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Inequality of opportunity in access to and consumption of modern energy in Togo: A parametric approach

Tchablemane Yenlide[1] · **Mawussé Komlagan Nézan Okey**[1]

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Abstract
The transformation towards cleaner energy consumption in Togo is progressing at a slow pace due to a combination of unfavourable socioeconomic, demographic, and spatial factors that favour traditional fuel use over clean and efficient energy. This study tries to quantify the inequality in modern energy access by applying the inequality of opportunity framework. We use a parametric approach to the 2015 Togolese Living Standard Survey; our results show that, on average, 40.76% of inequalities in household modern energy access and consumption in Togo are due to unequal circumstances beyond their control. A Shapley-value decomposition shows that inequalities of opportunity are greater for older persons and women than for youths and men, respectively. Moreover, these inequalities are more pronounced in rural areas and poor regions, especially the Savanna and Kara regions. Consequently, policies aimed at reducing inequality of opportunity in modern energy access and consumption in Togo should emphasise demographic factors, such as gender, age composition, and geographic location of households.

Keywords Energy consumption · Electricity · Inequality of opportunity · Togo

1 Introduction

Energy consumption is an essential element, forming the backbone of economic growth and well-being (Ahmed et al. 2016; Liu et al. 2015; Wang and Yang 2014; Yuan et al. 2014; Zhang et al. 2017). However, traditional fuel energy is still important and is one of the main contributors to carbon emissions. The World Health Organization (WHO) estimated that in 2016 over 3 billion people depended on biomass fuels for domestic purposes (cooking, heating, and lighting); in Africa, more than 600 million people live without electricity, 80% of whom live in rural areas (Blimpo and Cosgrove-Davies 2020). The use of biomass contributed to nearly 600,000 premature deaths in 2012 (WHO 2014). Switching

✉ Tchablemane Yenlide
yenlidegeorges@gmail.com

Mawussé Komlagan Nézan Okey
mawusseo2000@gmail.com

[1] Faculté Des Sciences Economiques Et de Gestion, Université de Lomé, P.O. Box : 1515, Lomé, Togo

to modern and renewable energy sources would address this negative trend (Rehfuess 2007).

Like many developing countries, Togo has committed to improving electricity access: the 2018–2030 national electrification program aims at achieving a 75% electricity access rate by 2025 and universal access by 2030 despite various challenges. Recent surveys in Togo show significant disparities in modern energy access and consumption. While access to electricity in the country has reached 50% (INSEED 2020), households living in rural areas still are the most disadvantaged – with an access rate of 26% compared to 88% for urban areas. Biomass stays the primary energy source in rural areas (97%) and poor regions (98% and 95% for the Savanna and Kara regions, respectively). Recent studies confirm that women in Togo are disadvantaged by the dynamics of gender income inequalities (Couchoro and Dout 2019). Further, in African countries, modern energy (electricity or gas) access is concentrated in male-headed households (Sana et al. 2020), showing, to some extent, the persistence of inequality of opportunity in modern energy access and consumption in the country.

This study investigates inequalities of opportunity in modern energy access and consumption in Togo using a parametric approach. Inequalities of opportunity analyses emphasise that inequality in outcomes is neither all good nor all bad (Shi 2019). Roemer (1998a; 1998b) contributed two approaches to understanding inequality. The first focuses on inequality of opportunity arising from differences in circumstances beyond the individual's control, for example, gender and region of birth. The second approach treats inequality as deriving from levels of effort by individuals in respect of factors for which they are responsible, for example, education and health. Inequality of opportunity has been estimated using a variety of methods for a wide range of outcomes, including households' per capita income, consumption expenditure (Bourguignon et al. 2007; Ferreira et al. 2011) and educational (Golley and Kong 2018) and health outcomes (Jusot et al. 2013; 2017). However, less research has focused on the inequality of opportunity in energy consumption (Shi 2019).

Several studies addressing access to modern energy issues in sub-Saharan Africa's developing countries have found that income and high energy costs significantly affect household fuel choices (Ouedraogo 2006; Mekonnen and Köhlin 2008; Sana et al. 2020). However, few studies have examined inequality of opportunity in households' modern energy access and consumption in these countries. In this study, we use nationwide data from the 2015 Togolese living standard survey to estimate the inequality of opportunity in modern energy access and consumption in Togo. The study has two purposes. First, to quantify the degree of inequality of opportunity in modern energy consumption expenditure and second, to estimate the relative contribution of each determinant of unequal opportunities.

The results of this study highlight the existence of inequalities of opportunity in access to modern energy in Togo. It is essential to contextualize these findings to better understand their implications beyond the borders of Togo. By considering the implications of these conclusions for other countries facing similar challenges, this article proposes avenues for reflection to adapt energy policies and promote more fair approaches to electricity access. A better understanding of the underlying factors contributing to these inequalities can inspire the implementation of effective measures aimed at improving access to modern, clean, and affordable energy on an international scale.

The rest of the paper is organised as follows: Section 2 offers a brief overview of the concept of inequality of opportunity and Section 3 sets out our methodological approach, and Section 4 describes the survey design and main variables; the estimation results are

presented and discussed in Section 5. Finally, Section 6 concludes and summarises the empirical findings.

