributed to the involvement of both females and males in household decision-making, particularly in making decisions on expenditures such as the expenses of fuel, particularly within marital contexts [18].

Moreover, the mass media significantly contributes to the existing gap. According to the results, the mass media widens the rural-urban disparity in the use of clean cooking fuel by limiting access to alternative energy information in rural regions. Urban areas benefit from awareness campaigns that rural areas lack, and media-driven behavioural shifts towards cleaner options occur more readily in urban contexts. A study conducted in Bhutan revealed that households with access to information are more likely to adopt clean cooking fuels and less likely to adopt dirty fuels when exposed to relevant information [45].

Additionally, the educational level of household heads significantly contributes to the gap in the use of clean cooking fuel between rural and urban households. The level of education of a household head contributes to the rural-urban gap in the use of clean cooking fuel by fostering awareness and affordability. Educated household heads in urban areas understand the benefits of clean fuel and can better afford alternatives, thus reducing dependence on traditional fuel compared to educated household heads in rural areas. These findings are in line with previous studies for example Tabiri et al. [23]. Increased household awareness of health and environmental risks linked to fuelwood, combined with access to LPG market details, was found to increase LPG-preferred energy mixes in Tanzania [22], while education in Ethiopia enables an understanding of the adverse health effects of the use of biomass fuel, with possible environmental implications [46]. Furthermore, studies conducted in Pakistan [12], Northern Sudan [47], and Cameroon [21] have unveiled a positive correlation between the educational level of the household head and the adoption of clean fuels.

Additionally, inequality can be explained by household access to electricity where urban households have more access to electricity compared to rural households. Household access to electricity plays a pivotal role in reducing the rural-urban gap in clean cooking fuel utilization by enabling rural areas to adopt modern electric cooking technologies. This transition from traditional biomass fuels to electric energy contributes to a more balanced use of clean cooking fuel between rural and urban settings. In Tanzania, access to electricity has increased from 49.3% in 2016 to 69.6% in 2019/20 [8].

Household economic status is another contributor to inequality. Evidence shows that urban households have a better economic status compared to rural households. This translates into inequality in the use of clean cooking fuel between rural and urban households. Economic status exacerbates the disparity in the use of clean cooking fuel between rural and urban areas due to affordability differences. Urban people with higher economic status can readily adopt cleaner alternatives, while rural people face limitations in affording modern cooking technologies, thus finding themselves compelled to rely on traditional biomass fuels. This economic inequality reinforces the gap in the utilization of clean cooking fuel between the rural and urban areas. The contribution of economic status to the existing gap between urban and rural areas in the use of clean cooking fuels is reported to have increased rapidly between 2014/15 and 2020/21. In Tanzania, there has been an increase in consumption between 2011/12 and 2017/18(42). Furthermore, prior research has underscored the significance of household economic conditions in influencing the utilization of clean energy sources in various countries, including Tanzania [22], India [48], South Asia [49], and Ethiopia [50].

Lastly, the contribution of the zone of residence to the existing gap in the use of clean cooking fuel decreased dramatically from 21 % in 2014/15 to only 8 % in 2020/21. This could be attributed to the massive electrification in the country during this period, especially in rural areas. The existing gap in the use of clean cooking fuel between rural and urban areas is influenced by the regional zone of residence, composed of diverse regions. Urban areas, which are typically better developed, have easier access to clean cooking fuel options due to advanced infrastructure. However, variations in infrastructure, economic conditions, and government interventions across different rural regions contribute to differences in the levels of accessibility and affordability of clean cooking fuels, hence accentuating the disparity.

6. Conclusion

This study contributes to the existing stock of knowledge on the use of clean cooking fuel in Tanzania, particularly on the economic and rural-urban inequalities in the use of such fuel. Aligning with the National Energy Policy and UN Sustainable Development Goals, the study provides insights into the challenges constraining the effort towards universal access to affordable and clean energy services by 2030. The study uses nationally representative data from two National Panel Surveys of 2014/15 and 2020/21 to explain the rise in economic and rural-urban inequality in the use of clean cooking fuel in Tanzania. Erreygers Concentration Index was used to measure the economic inequality in the use of clean cooking fuel between the survey periods. Additionally, the Fairlie decomposition technique, an extension of the Blinder-Oaxaca decomposition method, was used to identify the factors that contribute to the existing rural-urban gap in the use of clean cooking fuel. The study's findings reveal a prevalent reliance on dirty cooking fuel in Tanzania, which has substantial economic, social, environmental and public health effects. Also, the study findings indicate a gap in the use of clean cooking fuel between rural and urban areas, with urban households using clean cooking fuels more than rural ones. According to the findings, the gap has increased between the two surveys. Overall, household size, marital status, mass media access, household head education, economic status, household connection to electricity, and the zone of residence contribute to the existing inequality.

The analysis underscores the role of various factors that contribute to rural-urban inequality in the use of clean cooking fuel.

Household economic status has emerged as the main contributor to the existing inequality, where as a result of having a better economic status, urban households are more likely to adopt clean cooking fuel than rural households. The study suggests that improving the level and distribution of wealth both in rural and urban areas can increase the use of clean fuel for cooking. Additionally, the zones of residence which differ in terms of infrastructure and access to energy resources contribute to rural-urban inequality in the use of clean cooking fuel. However, the contribution of the zones of residence was found to have decreased between the study periods. Thus, the variations in the zones of residence call for tailored policy interventions to address the challenges which can be unique to different areas.

Household head education and household access to the media play important roles in influencing the existing gap in the use of clean cooking fuel between rural and urban households. The increase in education level both the expected year of schooling and mean year of schooling in Tanzania between 2010 and 2019 can be the reason for the decrease from 32 % to 19 % between the study periods. Educated heads of households understand the advantages of clean cooking fuels, unlike uneducated ones. Moreover, household access to the media has an impact on behaviour change and awareness. It significantly influences the use of clean cooking fuels. Since urban households are more exposed to the media, they easily adopt clean energy as they get the messages from the campaigns against dirty cooking fuels. This implies that education and the media have to be made accessible to both rural and urban residents. Moreover ensuring access to affordable electricity will help to bridge the gap between rural and urban households in the use of clean cooking fuel.

The study also emphasizes the importance of gender equity and household connection to electricity. Female-headed households are more likely to adopt clean cooking fuel, owing to the role that women play in the household when it comes to issues related to cooking. Female heads of households are more likely to contribute to narrowing the gap in the use of clean cooking fuel between urban and rural households. This implies that female-headed households in rural areas are likely to use clean fuel for cooking contributing to the narrowing of the gap.

In summary, this research underscores the multifaceted nature of the gap in the use of clean cooking fuel between rural and urban areas in Tanzania. The findings highlight the need for comprehensive policies that address economic disparities, regional inequalities, education, media influence, gender equity, and connection to electricity to achieve a more equitable distribution of clean energy sources in the country.

The robustness of the study stems from its utilization of a non-linear decomposition technique considering the ordering of variables. This technique enables the measurement of the impact of the identified factors on the urban-rural gap in clean cooking fuel use. In contrast to prior studies that solely pinpointed the factors determining the choice of cooking fuel, this study goes further by quantifying their effects. The current study has two limitations, however. Firstly, the use of consumption per adult equivalent per month is susceptible to seasonality and potential underreporting. Additionally, the nonlinear decomposition analysis employed in the study cannot establish causal relationships.

Data availability

The data was sourced from the publicly available Tanzania Living Standards Measurement Study (LSMS) National Panel Surveys, for Wave 4 (2014–15) and Wave 5 (2020–21).

CRediT authorship contribution statement

Magashi Joseph Ntegwa: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Lulu Silas Olan'g:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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