2 The concept of inequality of opportunity: a brief overview

The assumption that underpins the concept of inequality of opportunity in the literature is that seen inequalities in welfare indicators can arise from several sources. Several authors have assessed inequality of opportunity in specific areas, for example, primary goods (John 1971), opportunities (Arneson 1989) and capabilities (Sen 1992). Roemer (1998a) shed light on the difference between individuals' circumstances and their efforts. Circumstances are the environmental attributes out of an individual's control and that affect the attainment of their goals. By contrast, effort refers to individual behaviours and decisions that figure out the level of goal they achieve.

Based on Roemer's conceptual framework, several authors have implemented empirical applications using indicators related to education, health (Golley and Kong 2018), consumption (Bourguignon et al. 2007), telecommunications (Wonyra et al. 2021), and individual wages (Björklund and Salvanes 2011).

Sanoussi (2017) studied inequality of opportunity in access to maternal and child health services in Togo between 1998 and 2013, focusing on changes in the following indicators: birth in health centres, access to immunisation, access to prenatal care, having at least four antenatal visits and adequate care. The author found increased inequality of opportunity in access to antenatal care and access to adequate care. This inequality decreased for births in a health centre, access to immunisation, and access to prenatal care and antenatal visits. Parents' education, region and place of residence were the most significant contributors to these outcomes.

In another study of the health sector, Sanoussi et al. (2020a) analysed inequality of opportunity in access to child health and nutrition in the Democratic Republic of Congo (DR Congo), Guinea Bissau and Mali. The study revealed inequality of opportunity was an important determinant of immunisation for DR Congo (83.79%) and access to health services before and after delivery for Guinea Bissau (43.85%) and Mali (41.67%).

Studies on inequalities of opportunity in education have also yielded valuable insights. For instance, using two related measures of educational inequality, Ferreira and Gignoux (2014) found that inequality of opportunity accounts for up to 35% of all disparities in academic achievement; this inequality is more pronounced in Europe and Latin America than in Asia, Scandinavia, and North America.

Sanoussi et al. (2020b) examined the transition from school to work in Benin, Liberia and Togo, concluding that inequality of opportunity is more pronounced in Benin for job opportunities (33.6%) and contracts (40.8%) and in Liberia in respect of job opportunities with insurance (49.3%). Demographic factors contribute much more to inequality in access to employment in Liberia (78.02%) than in Benin (74.26%) and Togo (45.05%); however, family background contributes more to inequalities of opportunity in job access in Togo than in other countries.

Wonyra et al. (2021) investigated inequality of opportunity in accessing telecommunication services in Togo, showing that, on average, 12.27% of inequality of access and use was attributable to unequal circumstances beyond the individual's control. A decomposition of the Shapley value revealed that an individual's place of residence and region of birth are the two main contributors to inequality of opportunity across age cohorts.

More recently, Shi (2019) focused on inequalities of opportunity in China's energy sector and showed that 10.02% of inequality in energy consumption could be explained by inequality of circumstances beyond individual control; hukou status and region of residence were the two main contributors. Compared to the existing literature, this study contributes by applying an inequality of opportunity approach to the Togolese context and beyond traditional fields of study such as education, health and telecommunication.

3 Methodological framework

3.1 Parametric approach to inequality of opportunity

Inequality of opportunity in modern energy access and consumption in Togo is investigated by employing a parametric approach (Bourguignon et al. 2007) and applying the methodological framework of Wonyra et al. (2021), who quantified inequality of opportunity in access to telecommunication services. Based on the approach of Roemer (1998a), the modern energy consumption function is expressed as follows:

$$y_i = f\left(C_i, E_i, u_i\right), \tag{1}$$

where y_i is the modern energy consumption expenditure of individual i, C_i is a vector of circumstance variables, and E_i is a vector of effort variables.

The log-linear form of Eq. (1) is:

$$\ln y_i = \alpha C_i + \beta E_i + u_i, \tag{2}$$

$$E_i = \gamma C_i + \vartheta_i \tag{3}$$

The developed form of Eqs. (2) and (3) is:

$$\ln y_i = C_i(\alpha + \beta\gamma) + \vartheta_i\beta + u_i \tag{4}$$

We obtain a reduced form of Eq. (4) which can be estimated by the ordinary least squares (OLS) method as follow:

$$\ln y_i = C_i\varnothing + \varepsilon_i \tag{5}$$

where ϕ is the vector of coefficients, ε_i the error term. For each individual i, predicted values of energy expenditure are figured by aggregation, considering their opportunities and using OLS in a multiple regression setting. Inequality of opportunity is measured by employing the coefficient $\widehat{\varnothing}$ obtained through OLS estimation in Eq. (5) to capture a counterfactual distribution $\widehat{y_i}$ using Eq. (6), which is specified as follows:

$$\widehat{y_i} = \exp\left(C_i\widehat{\varnothing}\right) \tag{6}$$

The absolute measure of inequality of opportunity is defined as $\left(IO_A\right) = I\left(\left\{\widehat{y_i}\right\}\right)$ and the share of inequality of opportunity $\left(IO_R\right)$ in total inequality (relative measure) is given by the relation $\left(IO_R\right) = I\left(\left\{\widehat{y_i}\right\}\right)/I\left(\left\{y_i\right\}\right)$, with $I\left(\left\{y_i\right\}\right)$ representing the total inequality in the distribution of consumer spending on modern energy. The generalized entropy index of degree zero, GE(0), is used to quantify the distribution of inequality in modern energy consumption expenditure (Ferreira et al. 2011).

3.2 Estimation of contributions of circumstance variables

From the general approach to estimating inequality of opportunity, the partial effect for a specific circumstance can be estimated using the counterfactual distribution of Ferreira et al. (2011) as follows:

$$\widehat{y}_i^j = \exp(\overline{C}^j \widehat{\varnothing}^j + C_i^{j\neq J} \varnothing^{j\neq J} + \widehat{u}_i) \tag{7}$$

The variation in expenditure due to circumstance J is neutralised while keeping variations due to other circumstances. The effects of differences between circumstances (inter-opportunity inequality) are neutralised by estimating a counterfactual distribution ($\widehat{y}_i$) and assigning the same value to all the selected circumstance variables and, for each circumstance, the value of the average of all circumstances $\left(\overline{C}\right)$.

The inequality of opportunity attributable to circumstance J (IO_A^{PJ}) and the relative share of inequality due to that circumstance (IO_R^{PJ}) are given by:

$$IO_A^{PJ} = I(\{y_i\}) - I\left(\left\{\widehat{y}_i^j\right\}\right) \tag{8}$$

$$IO_R^{PJ} = 1 - \frac{\left(\left\{\widehat{y}_i^j\right\}\right)}{(\{y_i\})}, \tag{9}$$

where $I\left(\left\{\widehat{y}_i^j\right\}\right)$ is the inequality due to variation in the other circumstance variables. Following Björklund et al. (2011), Shapley decomposition is used to estimate the partial contribution of circumstance variables. The process starts with the estimation of the inequality measures for all possible permutations of the circumstance variables and ends with the calculation of the average marginal effect of each circumstance on the inequality measure. Shapley decomposition offers two advantages: i) it does not depend on the order, and ii) inequality of opportunity is the sum of the contributions of each circumstance variable.

4 Data

4.1 Description of the survey

The data used in this paper are from the Togolese 2015 living standards survey (QUIBB). This survey, conducted by the National Institute of Statistics, Economics and Demographic Studies (INSEED), supplies useful information for welfare measurement in several dimensions, including energy. Multi-stage stratified random sampling is used in the survey design. The survey uses two questionnaires: a main questionnaire on issues of access to social services like education, health, energy, and housing and socioeconomic characteristics and a second questionnaire about household income, consumption and expenditure.

The expenditures were grouped along 12 dimensions: alcohol and tobacco, clothing and footwear, education, electricity, food, health, household goods and maintenance, housing, hotels and restaurants, leisure and culture, miscellaneous goods and services, telecommunications, and transport.

Table 1 Descriptive Statistics

Variable	Observations	Mean	Percentage
Monthly energy expenditure (F CFA)	1,924	9,152.16	100%
Age	1,924	39.93	100%
Gender			
Male	1,466	0.762	76.20%
Female	458	0.238	23.80%
Place of residence			
Urban	1,328	0.69	69.02%
Rural	596	0.31	30.98%
Region of birth			
Lomé	685	0.356	35.60%
Maritime	232	0.121	12.06%
Plateaux	308	0.16	16.01%
Central	198	0.103	10.29%
Kara	262	0.136	13.62%
Savanna	239	0.124	12.42%

Source: Authors' calculations using the QUIBB 2015 database

Note: The currency used in the West African Economic and Monetary Union (WAEMU) countries. On 8 February 2022, the exchange rate is as follows: 1 CFA FRANC = 0.0017 USD

The survey covered 2,400 households. We applied restrictions to the original data set. We keep only information for household heads aged between 20 and 60 and exclude households with missing information for spending on electricity consumption and other relevant variables (age, region of birth, and residence). Those restrictions reduced the sample size from 2,400 to 1,924 households (Table 1). To measure the inequality of opportunity in energy expenditure across age groups, we divide the sample into four birth cohorts: Cohort 1 comprises individuals born between 1985 and 1995, Cohort 2 includes those born between 1975 to 1984, Cohort 3 those born between 1965 to 1974, and finally Cohort 4 for those born between 1955 and 1964.

4.2 Main variables

We use households' monthly expenditure on electricity consumption as the principal measure of modern energy since there is a lack of information about other modern energy sources. Energy in Togo comes from three sources: biomass, petroleum products and electricity INSEED (2020). Togo has experienced rapid growth in electricity access, which rose from 23% in 2010 to 54% in 2020, and this is mainly derived from oil (50.6%), hydro (49%) and biomass (0.4%). This measure may not reflect the whole story of modern energy consumption in Togo and could be improved with access to data on expenditure for other modern energy forms. This will be the focus of our future research.

Based on earlier studies on inequality of opportunity (Bourguignon et al. 2007; Singh 2012; Ferreira et al. 2011; Wonyra et al. 2021), this paper uses three circumstance variables, gender, place of residence and region of birth.

The first circumstance variable is gender. Several studies in developing countries have shown that gender is a critical factor in household energy choices (Ouedraogo 2006). For instance, Sana et al. (2020) found that the use of traditional fuels (e.g., wood and charcoal) is associated with women due to their lack of financial capacity and low levels of empowerment. In this paper, the role of gendered consumption patterns in shaping inequality of opportunity in energy consumption expenditure is examined using a dummy variable that takes the value of 0 for male heads of households and 1 for female heads of households.

The second circumstance variable included is the place of residence. Paudel et al. (2018) found that households across urban areas prefer modern energy for cooking and lighting than their counterparts in rural areas (who prefer wood, charcoal and oil), for whom access to modern energy is more limited. This paper includes residence as a dummy variable taking the value of 1 for rural households and 0 for urban households.

The final circumstance variable is the region of birth. Although Togo experienced a reduction in poverty in 2018, from 61,7% in 2006 to 45,5% (INSEED 2020), there stays substantial inequality across regions. The northern regions are poorer and suffer more from the scarcity of basic infrastructure (e.g., electricity, water, and sanitation) than those in the southern part of the country. The inclusion of region of birth as a circumstance variable addresses this vast diversity in inequality of opportunity in modern energy consumption across regions. The variable is reduced to six modalities: Lomé (capital), Maritime, Plateaux, Central, Kara and Savanna.

5 Results

5.1 Descriptive statistics

Table 1 presents the descriptive statistics of these variables in addition to the age of household heads and the monthly household expenditure on electricity energy consumption, expressed in CFA francs. In a sample of 1,924 respondents, nearly 24% were women. Most respondents were resident in urban areas (69%). Of the regions of birth, Lomé accounted for 36% of respondents, followed by the Plateaux (16%), Kara (13%), Savanna (12.42%), Maritime (12.06%) and Central (10.29%) regions. The average age of householders in the sample is 40 years old, and the average monthly expenditure on energy consumption is estimated to be 9,152 CFA francs.

Table 2 sets out the preliminary statistics for energy consumption across age cohorts. Consistent with expectations, energy consumption expenditures varied substantially across cohorts, and, on average, Cohort 1 (young people) had the lowest expenditure on energy consumption, while Cohorts 2 and 3 had the highest expenditure levels. Men spent more than women on modern energy consumption, regardless of age, place of residence, or region of birth. Moreover, people living in urban areas have higher spending on modern energy consumption than those living in rural areas. Finally, modern energy consumption expenditure is higher for householders born in Lomé, followed by those from the Maritime and Kara regions (depending on cohorts). Those born in the Savanna region had the lowest spending on energy consumption.

Table 2 Monthly energy consumption expenditure across cohorts

Average monthly energy expenses (FCFA)	Cohort 1 **1985–1995 (20–30)**	Cohort 2 **1975–1984 (31–40)**	Cohort 3 **1965–1974 (41–50)**	Cohort 4 **1955–1964 (50–60)**
Total	7,082.81	10,093.15	9,734.65	9,068.03
Gender				
Male	6,870.52	10,224.77	10,363.83	9,069.98
Female	7,838.38	9,548.15	7,965.09	9,063.56
Place of residence				
Urban	8,612.54	13,496.22	13,892.42	13,031.21
Rural	1,856.23	2,116.06	2,003.80	2,343.62
Region				
Lomé	10,617.57	17,282.33	17,503.05	17,311.67
Maritime	6,649	7,893.81	7,318.87	5,511.4
Plateaux	4,893.63	6,524.38	5,647.26	5,052.52
Central	2,874.60	4,984.62	4,961.83	6,091.06
Kara	5,779.68	6,048.14	5,776.46	5,170.59
Savanna	3,858.20	4,138.40	3,549.55	4,423.91

Source: Authors' calculations using the QUIBB 2015 database

5.2 Preliminary evidence of inequality of opportunity

This section presents our preliminary evidence on inequality of opportunity using Trannoy et al. (2010) stochastic dominance at the first order. We assume two outcome distributions, A and B, with cumulative distribution functions $F_A(y)$ and $F_B(y)$. The outcome in distribution A is better than that in B if, and only if, $F_A(y_j) \leq F_B(y_j)$ for any outcome $y_j = \{y_1, y_2, \ldots, y_k\}$.

Figure 1 depicts the cumulative distribution function of electricity consumption expenditure according to the selected circumstance variables. Figure 1, Panel A shows that the distribution of electricity consumption expenditure for male-headed households dominates that for households led by women. Similarly, Fig. 1, Panel B shows that the distribution of individuals in urban areas dominates that of households in rural areas. Figure 1, Panel C shows that the distribution of electricity consumption expenditure of Lomé dominates that of other regions. Based on these results, we can conclude that there is inequality of opportunity in electricity consumption expenditure. As the stochastic dominance at the first order doesn't account for the full extent of inequality of opportunity, we compute the contribution of each circumstance variable to overall inequality based on the parametric approach set out in Section 3.

5.3 Determinants of energy consumption expenditure in Togo

The Eq. (5) regression results for the entire sample and each cohort are reported in Table 3. Column 1 presents the results for the whole sample, and the next columns hold the results for each cohort. The negative and significant coefficient associated with the variable

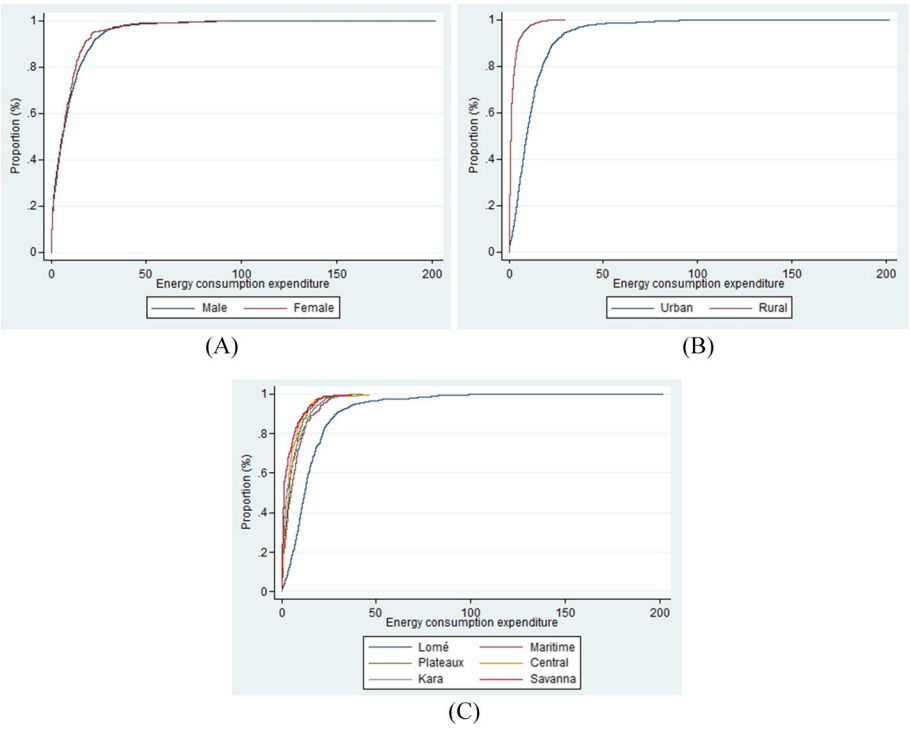

Fig. 1 Cumulative distribution functions of electricity consumption expenditure by circumstance variable. Source: Authors' calculations using the QUIBB 2015 database

"female" across cohorts reveals gender inequalities of opportunity in modern energy access and consumption in Togo. Having a male head of household is associated with electricity consumption that is 0.225 log points[1] higher than for women. The result is consistent with the findings of Räty and Carlsson-Kanyama (2010) and Shi (2019). Women in African countries are associated with traditional fuel energy consumption, for example, wood, charcoal, and animal dung (Sana et al. 2020) and, given the important levels of socioeconomic inequality between men and women on the continent, this result is unsurprising (Couchoro and Dout 2019).

The results show that the electricity consumption of people living in rural areas is 1.728 log points lower than that of their urban counterparts. In Togo, the poverty rate is much higher in rural (58.8%) than in urban (26.5%) areas (INSEED 2020). Rural residents experience difficulties accessing electricity due to their income level. Noglo (2014) and Noglo and Afawubo (2017) show that people living in rural areas earn less than their urban areas counterpart. The main activity in rural is agriculture, whose production is vulnerable to climate change, with low technological adaptability. The region of birth is also consistently associated with electricity consumption expenditure. Individuals birth in other regions achieve lower energy consumption spending than those birth in Lomé: on average, 1.072

[1] The exact percentage change for the log-linear form is given by exp (0.225)–1.

Table 3 Determinants of the energy consumption in Togo across cohorts

	All	Cohort 1 20–30	Cohort 2 31–40	Cohort 3 41–50	Cohort 4 51–60
Gender					
Female	−0.225***	0.107	−0.199*	−0.428***	−0.333**
	(0.064)	(0.138)	(0.114)	(0.12)	(0.154)
Place of residence					
Rural	−1.728***	−1.646***	−1.83***	−1.747***	−1.742***
	(0.068)	(0.153)	(0.115)	(0.131)	(0.17)
Regions					
Maritime	−0.386***	−0.336*	−0.397**	−0.389**	−0.419*
	(0.095)	(0.193)	(0.163)	(0.184)	(0.24)
Plateaux	−0.459***	−0.295*	−0.31**	−0.587***	−0.703***
	(0.087)	(0.169)	(0.142)	(0.18)	(0.233)
Central	−0.676***	−0.852***	−0.77***	−.617***	−0.656***
	(0.102)	(0.249)	(0.163)	(0.191)	(0.248)
Kara	−0.822***	−0.377**	−0.827***	−0.976***	−1.024***
	(0.092)	(0.188)	(0.153)	(0.175)	(0.239)
Savanna	−1.072***	−0.771***	−0.853***	−1.541***	−1.012***
	(0.098)	(0.196)	(0.166)	(0.192)	(0.256)
Constant	9.319***	8.883***	9.406***	9.515***	9.436***
	(0.049)	(0.098)	(0.079)	(0.094)	(0.135)
Observations	1924	424	622	549	329
R-squared	0.429	0.365	0.472	0.469	0.428

Standard errors are in parentheses

*** p < .01, ** p < .05, * p < .1

points lower for people birth in the Savanna region, followed by the Kara (0.822), Central (0.676), Plateaux (0.459) and Maritime (0.386) regions. These results are in line with the literature on regional disparities in poverty and inequality in Togo (Noglo and Afawubo 2017). Concerning the remaining columns, gender and region of birth are more significant as critical determinants of electricity consumption expenditure for all cohorts. Differences in place of residence are also consistently associated with differences in electricity consumption expenditure.

5.4 Inequality of opportunity in energy consumption in Togo

The counterfactual distributions related to Eq. (6) have been used to decompose the inequality of electricity consumption expenditure into factors related to circumstance and effort. In relation to our first goal, this section presents the inequality of opportunity in electricity consumption expenditure for the entire sample and for all cohorts (Table 4 and Fig. 2).

Togo's inequality index for electricity consumption expenditure is 0.56, according to the Gini index, and 0.57, according to the Theil-L index. The results vary across cohorts with the highest level of total inequality among members of Cohort 4; this is estimated as 0.60 and 0.64 for the Gini and Theil-L indexes, respectively. The estimated relative share

Table 4 Inequality of opportunity in Togo's electricity consumption

	Mean	Cohorts			
		Cohort 1	Cohort 2	Cohort 3	Cohort 4
Total inequality					
Gini	0.56	0.48	0.55	0.58	0.60
GE(0)	0.57	0.40	0.57	0.60	0.64
Inequality of opportunity					
Absolute (IOA)	0.008	0.007	0.008	0.009	0.009
Relative (IOR %)	40.76	35.55	43.04	45.59	44.88
Decomposition of Shapley value (% of IOR, % of total inequality)					
Gender					
IOR (%)	99.17	84.87	99.36	103.67	105.28
Total inequality	40.42	34.59	40.50	42.25	42.91
Place of residence					
IOR (%)	53.55	55.50	53.82	53.13	50.72
Total inequality	21.83	22.62	21.94	21.66	20.67
Region					
IOR (%)	89.85	70.89	87.73	97.14	100.48
Total inequality	36.62	28.90	35.75	39.60	40.78

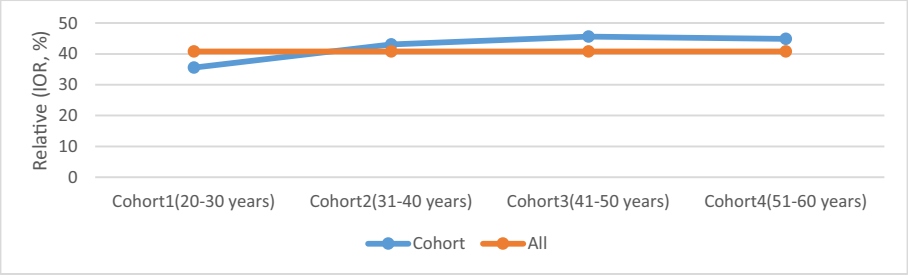

Fig. 2 Inequality of opportunity in electricity consumption by birth cohort. Source: Authors' calculations using the QUIBB 2015 database

of inequality of opportunity (IO_R) is 40.76%, suggesting that, on average, 40.76% of energy consumption inequality in Togo is attributable to inequalities of circumstance beyond peoples' control. There is variation in IO_R across cohorts, peaking at 45.59% for Cohort 3 and 35.55% for Cohort 1 (youths).

The relative share of inequality of opportunity (IO_R) for energy consumption expenditure here is higher than for China (10.02%), as found by Shi (2019). This is not surprising considering the level of China's infrastructure development and financial strength. Furthermore, many studies focusing on inequality of opportunity have found that these are more pronounced in developing countries. For instance, Ferreira and Gignoux (2014) found that inequality of opportunity in educational achievement and opportunity was greater in continental Europe and Latin America (above 30% in Bulgaria, Hungary, Argentina, Brazil and Chile) than in Asia, Scandinavia, and North America (below 20% in Finland, Iceland, Norway, Azerbaijan, Macao and Hong Kong, and 25% in the US). Focusing on income and

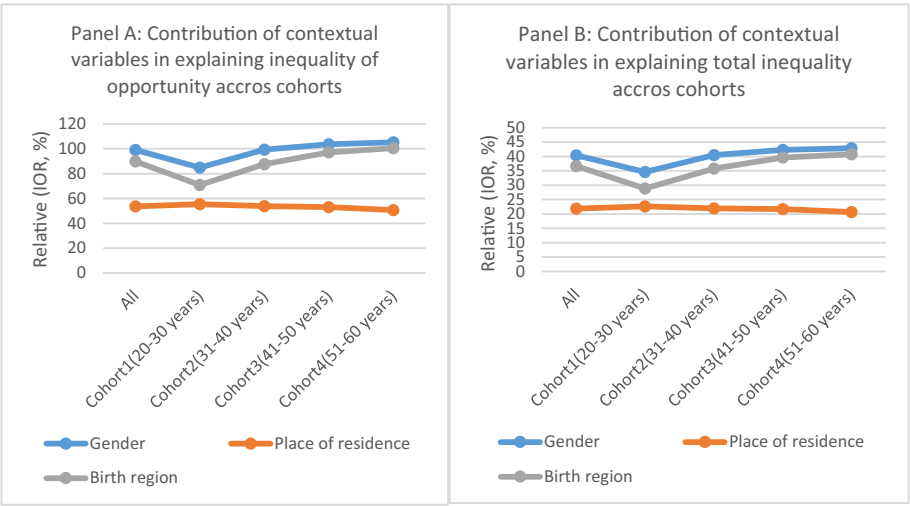

Fig. 3 Contribution of circumstance variables to inequality of opportunity in energy consumption in Togo. Source: Authors' calculations using the QUIBB 2015 database

household consumption, Ferreira et al. (2011) and Singh (2012) found that inequality of opportunity is 32.2% in Brazil, 33.5% in Guatemala, 30.1% in Panama, 27.9% in Peru and 25.9% in Colombia and ranges from 16 to 26% in India.

The partial contributions of each circumstance variable to explaining inequality of opportunity (Panel A) and total inequality (Panel B) using the Shapley decomposition described in Section 3 are presented in Table 4 and Fig. 3. The results show that gender and region are the two most important circumstances for the entire sample and each cohort, particularly for Cohort 4 (older persons).

5.5 Contribution of each circumstance variable in explaining inequality of opportunity in energy consumption across other circumstance-variable components

In respect of our second goal, in this section, we examine how inequality of opportunity in energy consumption expenditure differs across sub-groups by taking each of the circumstances out of the regression in turn.

The results reported in Table 5 show that the total inequalities are important in all components of circumstance variables. Using the Theil-L index, total inequality is higher amongst women (0.58) than men (0.55) and in rural (0.70) than in urban areas (0.38). Across the six administrative regions, the highest levels of total inequality were seen for those born in the Savanna (0.78) and Kara (0.62) regions. The first two columns of Table 5 present the relative share of inequality of opportunity for female- and male-headed households. The results showed that IO_R is more important for women (41.39%) than for men (33.28%), and the householder's region of birth is the main contributor to inequality in electricity consumption expenditure.

In the next columns, place of residence and region of birth are excluded from the regressions to examine the heterogeneity between the rural and urban samples and across regions

Table 5 Partial contributions to inequality of opportunity in energy consumption in Togo, by circumstance variable

	Gender		Place of residence		Regions					
	Male	Female	Urban	Rural	Lomé	Maritime	Plateaux	Centrale	Kara	Savanna
Total inequality										
Gini	0.55	0.56	0.46	0.61	0.43	0.52	0.52	0.57	0.60	0.66
GE(0)	0.55	0.58	0.38	0.70	0.35	0.46	0.47	0.58	0.62	0.78
Inequality of opportunity										
Absolute (IOA)	0.008	0.006	0.001	0.001	0.001	0.008	0.008	0.008	0.008	0.008
Relative (IOR %)	33.28	41.39	4.94	6.44	0.33	39.12	39.12	38.73	38.58	39.22
Decomposition of Shapley value (% of IOR, % of total inequality)										
Gender			8.43	10.30		70.33	72.11	77.43	78.51	85.55
			(3.44)	(4.20)		(28.67)	(29.39)	(31.56)	(32.00)	(34.87)
Place of residence	52.02	54.03			0.35	0.49	0.41	0.37	0.40	0.42
	(21.20)	(22.03)			(0.14)	(0.20)	(0.17)	(0.15)	(0.16)	(0.17)
Region	79.97	92.94	0.46	0.63						
	(32.60)	(37.88)	(0.19)	(0.25)						

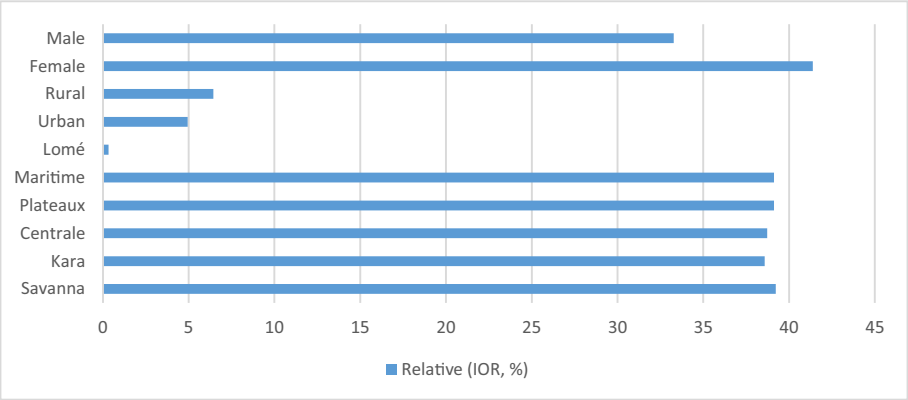

Fig. 4 Inequality of opportunity in energy consumption in Togo across circumstance variables. Source Authors' calculations using the QUIBB 2015 database

of birth, respectively. Not surprisingly, gender is a significant determinant of electricity consumption inequality in both cases. Furthermore, the contribution of gender in modern energy consumption expenditure is more important for the rural sample (10,30%) than for the urban sample (8,43%), suggesting the lower modern energy consumer spending capacity of female-headed households, particularly in rural areas.

These results can be explained by the fact that although there has been a slight improvement in living conditions in Togo between 2011 and 2015 – with the poverty rate falling from 58.7% to 51.1% – over the same period, this rate increased from 54.3% to 57.5% for female-headed households (INSEED 2020). Our results are consistent with Shi (2019), who found that the contribution of gender to energy consumption inequality in China for the rural sample largely exceeds that for the urban sample. Numerous studies of household energy choice in developing countries have shown that the use of solid fuels appears to be more prevalent in female-headed households and mainly in rural areas, while the use of gas and electricity appears to be more prevalent in male-headed households (Sana et al. 2020).

The trends presented in Figs. 4 and 5 clearly suggest that vulnerable groups, especially those born in the Savanna and Kara regions and women, endure the most of unequal opportunities in accessing and consuming modern energy. There are clear regional socioeconomic inequalities and disparities in Togo. For instance, the Savanna region has the highest incidence of poverty at 65.1% compared to 22,3% in Lomé (INSEED 2020), reflecting the low capacity of households in the region to access modern energy services. In 2015, the consumption expenditure of the richest 10% of the Togo's population was six (6) times higher than that of the poorest 10%.

Given our results, to the extent that the circumstances of vulnerable groups are beyond individuals' control, it is critical that public policy enhance resilient and inclusive energy policies.

5.6 Policy implications

Our findings have interesting policy implications. Since the Shapley decomposition approach shows that gender and region of birth are the two largest contributors to inequality of opportunity across age cohorts (being most clear for older persons), the government

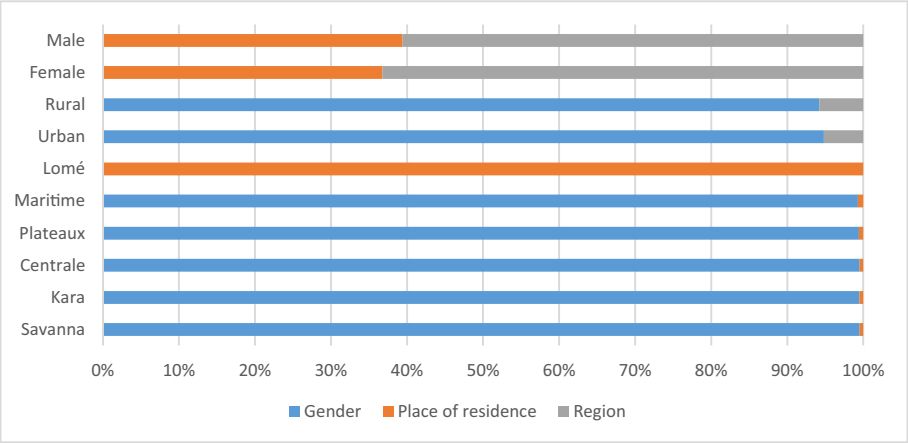

Fig. 5 Partial contributions of each circumstance variable to inequality of opportunity in energy consumption. Source: Authors' calculations using the QUIBB 2015 database

should pay particular attention to these factors and how they impact the capacity to access modern energy. This study provides a solid foundation for targeting the most disadvantaged groups regarding energy consumption in Togo, that is, women and older persons, especially in rural areas and the Savanna region.

Public authorities should focus on improving the electricity supply, especially in the Savanna region and rural areas. This can be achieved by a best combination of grid extensions and non-grid technologies (mini-grids and solar kits). Traditional electrification from connection to the national grid and managed by the Electric power company of Togo is the cheapest option for densely populated areas near the grid. Rural areas and poor regions out of reach of the national grid might adopt alternative modern energy. For these and other areas that are not densely populated, systems powered by solar panels, diesel or hydro, that can supply many households and solar power via photovoltaic panels that can supply the whole household are the cheapest options.

To ensure full access to affordable, modern and efficient energy for the entire population, including in rural areas and poor regions, in 2017, Togo's government created the Togolese Rural Electrification and Renewable Energy Agency. This agency implements electrification projects such as the CIZO project, which aims to provide two (2) million Togolese (300,000 households) with access to electricity through individual solar kits paid for via mobile wallets (PayGo). Kekeli Efficient Power (launched in 2021) and Blitta solar power public–private partnerships are some of the projects that might be replicated to increase the electricity supply in Togo. The government should pursue electricity supply liberalisation efforts at the national level with incentives (e.g., tax exemptions and proper regulatory framework) for the private sector and through public–private partnerships.

The free availability of biomass, especially in rural areas, combined with the low income in these areas, hinder the process of substituting biomass with clean energy. There is a need for the right incentives for households to make a sustainable switch from traditional fuels to modern energy. Thus, strategies to increase people's access to energy that target women and older persons in rural areas and poor regions should include the goal of improving their financial capacity through electricity aid programmes. In 2022, Togolese authorities launched a fund for universal access to electricity. Referred to as "Tinga", this

instrument is a mechanism to facilitate access to electricity for low-income populations. This fund supplies repayable grants for universal access to electricity grids. It is particularly important to strengthen this mechanism for the Savanna region and to focus on households headed by women and older persons, especially in rural areas.

6 Conclusion

This study seeks to quantify the role of inequality of opportunity in energy consumption in Togo using the 2015 Togolese living standard survey and a parametric approach. We presented estimates of overall inequality of opportunity in electricity consumption expenditure, both as a level and as a share of total inequality in electricity consumption. The circumstance-specific shares of inequality in energy consumption expenditure were also analysed. The results show that total inequality in electricity consumption expenditure is 0.56 in Togo (according to the Gini index) and 0.57 (for the Theil-L index). The results vary across cohorts, with the highest level of total inequality found among people in Cohort 4, estimated to be 0.60 and 0.64 for the Gini and Theil-L indexes, respectively.

The estimated relative share of inequality of opportunity (IO_R) is 40.76%, suggesting that, on average, 40.76% of inequality in energy consumption in Togo is the result of unequal circumstances that are beyond peoples' control; the highest relative share (45.59%) is for Cohort 3, and this is lower for Cohort 1, the youth (35.55%). Across the components of circumstance variables, the results showed that the relative share of inequality of opportunity is greater for women than men and that the Savanna region has greater inequality of opportunity than Lomé. Further, urban areas are less affected by inequalities of opportunities than rural areas. The results of the Shapley decomposition showed that gender dominates the contributions in explaining total inequality and inequality of opportunity in energy consumption in Togo, followed by the region of birth and the place of residence.

To overcome these challenges and work towards a more inclusive and sustainable energy future for all, it is crucial to review energy policies to promote more fair access to electricity, not only at the national level but also on an international scale. Strengthened international cooperation and concerted measures are necessary to ensure that every individual has access to modern, clean, and affordable energy, thereby fostering a more balanced and environmentally friendly global development.

Authors' contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Tchablemane YENLIDE. The first draft of the manuscript was written by Tchablemane YENLIDE and Mawussé Komlagan Nézan OKEY and all authors commented on earlier versions of the manuscript. All authors read and approved the final manuscript.

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Declarations

Conflicts of interest Authors have no competing interests to declare.

Ethical Approval Not applicable.

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